1984-03

Analysis and evaluation of computer support for afloat submarine IMA maintenance planning

Bischoff, Douglas A.

Monterey, California. Naval Postgraduate School

https://hdl.handle.net/10945/30676

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

ANALYSIS AND EVALUATION OF COMPUTER SUPPORT FOR AFLOAT SUBMARINE IMA MAINTENANCE PLANNING

by

Douglas A. Bischoff

March, 1990

Thesis Advisor: Robert Knight, LCDR, USN(SC)

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Naval Postgraduate School / 6b. OFFICE SYMBOL (If applicable): 54	7a. NAME OF MONITORING ORGANIZATION: Naval Postgraduate School
6c. ADDRESS (City, State, and ZIP Code): Monterey, CA 93943-5000	7b. ADDRESS (City, State, and ZIP Code): Monterey, CA 93943-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION / 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
ANALYSIS AND EVALUATION OF COMPUTER SUPPORT FOR AFLOAT SUBMARINE IMA MAINTENANCE PLANNING

12. PERSONAL AUTHOR(S)
Bischoff, Douglas A.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Master's Thesis	FROM ____ TO ____	March 1990	143

16. SUPPLEMENTARY NOTATION The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Ship Repair, Ship Maintenance, Submarine Repair, Productivity Enhancement

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Late identification of work and inadequate administrative controls are principle causes of untimely preparation of Controlled Work Procedures (CWPs) at one heavily loaded, afloat, submarine Intermediate Maintenance Activity (IMA). Untimely CWP preparation, however, is symptomatic of a more widespread problem of inadequate communications and decision support in the IMA maintenance planning process. The Maintenance Resource Management System's (MRMS) Engineered Time Value standards provide significant improvement in resource estimation accuracy over the Maintenance and Material Management (3-M) Intermediate Maintenance Management System (IMMS). However, both IMMS and MRMS (version 0) emphasize transaction processing and structured, upline reporting. Neither system provides tools necessary for optimal decision making to IMA maintenance supervisors.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL: Robert Knight, LCDR, USN(SC)	22b. TELEPHONE (Include Area Code): (408) 646-2771 / 22c. OFFICE SYMBOL: Code 54Kt

Approved for public release; distribution is unlimited.

ANALYSIS AND EVALUATION OF COMPUTER SUPPORT FOR AFLOAT SUBMARINE IMA MAINTENANCE PLANNING

by

Douglas A. Bischoff
Lieutenant, United States Navy
B.S., University of Minnesota

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN INFORMATION SYSTEMS

from the

NAVAL POSTGRADUATE SCHOOL
March 1990

Author: [redacted]
Douglas A. Bischoff

Approved by: [redacted]
Robert Knight, LCDR, USN(SC), Thesis Advisor

[redacted]
James Suchan, Second Reader

[redacted]
for David R. Whipple, Chairman
Department of Administrative Sciences

ABSTRACT

Late identification of work and inadequate administrative controls are principle causes of untimely preparation of Controlled Work Procedures (CWP) at one heavily loaded, afloat, submarine Intermediate Maintenance Activity (IMA). Untimely CWP preparation, however, is symptomatic of a more widespread problem of inadequate communications and decision support in the IMA maintenance planning process. The Maintenance Resource Management System's (MRMS) Engineered Time Value standards provide significant improvement in resource estimation accuracy over the Maintenance and Material Management (3-M) Intermediate Maintenance Management System (IMMS). However, both IMMS and MRMS (version 0) emphasize transaction processing and structured, upline reporting. Neither system provides tools necessary for optimal decision making to IMA maintenance supervisors.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

3-M	Maintenance and Material Management
ADP	Automated Data Processing
AMMIS	Area Maintenance Management Information System
APL/AEL	Allowance Parts List/Allowance Equipage List
ARRS	Analysis Records and Reports Section
AWC	Assisting Work Center
CNO	Chief of Naval Operations
CSMP	Current Ships Maintenance Project
CWP	Controlled Work Procedure
ETV	Engineered Time Value
IMA	Intermediate Maintenance Activity
IMMS	Intermediate Maintenance Management System
LWC	Lead Work Center
MDS	Maintenance Data System
MRMS	Maintenance Resource Management System
NAVSEA	Naval Sea Systems Command
OMMS	Organizational Maintenance Management System
P&E	Planning and Estimating
PMA	Production Management Assistant

LIST OF ABBREVIATIONS (CONT.)

QA	Quality Assurance
ROV	Repair of Other Vessels
SIMMIS	Submarine Intermediate Maintenance Management Information System
SRA	Selected Restricted Availability
SUADPS	Shipboard Uniform Automatic Data Processing System
SUBPAC	Submarine Force Pacific Fleet
TAMS	TYCOM Alteration Management System
TYCOM	Type Commander
TYCOM Rep	Type Commander Representative
URO/IMMP	Unrestricted Operations/ SSN Integrated Maintenance and Modernization Program (Refer to Submarine Material Certification Requirements Manual, NAVSEA 0924-062-0010)
WMMS	Waterfront Maintenance Management System

I. INTRODUCTION

The increasing complexity and advancing age of ship systems, and limited resources available for their repair, continue to increase the importance of effective ship maintenance. A maintenance activity's effectiveness is greatly impacted by the success or failure of its maintenance planning and control efforts. To enhance effective planning and control, it is prudent to provide automated tools to all levels of maintenance activities: Organizational, Intermediate, and Depot.

A. BACKGROUND

All Intermediate Maintenance Activities (IMAs) utilize the Maintenance and Material Management (3-M) System to manage maintenance actions. Computer support for the 3-M System is provided by the Intermediate Maintenance Management System (IMMS) and a mix of Type Commander (TYCOM) sponsored prototype systems. Most of these computer systems are designed primarily for transaction processing and reporting. All provide support for maintenance control, but few meet user requirements for maintenance planning.

Using IMMS, the Planning and Estimating (P&E) division on a heavily loaded, afloat submarine IMA is unable to consistently plan maintenance in a timely manner. For example, on the USS MCKEE (AS-41), preparing a

Controlled Work Procedure (CWP) requires an average of 30 man-hours. [1] To meet the average demand, CWP preparation should take no more than 13 man-hours. [Ref. 1]

To generate CWPs and complete repairs in time for the submarines to meet operational commitments, CWP preparation for each submarine upkeep proceeds under crisis management. P&E planners, under heavy pressure from IMA management because repair work is being delayed, work overtime to prepare CWPs. Planners face frequent and unexpected changes in tasking and priorities as schedules are rearranged. The CWP which is urgent in the afternoon, for example, is unnecessary by evening.

Contributing to the crisis environment is an apparent insensitivity on the part of maintenance managers to efficient use of manpower resources. Indifference toward cyclical, beyond-capacity workloads on IMA work centers and toward frequent, widespread use of overtime, hurts the total IMA effort. Overloaded, and lacking guidance on the relative importance of various work requests, Work Center Supervisors make uncoordinated decisions on work priority and use of overtime. When these decisions are incorrect, manpower resources are wasted, the total repair effort suffers, and relations between the customer ship and IMA are strained. No planning and control system can be effectively used without a genuine concern by its users for efficient and effective use of the resources the system is designed to support.

[1] A CWP is a set of detailed instructions for performing a maintenance action. CWP preparation is one aspect of the maintenance planning process.

Crisis management results in inadequate attention to job scheduling, job priority, and production shop workload. Long hours working in a crisis mode also deflates the morale of planning personnel and probably diminishes productivity.

Crisis management also results in planning work which cannot, or should not, be done during an upkeep. This wastes planning and material resources. From 1986 to 1988, on USS MCKEE (AS-41), 19.8 per cent of all jobs requiring CWPs were cancelled [Ref. 1]. According to P&E's Lead Planner, from March to September of 1989, the cancellation rate was 41 percent.

Resources spent planning jobs which are subsequently cancelled are not available to plan other necessary work. Modernization work is one such example. In March of 1989, USS MCKEE had a backlog of approximately 500 alterations [Ref. 1]. This backlog represents a significant reduction in the readiness and capability of the tended submarines.

An informal IMA review of Controlled Work Procedure (CWP) preparation resulted in some improvements to the review and revision process. To prevent CWPs from being lost in routing, for example, until the CWP is ready to take to the job site it remains in the planning office. Some improvements in efficiency resulted, but CWP preparation remains untimely. Reducing the existing CWP backlog, and improving planning productivity requires more than simply modifying current job processing methods. It also requires more than just adding people to the maintenance planning work force, because no planning personnel are available, at any skill level.

Managerial planning problems, such as accumulating a large planning backlog or working in an endless crisis management mode, may be caused by lack of relevant data or processing capability. Computer systems such as IMMS do not provide adequate support for IMA maintenance planning. Although maintenance planning data is collected, IMMS is designed primarily to report maintenance performance. Thus, maintenance planners have only limited access to relevant planning data and no useful capability to manipulate that data in support of planning functions.

B. OBJECTIVES

This study's major purpose is to determine how lack of data or processing capability contributes to IMA maintenance planning problems.

Two computer systems germane to this study are IMMS and the Maintenance Resource Management System (MRMS). In the Pacific Fleet, MRMS is installed at shore IMA facilities and is planned for installation on afloat IMA facilities.

More specifically, the objectives of this study are:

1. to analyze the maintenance planning problems onboard USS MCKEE,
2. to determine the information requirements for maintenance planning at the IMA level,
3. to evaluate the computer support provided to IMA maintenance planning by IMMS-II and MRMS, and
4. to recommend improvements in the computer support for maintenance planning where support for maintenance planning is inadequate.

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

1. Scope

While managerial problems in maintenance planning occur at all levels of the Navy, the scope of this study includes only information system deficiencies causing the planning backlog experienced by heavily loaded, afloat submarine IMAs. Although investigating other possible causes such as insufficient manning and training are important to this study's analysis, they do not have the broad impact on maintenance planning effectiveness that computer systems do. These other causes may be unique to an individual IMA. The information-related deficiencies, conversely, may affect maintenance planning effectiveness at all maintenance activities where centralized, transaction-oriented systems are used.

The scope of this study is also bounded by the control and reporting structure of the 3-M system and supplemental direction contained in the Submarine Force, Pacific Fleet (SUBPAC), Maintenance Manual. [Ref. 2]

2. Limitations

A limitation on this study was the inability to observe the use and operation of MRMS. Evaluation of MRMS support for maintenance planning is, therefore, based primarily on system documentation. Although installed at many shore maintenance activities in the Pacific Fleet, MRMS had not been implemented on any afloat IMA until late in 1989. Time limitations prevented direct observation of afloat operation. However, several telephone interviews with MRMS users were conducted.

3. Assumptions

A key assumption in proposing broad application of the study's conclusions to all submarine IMAs is that the structure imposed by the 3-M system and its supporting computer systems results in, essentially, one submarine IMA maintenance planning process. This study assumes that while a particular function may be performed by different groups from one IMA to another, the information required to perform that particular function will be the same.

D. SUMMARY OF FINDINGS

The most significant finding of this study is that most of the relevant data for IMA maintenance planning is captured by IMMS and MRMS. However, IMA maintenance supervisors are not afforded adequate communications and decision support to optimize maintenance planning decisions. For nearly all planning functions, data is accessible only via standard printed reports. Extraction of planning information requires a manual search through pages of computer printouts and then transcription into a form suitable for further analysis.

The newer MRMS provides better support for planning than does the older IMMS-II it is replacing. Much of the improvement is in its "real time" processing and more precise job estimating capabilities. MRMS (version 0), however, is functionally similar to IMMS, and does not address communications and decision support issues. If developed to the extent described in the MRMS functional description, some support will be provided in future versions.

Late identification of work and inadequate administrative controls are principle causes of untimely CWP preparation. The TYCOM Rep and IMA supervisors should continue to monitor patterns of work identification and ensure tended units submit requests for controlled work as early in the upkeep cycle as possible. To improve administrative controls, P&E should maintain an index of CWPs, preferably as a database on a Local Area Network. Typing efficiency, and therefore productivity, could be improved by more extensive use of the keystroke reducing capabilities of the word processing software used to write CWPs.

II. BACKGROUND

A. SHIP MAINTENANCE AND THE IMA 3-M ORGANIZATION

1. Fleet Repair Organization

There are three levels of ship maintenance, each requiring a greater capability by the repair activity. They are Organizational, Intermediate, and Depot. Organizational level maintenance is the corrective and preventative maintenance performed by the ship's crew. Intermediate level maintenance is maintenance beyond the capability of a tended ship's crew, and is performed by personnel on tenders, repair ships, aircraft carriers, and at Fleet support bases ashore. Depot level maintenance requires a greater industrial capability than is available at organizational or intermediate level activities. Shipyards perform depot level maintenance. [Ref. 3:pg. B-5,B-6]

On afloat, intermediate level activities, the Repair Department performs maintenance on tended units. Part of the Repair Department organization for a typical afloat IMA is shown in Figure 1.

At the intermediate and organizational levels, the management of maintenance is closely coupled to the 3-M reporting system. The 3-M system provides a framework for the development and processing of ship maintenance actions. Mandatory use of 3-M system forms predetermines the transactions and data elements to be recorded. Computer systems process and store maintenance

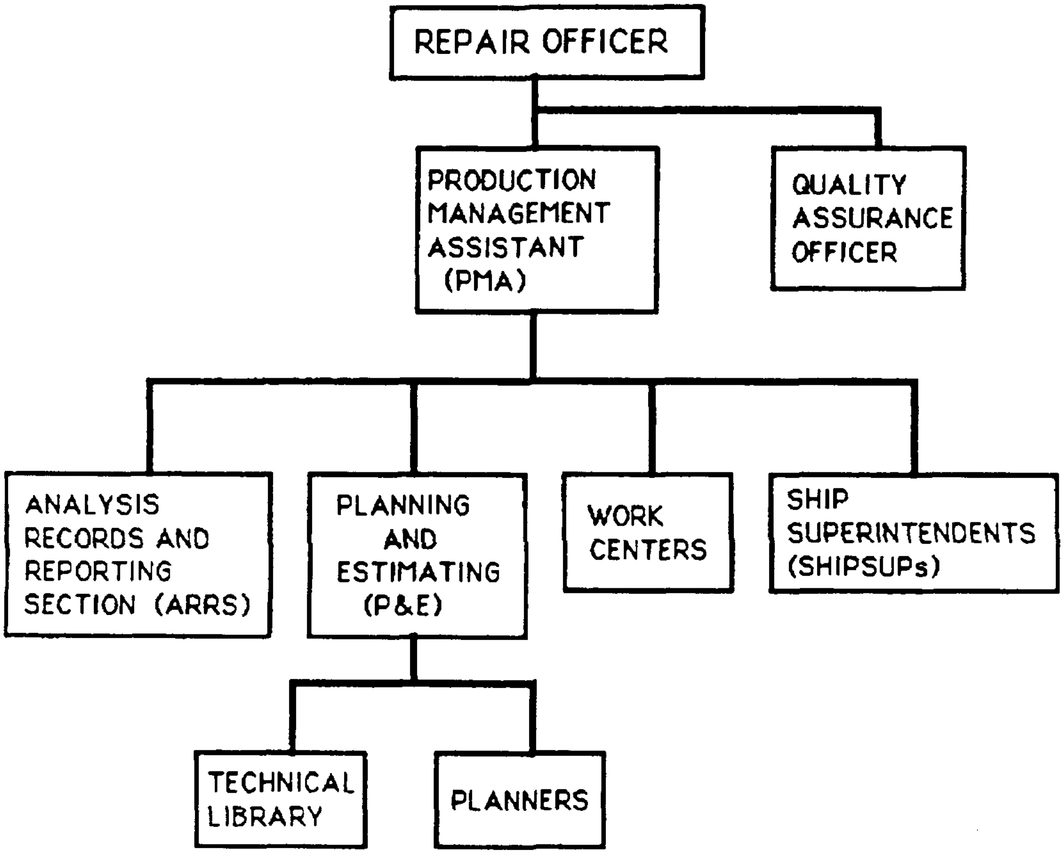


Figure 1 IMA Repair Department Organization.

transactions, and provide status and performance reports. In the submarine force, the intermediate level is the lowest maintenance level with dedicated computer support for the maintenance planning and controlling functions.

2. The 3-M System

The 3-M system has two major subsystems: the Planned Maintenance System (PMS), and the Maintenance Data System (MDS). The purpose of PMS maintenance is to maintain equipment in a fully operational condition and identify a need for replacement prior to failure. PMS maintenance is performed and managed under a distinctly different process than corrective and alteration maintenance, and therefore is of no further interest in this study.

The MDS is a means for reporting corrective, alteration, and preventative maintenance (not covered by PMS) on all types of equipment. Its basic premise is maintenance data will be recorded only once and then retrieved from the MDS data bank by those who need it. Maintenance activities are, therefore, not expected to maintain extensive 3-M material histories. [Ref. 4:pg 1-6]

a. The Maintenance Data System

Figure 2 shows the flow of information in the MDS. Ships (through their squadrons) and IMAs submit maintenance action data on 3-M system forms to their automated data processing (ADP) facilities. From the data submitted, a Current Ship's Maintenance Project (CSMP) file is generated and maintained. A series of computer reports from the CSMP file is provided to the

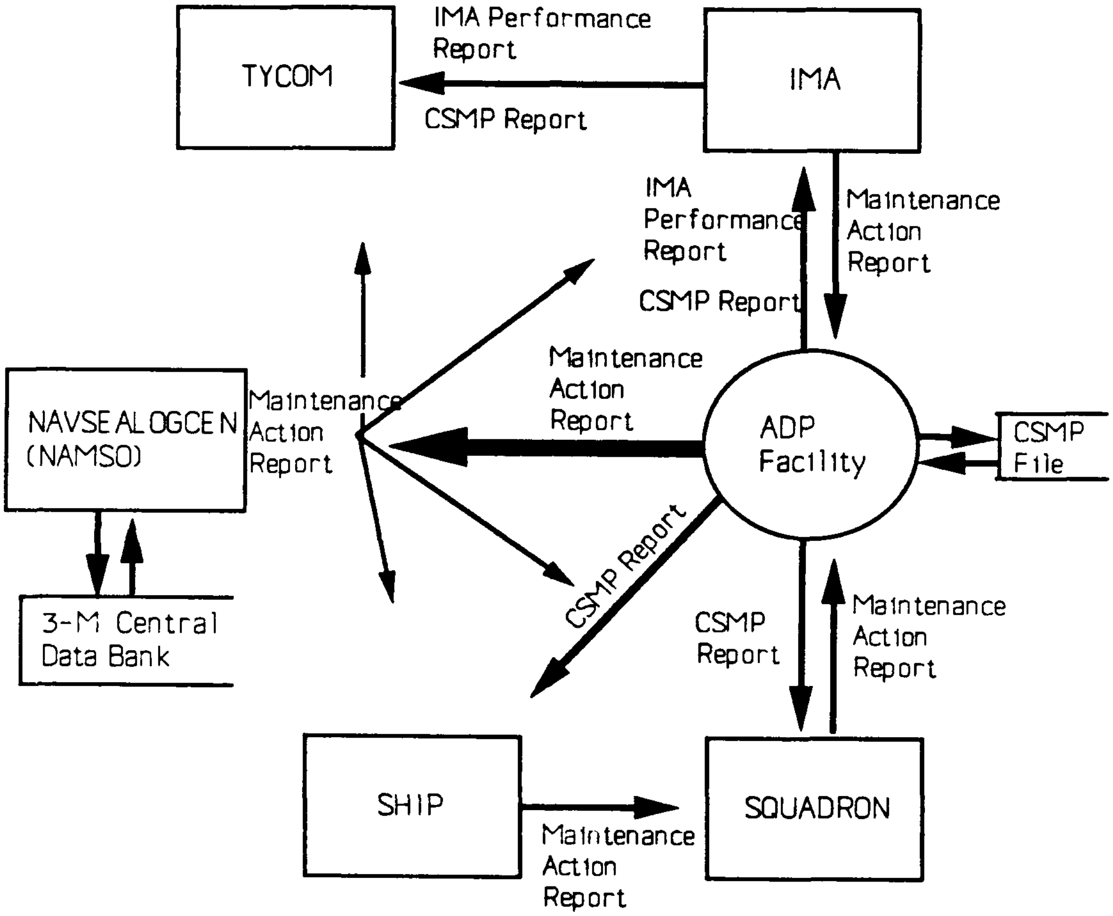


Figure 2 Maintenance Data System Information Flow.

ships and IMA. Some of these reports are also forwarded to the TYCOM. All maintenance data is eventually forwarded to the 3-M Systems Central Data Bank, maintained at Naval Sea Logistics Center (Navy Maintenance Support Office Department) (NAVSEALOGCEN (NAMSO)), located in Mechanicsburg, Pennsylvania. The Central Data Bank is the sole source of data for 3-M reports requested by Navy activities, including the ships and IMAs that may have been the data originators. [Ref. 4: pg 1-6] It is the author's experience that the turnaround time for these reports is too long and the content of available reports is too limited for practical fleet use. In one instance, a historical record of alterations performed on a piece of equipment was desired. The only report offered which included alterations was a detailed description of all maintenance actions reported on the equipment of interest. The detailed report also took more than one week to arrive. This is too long for ships facing the pressures of operational commitments.

b. 3-M Organizational Interfaces

The organization of the 3-M system provides the interface between a ship's operational chain of command and the repair activity. The relationships between the key offices and functions in the IMA 3-M organization are shown in Figure 3.

The TYCOM exercises command over both the squadron and the IMA. Within the squadron, the Maintenance Document Control Office (MDCO) handles the receipt, input to the ADP facility, and routing of MDS documentation. The MDCO serves as the interface between the ADP facility, the

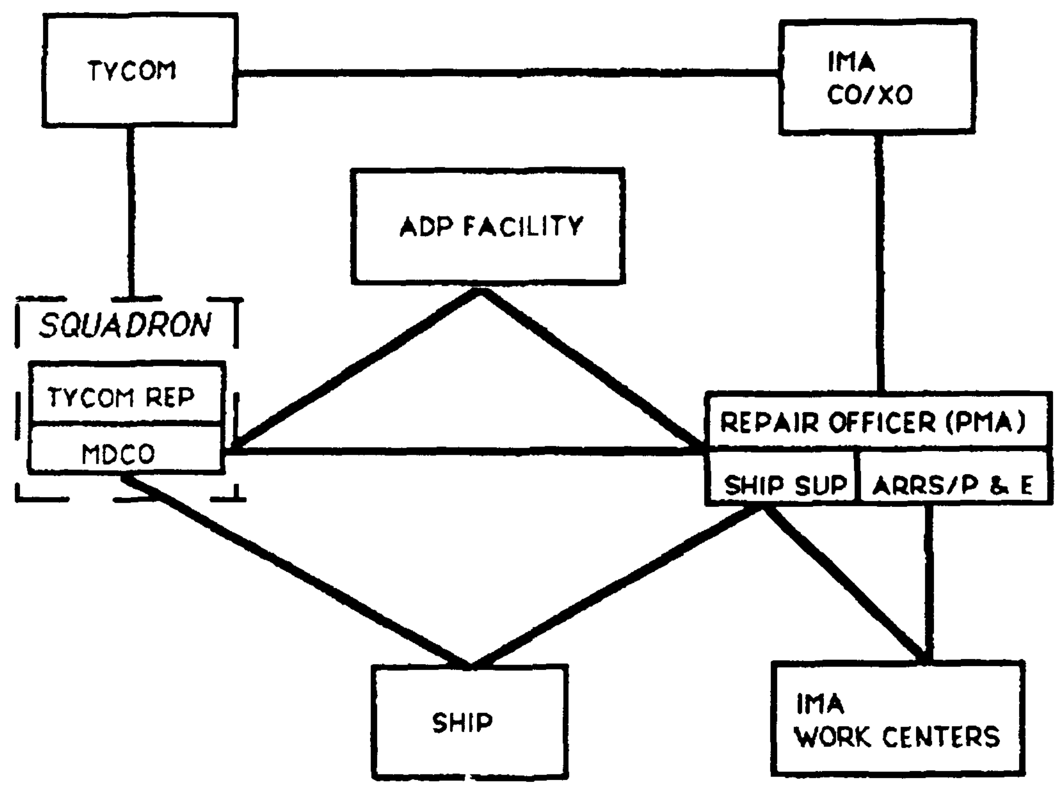


Figure 3 IMA 3-M Organization

TYCOM Rep, and the ships assigned to the squadron. The MDCO also serves as the interface between the TYCOM Rep, the Analysis Records and Reports Section (ARRS), and the assigned ships.

The IMA's repair efforts are coordinated with the ship's upkeep schedule through TYCOM Rep screening of all deferred maintenance. [2] The TYCOM Rep establishes the time frame of repair and assigns responsibility for accomplishment to either the ship, the IMA, or a depot level repair facility. He also establishes which ADP facility reports will be used in managing upkeep work. In SUBPAC, the TYCOM Rep is the Squadron Engineer/Material Officer. [Ref. 2:pg IV-11-1]

Within the IMA, the Repair Officer manages the repair function. The Production Management Assistant (PMA) is the Repair Officer's primary assistant, controlling the production effort and screening 3-M documentation. Serving under the PMA are one Ship Superintendent (SHIPSUP) for each submarine in an upkeep status, the ARRS, and the Planning and Estimating (P&E) section. The SHIPSUP is the liaison between the IMA work centers and work centers on the tended ships. The ARRS utilizes the ADP facility to collect, process, and distribute maintenance management data to IMA managers. The P&E section coordinates and performs advance planning of work assigned to the IMA. [Ref. 2:pg IV-11-2,3]

[2] An upkeep is an extended period of time, usually four weeks, during which the submarine is available for accomplishment of relatively involved work.

c. *Maintenance Documentation*

Maintenance action data is captured using standard forms established in the 3-M Manual. Data from five 3-M forms are used in maintenance planning. These forms are shown in Appendix A and described below:

1. The Ship's Maintenance Action Form (2-KILO), OPNAV 4790/2K, is used by submarines to document all maintenance, except PMS.

2. The Supplemental Form (2-Lima), OPNAV form 4790/2L, is used with the 4790/2K to provide supplemental information, usually in the form of sketches or customized plans. The 4790/2L may also be used to request routine maintenance and services, of a repetitive nature, which the IMA has already planned in detail and electronically stored under a Master Job Catalog Number. Instead of re-entering all the required data on a new 4790/2K, the 4790/2L simply specifies the Master Job Catalog Number.

3. The Maintenance Planning & Estimating Form (P&E), OPNAV 4790/2P, is used by the IMA for detailed screening and planning of work assigned to the IMA.

4. The Automated Work Request, OPNAV 4790/2R, is usually printed by the ADP facility and combines the information from the OPNAV 4790/2K and 4790/2P forms.

5. The DOD Single Line Item Requisition System Document, DD Form 1348, is used to order parts and materials needed to complete any maintenance action.

In this study, "work request" means deferred maintenance scheduled for IMA accomplishment, as documented by an OPNAV 4790/2R or an OPNAV 4790/2K (with or without an accompanying OPNAV 4790/2P). "Requisition" refers to the DD Form 1348 supply document.

Figure 4, adapted from the 3-M Manual, shows the functional flow of 3-M documents and presents a broad overview of the maintenance planning process. Chapter III provides more detail on the personnel involved and how maintenance planning functions are accomplished.

The MDCO receives 4790/2Ks or 4790/2Rs reporting completion or deferral of maintenance by a tended submarine. Reports of deferral of maintenance to be accomplished by the ship are sent to the IMA's ADP facility for entry into the CSMP file. All other deferral reports (work requests) have a 4790/2P attached, if required, and are forwarded to the TYCOM Rep for screening. The TYCOM Rep either approves or disapproves the work request and schedules approved work for accomplishment by the IMA or a depot. Screened work requests are returned to the MDCO.

Work scheduled for IMA accomplishment is forwarded to the PMA for Repair Officer screening. The PMA accepts or rejects the work for the IMA. Accepted work is evaluated for quality assurance or other special requirements, and, if planning is required, is forwarded to P&E. The P&E section verifies any special requirements indicated by the PMA, assigns IMA work centers, estimates resources required, and fills in scheduling information. The P&E planners write CWPs for work requiring special controls, and deliver them to the work center assigned to perform the work.

Planned and estimated work requests are forwarded to the ADP facility, through the ARRS, for data entry into the CSMP file. The ADP facility generates 4790/2Rs, which the ARRS distributes to the Lead and Assist Work

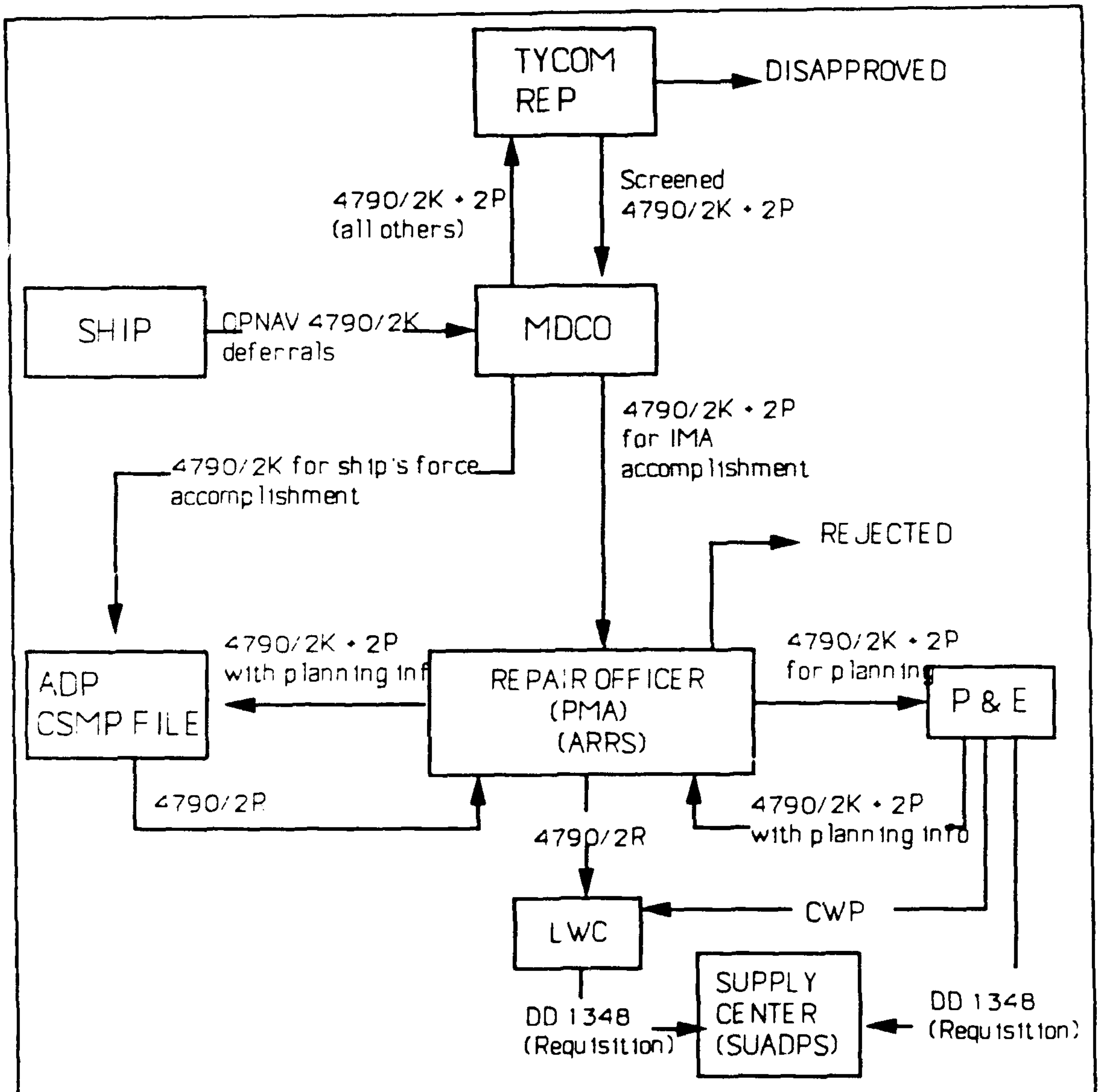


Figure 4 Functional Flow of Maintenance Documentation

Centers (LWCs and AWCs) in the IMA. Requisitions are submitted to the Supply center by P&E or IMA work centers using DD Form 1348, where they are processed by a separate computer system. This system is usually the Shipboard Uniform Automatic Data Processing System (SUADPS). The computer system used for processing maintenance data interfaces with SUADPS to provide for reporting on the status of requisitions.

Work requests disapproved by the TYCOM Rep become part of the CSMP file, but are returned to the ship without further action by the IMA. Work requests rejected by the IMA are evaluated by the TYCOM Rep for their impact on the ship and re-screened. Further handling is similar to that for disapproved work requests.

B. INTERMEDIATE MAINTENANCE MANAGEMENT SYSTEM

1. System Overview

IMMS is a subset of the MDS portion of the 3-M System. It was developed to directly support management of intermediate level maintenance, collect MDS maintenance data, and report upline to the 3-M Systems Central Data Bank. Specifically, IMMS consists of computer programs and administrative procedures which:

1. Allow the processing of MDS documentation and the production of standard automated Current Ship's Maintenance Project (CSMP) reports.

2. Provide for the maintenance of the master CSMP files for supported units.

3. Provide management tools for the planning, estimation, and progressing of work done by the IMA.

4. Maintain a Master Job Catalog (MJC) for listing work of a repetitive nature and improving supply support through use of automatic parts ordering.

5. Create reports used by higher authority to evaluate the performance of IMAs.

6. Provide for the reporting of configuration changes to the Ship Equipment Configuration Accounting System (SECAS) via the TYCOM.

7. Provide for the upline reporting of MDS documentation. [Ref. 4:pg 12-1]

Two versions of IMMS are currently in operation. The version installed on USS MCKEE, IMMS-II, is batch oriented. Maintenance action data is entered onto a transaction tape via terminals or key-punched card readers. Periodically, the transaction tape is processed against the master CSMP and other files. The ADP facility operators control all computer program operations. IMMS-RT is a "real time" version of IMMS-II. Maintenance action data is processed against the IMA's MDS database as it is entered. Using IMMS-RT, terminal operators have more capability to access and perform operations on maintenance and management data than with IMMS-II.

Reference 4 requires use of IMMS procedures by all IMAs. Activities are permitted, however, to use developmental maintenance management software systems such as MRMS with Naval Sea Systems Command (NAVSEA CEL-TD) approval. Such developmental programs must provide at least the same capabilities as IMMS and satisfy the reporting requirements of the MDS.

C. MAINTENANCE RESOURCE MANAGEMENT SYSTEM

1. System Overview

MRMS is a developmental maintenance management system, developed in the mid '80s. Managed under the Shipboard Non-tactical ADP Program (SNAP), MRMS' functional sponsor is the Deputy Chief of Naval Operations (CNO) for Logistics (OP-043). MRMS is a blending of various TYCOM prototype systems (Area Maintenance Management Information System (AMMIS), Submarine Intermediate Maintenance Management Information System (SIMMIS), Waterfront Maintenance Management System (WMMS)), IMMS-RT, Organizational Maintenance Management System (OMMS), and various local ADP and manual systems. The objectives of MRMS are to consolidate these systems into a single, commonly understood system, employ a standards based estimation methodology for measuring productivity, standardize production control and task tracking methodologies, and facilitate data sharing between geographically separated processing sites. [Ref. 5:pg. ii]

From a maintenance planning standpoint, the fundamental differences between MRMS and IMMS are its application of Engineered Time Value (ETV) standards and its objective of "on-line" access to geographically separated 3-M databases.

Development of ETV standards was motivated by an increasing emphasis on productivity measurement and enhancement within the Federal Government and The Department of Defense in the early 1970's. It was felt the improved estimation and measurement accuracy afforded by ETVs would extend the IMA's repair capability for any given budget level. [Ref. 6:pg 16]

The Navy's first ETV standards were developed and implemented in 1980 by Planning Research Corporation of McLean, Virginia when AMMIS, sponsored by COMNAVSURFLANT, was installed at Shore Intermediate Maintenance Activity (SIMA), Norfolk, Virginia. This system consolidated the CSMP files of the ships serviced by SIMA, Norfolk in a single location, facilitating 3-M processing, work screening, assignment, and tracking. AMMIS was gradually expanded to include SIMAs at Little Creek, Virginia, Mayport, Florida, Charlestown, South Carolina, and Newport, Rhode Island. Other ETV prototype systems soon followed. [Ref. 5:pg. 2-1]

In 1981, WMMS, a COMNAVSURFPAC prototype system based largely on AMMIS, was installed in Pearl Harbor, Hawaii. By 1985, WMMS had expanded to include SURFPAC IMA facilities throughout the Pacific, linked by telecommunications. [Ref. 5:pp. 2-1--2-2]

Finally, COMSUBPAC implemented its own AMMIS-based prototype system, named SIMMIS, at Submarine Base, Pearl Harbor, in 1984. Unlike AMMIS and WMMS, SIMMIS was not expanded to include other SUBPAC IMAs. [Ref. 5:pg. 2-1]

Through the efforts of the SUBPAC Logistics Office, in October 1989 an afloat version of MRMS was implemented by Planning Research Corporation onboard USS DIXON (AS-37). According to the MRMS functional sponsor's office, through a combination of budgetary limits on acquisition and development of parallel ADP systems, the initial success of the MRMS installation on USS DIXON using the SNAP III AT&T-3B2 minicomputer, and imminent expiration of the Honeywell DPS-6 computer support contract for IMMS,[3] MRMS has been designated the maintenance management system for the Navy by CNO (OP-094).[4] In the near future, this action will probably result in implementation of MRMS on all afloat IMAs. Development of additional capabilities proposed in the MRMS functional description but not yet implemented, might also proceed.

2. System Operation

As installed on USS DIXON (AS-37), MRMS (version 0) is functionally similar to IMMS-II. The biggest differences are MRMS provides real time updating of CSMP files and provides on-line use of ETV standards for job estimation. Applications are interactive, and menu driven. Based on maintenance management functions, menus direct users through the data entry and decision requirements of maintenance planning and work progressing.

---

[3] The IMMS software is designed to run on the Honeywell DPS-6 minicomputer, which has a proprietary operating system. IMMS software is therefore, unable to be transported to other hardware configurations.

[4] Although OP-043 is the functional sponsor for maintenance management ADP systems, OP-094 is the SNAP program coordinator. As previously stated, MRMS is part of the SNAP program. The decision on MRMS is described in message from CNO (OP-094) DTG 202232Z February 1990.

D. THE CWP PREPARATION PROBLEM

Submarine Squadron Eleven, a typical submarine squadron, is assigned an average of nine submarines. Each submarine completes three or four upkeep periods each year, and a Selected Restricted Availability (SRA) period every three to four years. An SRA is an extended maintenance period, typically two months, during which the submarine is available for depot level maintenance and some intermediate level maintenance.

According to the PMA, USS MCKEE (the IMA for CSS-11) plans and performs approximately 30 upkeeps and two SRAs each year. Roughly 15 percent of the maintenance has special requirements, necessitating a CWP. Throughout 1989, on USS MCKEE, an average of nine planners wrote CWPs using five, stand-alone, IBM-AT compatible computers connected to dot matrix printers.

Early in 1989, the IMA workload was heavy. In addition to the submarines of Squadron Eleven, USS MCKEE was also those of Squadron Three. IMA Performance Summary reports showed work centers reporting labor expenditures at up to 140 percent of available capacity. Surprisingly, key maintenance supervisors appeared unconcerned about the widespread, heavy reported use of overtime. They explained that labor expenditures were probably over-reported.

Maintenance planning offices were also having difficulty meeting their workloads. Most conspicuously, the P&E section was unable to consistently prepare CWPs in a timely manner. This situation resulted in crisis management of CWP preparation, consuming a disproportionate amount of planning resources when compared to the actual volume of controlled work. Subsequently, aspects of maintenance planning for other work, such as alterations, were neglected.

An informal self review by USS MCKEE in early 1989 explored the causes of untimely CWP preparation. Procedural changes were implemented within the P&E section to reduce delays caused by poor administrative controls and slow routing of CWPs during technical review. The basic problem, however, remained unsolved.

1. Untimely CWP Preparation

CWP preparation is untimely when repair work is not able to proceed because of either delays in completing the writing of a new procedure or delays in incorporating changes to an existing procedure. Delays in CWP preparation can occur during induction of controlled work into the CSMP file, or during research, writing, review, or approval of CWP revisions.

a. Routing Delays

Delays during induction of controlled work into the CSMP file are usually caused by slow routing of the ship's paper 4790/2K work request. Both the ship and the IMA can cause routing delays. These delays contribute to untimely CWP preparation by forcing the P&E section to perform too large a proportion of their work in too short a period of time.

The ship can cause delays by holding back work requests with special requirements until too close to the start of the upkeep period. In the SUBPAC Maintenance Manual, the TYCOM acknowledges that planning a controlled job can take up to two weeks. Late submission of controlled work requests significantly increases the probability that the P&E section will not be able to properly complete planning for that work [Ref. 2:pg. IV-6-9]. On USS MCKEE, the P&E section claims it receives nearly all work requests requiring CWPs only one week before the start of the upkeep.

The IMA can also cause routing delays. Before P&E receives the work request, it is reviewed by the MDCO (twice), the TYCOM Rep and the PMA. Unless aggressively tracked, these reviews can delay the arrival of the work request in P&E by several days. The MDCO on USS MCKEE stated before it started performing substantially all work request data entry and began aggressively tracking work request routing, it was not uncommon for the work request routing process previously shown in Figure 4 to take up to five days.

b. Research and Writing Delays

Delays during technical research and writing of CWPs are commonly caused by poor documentation of the required maintenance by the ship, or, within P&E, by administration and training deficiencies. On USS MCKEE, research and writing delays attract the most supervisory attention because these delays occur solely within P&E. Although LWCs and AWCs may contribute to delays through slow technical review of CWPs, most delays are perceived to be P&E's fault.

To conduct research, P&E must be reasonably sure of the identification of the component to be repaired and have a problem description detailed enough to determine the probable cause of the component malfunction.

Accurate component information is necessary for retrieval of the correct reference drawings, technical manuals, and repair procedures used to write the CWP. A detailed problem description is necessary to determine the proper scope of the repair. Inaccurate component information or too general problem descriptions delay the start of CWP preparation until the information can be obtained from an on-site inspection (called a shipcheck). Frequently, the ship is at sea, unavailable for a shipcheck. In such cases, until the ship returns to port, little progress can be made on the CWP for that job.

Administrative handling of CWPs within the P&E section also contributes to research and writing delays. USS MCKEE's administrative controls on CWP preparation, storage, and retrieval are ineffective because of a misunderstanding of the capabilities of the stand-alone personal computers used to write CWPs. CWPs are stored haphazardly on the computers, with no indexing system to record status, applicability, or storage location. Delays are introduced when an individual, other than the CWP author, tries to find information concerning a specific CWP. This person must use a trial-and-error procedure to find CWPs due to lack of administrative controls. The informal self review by USS MCKEE estimated improvement in administrative controls could save 300 man-hours per year currently spent searching for CWPs believed to exist somewhere in electronic storage.

Insufficient training is an important cause of CWP research and writing delays. Personnel assigned as planners are generally expert within their individual rating specialty, but usually have little experience researching and writing technical maintenance procedures, especially for work in other ratings. Most have no practical experience with computers and are slow typists. Also, there is no formal training program for planners. On-the-job-training is the only practical method of planner training, and is not always of good quality.

USS MCKEE's informal self review [Ref. 1] found it takes an average of 30 man-hours to research and write a CWP. At the current level of nine planners in P&E (10071 planned productive man-hours per year), this rate of CWP preparation is sufficient to produce only 335 CWPs per year. From 1986 to 1988, the average demand was nearly 750 CWPs per year. Somehow, but with much stress, the planners are able to meet this demand. The short lead time for CWP preparation, described above, exacerbates the capacity shortfall by severely limiting opportunities for workload smoothing.

Although many practical suggestions were proposed in the self-review, even when their effects are considered cumulatively, there is still a shortfall in CWP production capacity. Additional personnel could not be assigned to P&E since production work centers of the Repair Department, more critical than P&E, were also undermanned in the ratings desired. Increasing the number of productive man-hours available to the nine planners by eliminating watchstanding duties and extending the normal workday would still leave a shortfall in capacity of close to 200 CWPs per year. Reducing the time required to research and write CWPs requires improving the productivity of the planners.

2. Controlled Work Volume

According to USS MCKEE's PMA, controlled work comprises only ten to twenty per cent of the IMA's average submarine upkeep workload. During an average upkeep, twenty per cent of the controlled work will be cancelled for reasons other than untimely CWP preparation. This means of the approximately 150 work requests accepted by the IMA for a typical submarine upkeep, 15 to 20 will require CWPs. Three or four of these will be cancelled, leaving only 12 to 16 work requests, out of 150, requiring completed CWPs.

Although a small proportion of the IMA workload, controlled work represents a large commitment of resources and receives much upper-management attention. Controlled work is complex and costly. Moreover, the risk of schedule overrun is high, especially when multiple work center coordination is required,. As a result, senior IMA management is keenly interested in the status of planning controlled work. When the P&E section falls behind, crisis management quickly returns, as P&E supervisors try to demonstrate sensitivity to the concerns of higher-level management.

3. Consequences of Crisis Management

In addition to its adverse impact on productivity and morale when overused, crisis management in P&E results in long term neglect of planning lower priority work. On USS MCKEE, crisis management in P&E shifted all available resources to the preparation of CWPs, leaving none for planning alterations. At the time of USS MCKEE's self review, this practice had resulted in a backlog of around 500 alterations. The effect of 500 overdue alterations on the readiness and capability of USS MCKEE's assigned submarines is not easily quantified, but is significant.

4. Problem Summary

The various planning problems experienced by USS MCKEE are summarized by Figure 5. The uppermost graph compares the TYCOM's objectives for timely identification of work to that reported as typical by the planners of the P&E section. Most of the work for an upkeep should be identified three to four weeks before the start of the upkeep. In contrast, the P&E section's planners receive the bulk of their CWP workload the week before the start of the upkeep.

The charts in the lower portion of Figure 5 show P&E's cyclic CWP backlog under typical conditions and under the TYCOM's objective conditions. Controlled work requirements are presented to P&E in batches corresponding to percentages shown in the upper graph. The results of late identification of work, delays, and other problems are made clear by examining the CWP backlog at the start of any unit's upkeep.

The planners in P&E work on CWPs for the unit to be in upkeep next. In Figure 5, five days before the start of unit #3's upkeep, P&E receives a batch of work requests. However, there are still two incomplete CWPs for unit #2's upkeep. The P&E planners finishes the CWPs for unit #2 prior to starting the CWPs for unit #3.

Typically, at the start of an upkeep, CWPs for one third of the controlled work identified up to that point are incomplete. With an expected ten

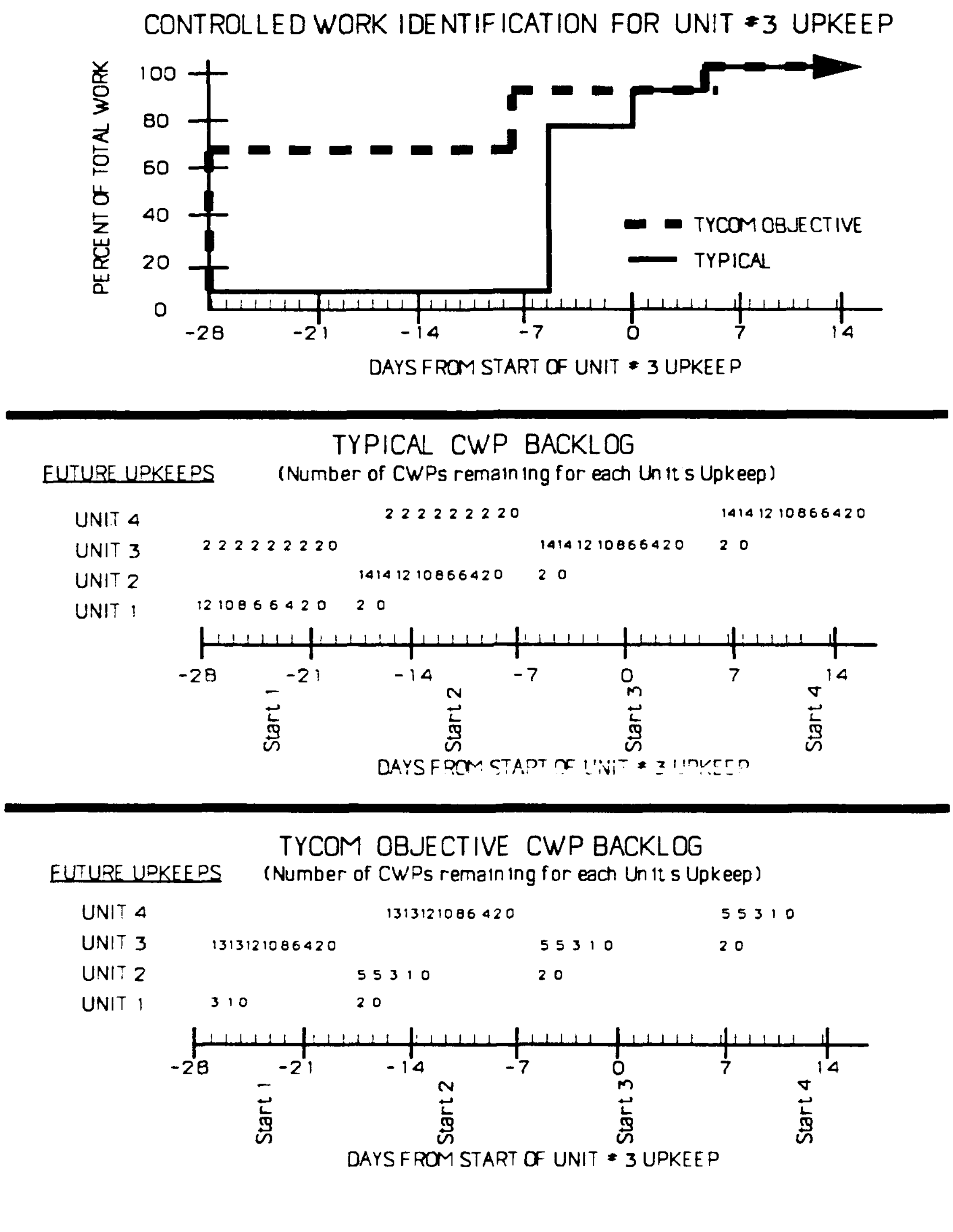


Figure 5 Controlled Work Identification and Resulting CWP Backlog

percent growth in work during the upkeep, this means fully 40 percent of all controlled work is planned during the upkeep. It is no wonder CWP preparation is perceived as untimely.

In contrast, if the TYCOM's objectives for timely identification of work are met, all CWP preparation for identified work is complete before the start of the upkeep. This is in spite of inadequate training and lack of administrative controls in P&E.

In constructing the graph and charts of Figure 5, it is assumed 30 upkeeps are performed per year and are evenly spaced, resulting in an upkeep starting every 12 days. Each upkeep is assumed to require 20 CWPs. Also, based on a demonstrated ability to supply the average demand of 750 CWPs per year, the planners are assumed to complete two CWPs per day.

The previous discussion suggests the primary cause of untimely CWP preparation is late identification of work. Unfortunately, it is not always possible to identify work any earlier. The objective of the remaining chapters is to analyze the entire maintenance planning process, and identify opportunities for reducing delays, improving planning effectiveness, and improving P&E planner productivity.

III. IMA MAINTENANCE PLANNING ANALYSIS

The research methods used in analyzing the maintenance planning process are a combination of generally accepted systems requirements analysis (Whitten, Bentley, and Ho [Ref. 7]) and object-oriented database design procedures (Kroenke and Dolan [Ref. 8]).

Traditional requirements analysis techniques are process-oriented. They identify data elements and system functionality by determining the data inputs and processes necessary to produce system outputs.

Object-oriented analysis focuses on relationships between data elements. Individual data elements are grouped to show characteristics of, and relationships between, objects and entities. The operations performed on objects and entities constitute the functionality of an information system.

In this paper, object-oriented techniques are used in representing maintenance planning data. Traditional analysis techniques are used as a guide for structuring the overall analysis and in presenting system functionality. Information and data used in maintenance planning is collected and organized into objects from examination of applicable instructions, input/output forms and reports, and interviews with maintenance planning personnel. System functionality is derived from the IMA 3-M organization and from operations required to produce information needed by the tended submarine, IMA work centers, IMA management, and the TYCOM.

The remainder of this chapter analyzes the people, objectives, information, and functions that comprise the maintenance planning process. An evaluation of computer support for IMA maintenance planning is presented in the following chapter.

A. IMA MAINTENANCE PLANNING ORGANIZATION

A list of personnel in the maintenance planning process, compiled from the 3-M Manual, the SUBPAC Maintenance Manual, and interviews with USS McKEE personnel is presented below in Table I.

TABLE I

MAINTENANCE PLANNING PERSONNEL ROLES

POSITION	ROLE
Ships Force	Submit 4790/2K work request. Provide data on component, location, symptoms, action taken to date, point-of-contact, desired time frame of repair.
TYCOM Rep	Screen and track all IMA work identified by the ship or as directed by proper higher authority.
MDCO	Liaison between ship and IMA. Screen 4790/2K for approval. Data entry of 4790/2K into ADP system. Route 4790/2K and 4790/2P for planning data collection.
PMA	Screen 4790/2K for acceptance, special requirements, assignment to upkeep, considering IMA capability and capacity (labor and equipment). Monitor IMA execution of planned work.

TABLE I (cont.)

POSITION	ROLE
P&E Officer/ Assistants	Coordinate planning effort. Track planning of alterations, contract work, and other long lead-time work.
Estimator	Determine method of repair; rough-out procedure. Assign lead and assist work centers. Estimate man hours required.
Lead Planner	Supervise, train, and assist Planners. Administer CWP database.
Planners	Research and write Controlled Work Procedures.
Quality Assurance (QA) Officer/ Inspectors	Review CWPs for documentation of Objective Quality Evidence to satisfy QA Manual requirements for controlled work. Track Controlled work.
LWC	Coordinate repair efforts among assisting work centers. Conduct detailed planning for assigned, non-controlled work. Requisition and stage material needed for repair. Technical review of CWPs. Report progress on, and expense labor and material against work requests.
AWC	Conduct detailed planning for assigned, non-controlled work. Requisition and stage material needed for repair. Report progress on, and expense labor and material against work requests. Technical review of CWPs.
ARRS	Interface between IMA, MDCO and ADP Facility. Provide reports as requested by PMA, MDCO or other authorized activities, and as directed by 3-M instructions. Forward 3-M data to 3-M Central Data Bank.

Figure 6 diagrams the relationships between IMA maintenance planning personnel. The interactions are similar to those of the IMA 3-M organization previously shown in Figure 3. The similarity emphasizes that 3-M system structure largely defines the IMA maintenance planning organization. The main

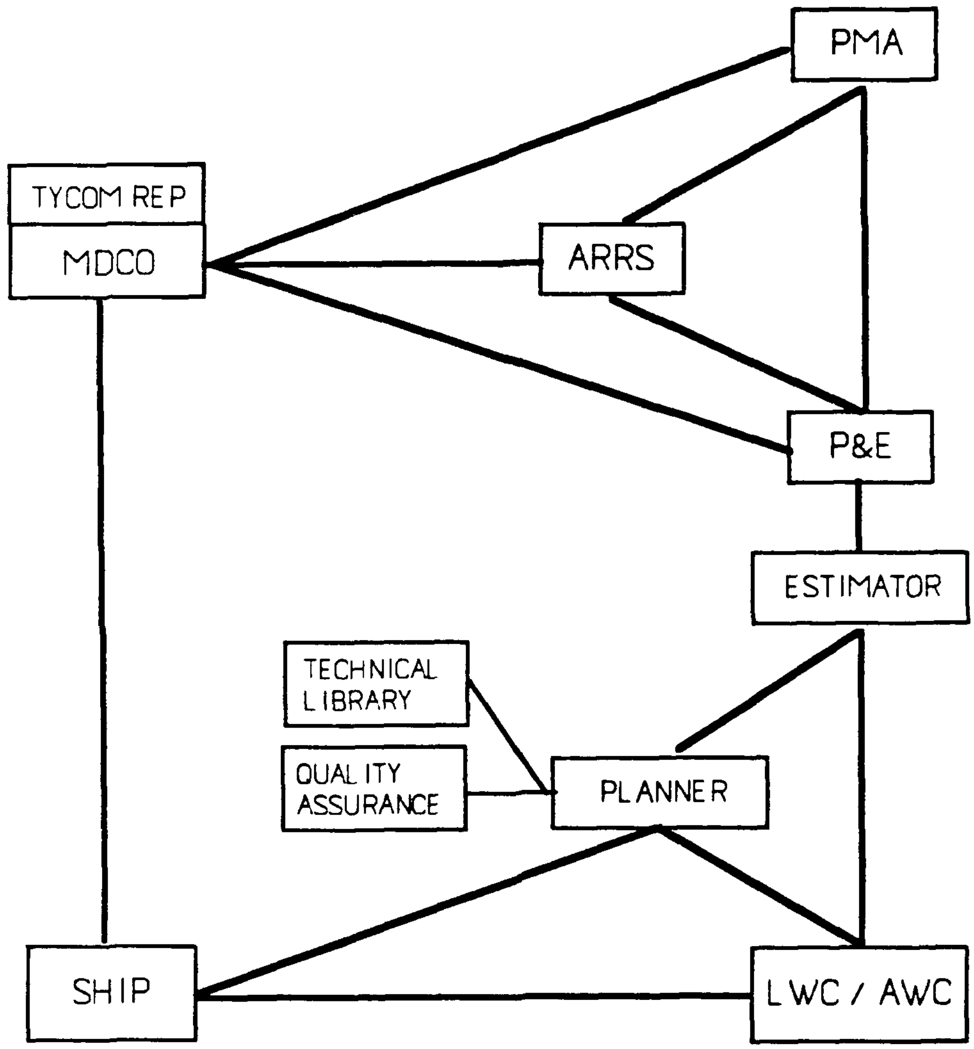


Figure 6 IMA Maintenance Planning Organization

difference is in the interface between the ship and the IMA. In the IMA maintenance planning process, Ship Superintendents have little or no role in upkeep planning. P&E planners and production work center personnel interface directly with the ship for maintenance planning issues.

B. MAINTENANCE PLANNING POLICIES AND OBJECTIVES

1. Navy Policies

Maintenance policies for the Fleet are established by the Chief of Naval Operations. The essence of these policies is that ships will be maintained "...in a material condition sufficient to allow them to accomplish their assigned missions." In implementing this policy, IMAs are specifically tasked to "... accomplish ship maintenance beyond forces afloat capability/capacity to the maximum extent feasible consistent with the availability of material, funds and skilled manpower." [Ref. 3]

Policy is also established for the employment of IMA maintenance personnel. While assigned to the IMA, sailors should be building on in-rate experience through training and maintenance to enhance the self-sufficiency of their ships when they return to sea.

2. IMA Objectives

a. IMA Maintenance Personnel Employment

To evaluate utilization of IMA manpower resources in support of the CNO's policies on employment of IMA maintenance personnel, two performance indicators are established by the TYCOM. The first, Repair Utilization, is a measure of the loss of potentially productive manpower to non-maintenance tasks such as watchstanding, cleaning, training, etc,. The second, called the Productivity Index, seeks to measure the amount of maintenance accomplished with the manpower resources available.

Expressed in equation form, these performance objectives and their target values are:

$$\textbf{Repair Utilization} = \frac{\text{Net Man-hours available for work}}{\text{Gross Man-hours available for work}} >= 0.65$$

$$\textbf{Productivity Index} = \frac{\text{Earned (expended) Man-hours}}{\text{Net Man-hours available for work}} >= 0.8$$ [5]

[Ref. 2:pg IV-6-20,21].

As additional support for the CNO's IMA maintenance personnel employment policy, a third objective is established for SUBPAC IMAs.

---

[5] Some IMAs have the resources to precisely estimate man-hours nominally required to accomplish a task. Tasks are decomposed into steps, for which Engineered Time Values (ETVs) are assigned. The ETV is the number of man-hours it should take to accomplish a specific step. When a step is completed, the IMA "earns" the ETV for that step. The "earned" man-hours are then used to calculate the Productivity Index. IMAs using ETVs have a target Productivity Index of 0.9.

Assignment of sailors in maintenance related ratings such as Hull Technician, Machinists Mate, and Electricians Mate to non-production functions, such as administration or planning and estimating is limited to 15 per cent of the total IMA manning. In other words, each IMA work center should have at least seven production personnel for every one production support person. [Ref. 2:pg IV-6-20]

b. Maintenance Planning Performance

Measurement of maintenance planning performance is implicit in the output-based Repair Utilization and Productivity Index figures and in IMA Performance Summary data. Effective planning should permit accurate forecasting of the IMA workload. Accurate forecasting facilitates both scheduling of resources to meet the Repair Utilization and Productivity Index goals and successful completion of the associated availability. The foundation on which workload forecasting rests is a combination of timely identification of work and accurate estimation of the resources required to complete that work.

To evaluate timeliness of identification of work, targets are established for submission of work requests by the ship and the squadron. Table II summarizes these targets for a typical availability of four weeks.The majority of the work requests for an availability should be submitted three to four weeks before the start of the availability, during the Pre-Arrival Conference (an availability planning meeting attended by the ship, the squadron, and IMA). Work requests submitted after the Pre-Arrival Conference should represent equipment failures occurring during the month before the availability, and should be relatively few in number. [Ref. 2:pg IV-6-21]

TABLE II

WORK REQUEST SUBMISSION GOALS

Event	# of Days from Start of Availability	Percentage of total Work Requests Submitted
Pre-Arrival Conference	-28	65%
Arrival Conference	0	90%
End of Availability	28	100%

In SUBPAC, no goals are formally established for accuracy of resource estimation. Measurement of estimation accuracy may be accomplished only by manually plotting and interpreting, for each upkeep, graphs of estimated and actual man-hour expenditures versus time.

3. Evaluation of IMA Objectives

Both maintenance planning effectiveness and evaluation of maintenance performance are heavily dependent on accurate estimation of resources required for repair. In SUBPAC, however, there is no explicit standard for estimation accuracy. Unless monitored, P&E estimates may become unreliable, and therefore worthless as a standard for planning and evaluating maintenance performance.

Based on the CNO's policy for IMAs, evaluators of IMA performance should be interested in three performance indicators: the amount of capacity made available to accomplish repairs, the amount of repairs accomplished with the available capacity, and the efficiency with which available capacity is used to accomplish repairs. The Repair Utilization and Productivity Index objectives provide only two of the necessary measures. Furthermore, for IMAs without Engineered Time Value standards, the Productivity Index is meaningless.

Missing from the TYCOM's performance objectives is an efficiency, or effectiveness indicator. An Efficiency Index could be defined as a ratio of man-hours earned (or estimated) to actual man-hours expended;

$$\textbf{Efficiency Index} = \frac{\text{Earned (Estimated) Man-hours}}{\text{Expended Man-hours}}$$

Using this measure, an IMA with a Efficiency Index of greater than one uses manpower resources more efficiently than planned, while an Efficiency Index less than one means the IMA uses manpower resources less efficiently than planned. To be used as a basis for comparing IMA performance, the TYCOM would have to exercise control over the estimation process; IMAs could use standardized man-hour estimates (such as ETVs) provided by the TYCOM, similar in concept to the labor scales used by automotive mechanics. The ability of the IMA to revise estimates would be necessarily limited.

An Efficiency Index, defined in terms of labor, would do more than provide the TYCOM with a measure of IMA performance. It would also discourage the longstanding and pervasive idea that military labor is "free". Increased management attention to labor resource usage would reduce both reliance on overtime to compensate for management errors, and over-reporting of man-hour expenditures. Over-reporting of man-hours may occur to either hide lost production time or stave off a "no reported progress" management report.

The maintenance management objectives established for SUBPAC IMAs permit only partial assessment of IMA performance and implementation of CNO maintenance policy. Lack of goals for the accurate estimation of resource requirements limits the TYCOM's ability to objectively evaluate IMA performance. Objectives which have been established allow evaluation of IMAs on the basis of manpower resources devoted to the repair effort, but not on the effectiveness of their use. Resources consumed are examined, but the resulting maintenance output is not. Without considering efficiency, it cannot be determined whether or not ship maintenance is being accomplished to the maximum extent feasible.

C. MAINTENANCE PLANNING OBJECTS

It does not appear that any part of the 3-M System database is relationally structured. It is useful, however, to consider the maintenance planning process from an object-oriented perspective. The data objects conceptually used in maintenance planning, with a brief description of each, are listed in Table III. These objects represent a consolidation of selected maintenance planning data elements from the 3-M system, the URO/IMMP programs, and Alteration Management System, into a relational framework. Data elements not from the sources above are based on interviews with maintenance planning personnel.

Appendix B provides detailed object diagrams, object and domain definitions, and entity/relationship diagrams.

TABLE III

MAINTENANCE PLANNING OBJECTS

OBJECT	DESCRIPTION OF OBJECT INSTANCE
Ship	A submarine.
Ship System	A group of interacting components which provide a specific set of functions on a ship or class of ships.
Ship System Component	The lowest level of equipment which has its own configuration identity.
Allowance Parts List/ Allowance Equipage List (APL/AEL)	A list of parts and assemblies of parts which identify the unique configuration identity of a ship system component.
Repair Part	Material, assemblies, or sub-assemblies of parts used for repair of a component.
Key Event	A milestone associated with a maintenance availability.
Work Center	A functional and administrative division of a Navy maintenance organization.
Worker	An individual, with associated skills and training, who performs maintenance tasks.
Task	A collection of worksteps which accomplish a specific aspect of a maintenance action.Ship Alteration Status
Workstep	The smallest unit of work into which a task can be reasonably subdivided.
Requisition	A request for a repair part necessary to perform a maintenance action.
URO/IMMP	A periodic, preventative maintenance requirement for the UnRestricted Operations/Limited In Depth and SSN Integrated Maintenance and Modernization Planning programs designed to ensure continued safe submarine operation, to design test depth, while extending the time between overhauls.

TABLE III (cont.)

MAINTENANCE PLANNING OBJECTS

OBJECT	DESCRIPTION OF OBJECT INSTANCE
Alteration	Engineering or configuration changes to a ship system or component.
Work Request	A maintenance action to be completed by the IMA.
Controlled Work Procedure	A written procedure which documents, in great detail, how work is to be performed.
Consolidated Shipboard Allowance List (COSAL) Line Item	Documents the relationship between a ship, an APL/AEL, and a repair part; A COSAL is a listing of all repair parts, sorted by APL/AEL, which make up a ship's components.
Key Event Date	Documents the relationship between a ship and a key event; determines the date of a key event.
Component Alteration Status	Documents the relationship between a ship and an alteration.
Ship Alteration Status	Documents the relationship between a ship system component and an uncompleted alteration
Ship URO/IMMP Status	Documents the relationship between a ship and a URO/IMMP.
Component URO/IMMP Status	Documents the relationship between a ship system component and a URO/IMMP.
Work Request Task	Documents the relationship between a work request and a task necessary to complete it.
Work Request Task Workstep	Documents the relationship between a work request task and a workstep.

D. IMA MAINTENANCE PLANNING FUNCTIONS

There are five major IMA maintenance planning functions:

1. identification of maintenance,
2. screening,
3. planning and estimating,
4. scheduling, and
5. reporting/monitoring of planning status.

1. General Discussion

Figure 7 is a high level conceptual data flow diagram which shows the inter-relations between IMA maintenance planning functions, objects, personnel, and external information systems.

Although not apparent from Figure 7, IMA maintenance planning is essentially a serial process. Work proceeds through identification, screening, planning and estimating, and scheduling in sequence. Dependencies between the screening, planning, and scheduling functions, however, can result in repetitions of the planning process. For example, the upkeep work schedule resulting from the first iteration of the planning process may be found to be unacceptable. Iterative rescreening, replanning, and rescheduling of work requests is performed until senior IMA managers agree an acceptable balance between resource utilization, maintenance effectiveness, and schedule is achieved. The data interfaces of each planning function are explained below. Later sections present a detailed data flow diagram and explanation for each function's internal processes.

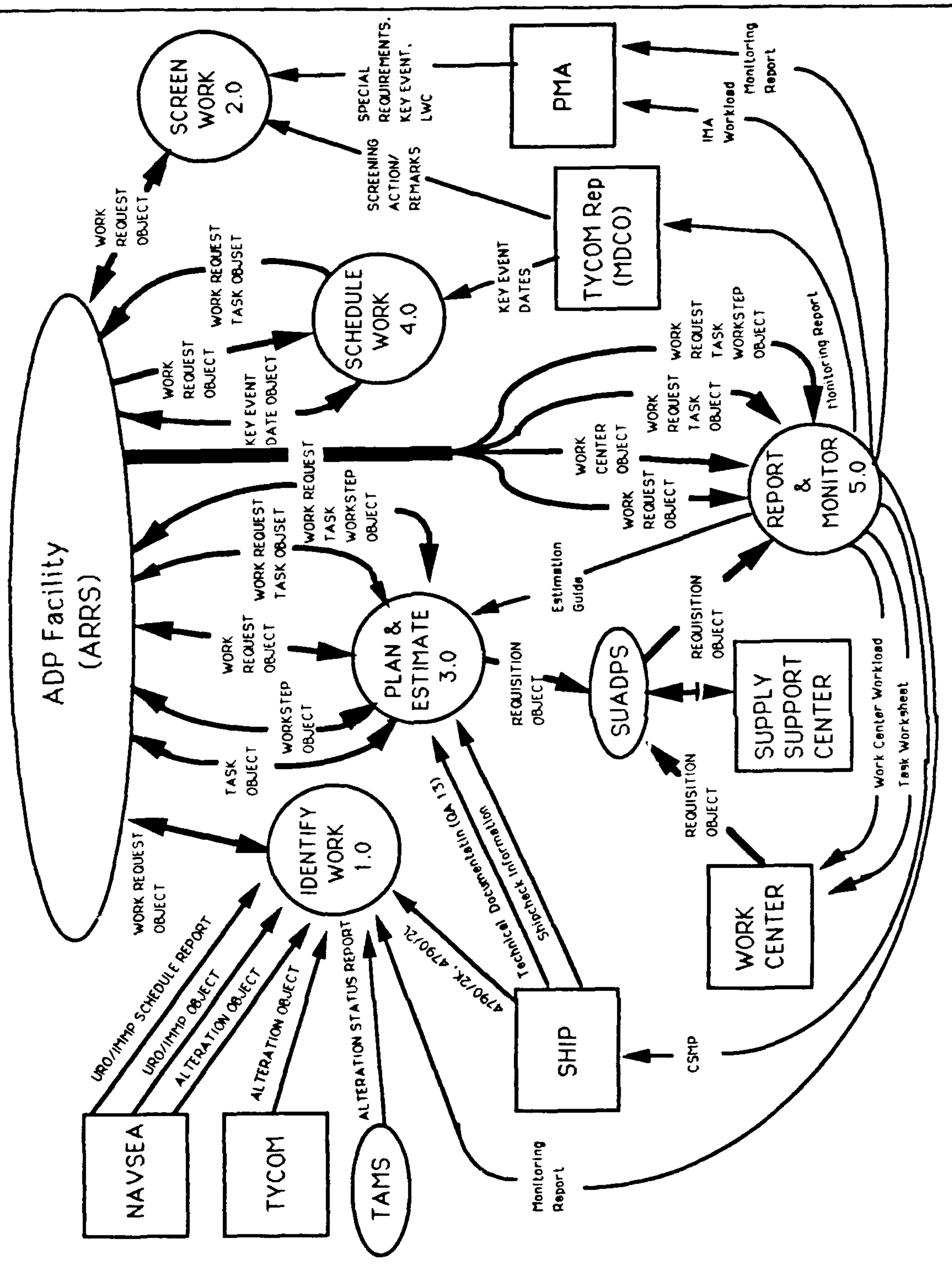


Figure 7 IMA Maintenance Planning Data Flow Diagram

a. Identification of Work

Identifying work is primarily the responsibility of the squadron. The TYCOM Rep and MDCO carry out this function, which is, essentially, to transform maintenance requirements into work requests.

Maintenance is introduced from one of three sources: Naval Sea Systems Command (NAVSEA), the technical and engineering authority for ship maintenance, the TYCOM, and individual ships all present requirements for preventative, alteration, and corrective maintenance to the IMA.

NAVSEA identifies URO/IMMP maintenance requirements and provides direction for accomplishing alterations from the Fleet Modernization Program.

The TYCOM is a second source of alteration maintenance requirements. The TYCOM organization provides reports on the applicability, authorization, priority, and status of both NAVSEA and TYCOM alterations via the TYCOM Alteration Management System (TAMS).

Finally, as a third source of maintenance requirements, tended submarines submit work requests for maintenance assistance using standard 3-M forms 4790/2K and 4790/2L.

Monitoring reports allow for supervision of proper induction of work into the ADP facility, and updating of alteration and URO/IMMP status.

b. Screening

Screening is performed by the TYCOM Rep and the PMA. The TYCOM Rep assigns responsibility for each maintenance action to either the ship, the IMA, or a depot level activity. The squadron is responsible for managing Repair of Other Vessels (ROV) funds used to effect repairs. Accordingly, to control ROV expenditures, the TYCOM Rep may also specify the scope, method, and relative priority of a repair. The PMA accepts work for the IMA, assigns responsibility to a Lead work center, indicates any Quality Assurance or other special requirements, and determines for which key event the maintenance must be completed.

c. Planning and Estimating

Planning and estimating, is jointly performed by P&E and the work centers, in two levels of detail. At one level, the P&E estimator organizes each work request into a series of tasks which facilitate management of the overall work and which recognize the specialized functions and capabilities of the various IMA work centers. Using printed or automated estimation guides, the P&E estimator determines the effort, in man-hours, necessary to accomplish each task. At a more detailed level, a task is further decomposed into a series of discrete worksteps, which are also estimated. In order to plan capacity and requisition material, each work center tasked by the P&E estimator must perform this detailed task decomposition.

For work with QA or other special requirements, P&E planners conduct and document detailed planning by generating a CWP. Some technical guidance from work centers is used as well as technical documentation from the ship (COMSUBLANT/COMSUBPACINST 4855.2, form QA-13).

d. Scheduling

Scheduling may be performed by the PMA or P&E. Scheduling involves assigning dates for accomplishment of each work request task, subject to the constraints of the work request's key event and the upkeep schedule. Key event dates are maintained by the TYCOM Rep.

e. Reporting and Monitoring

Reporting and Monitoring, is provided by the ARRS. The TYCOM Rep and PMA instruct the ARRS which reports to provide for the squadron and IMA, and with what periodicity. The Reporting and Monitoring function draws on all available files in the ADP facility to construct the required reports. These reports are used as planning aids and for monitoring various aspects of maintenance planning and performance.

2. Detailed Discussion

a. Identification

Figure 8 shows a more detailed view of the Identification function performed by the TYCOM Rep and MDCO. Alteration tracking, URO/IMMP tracking, and collecting the incoming stream of 4790/2Ks are the means of identifying alteration, preventative, and corrective maintenance requirements.

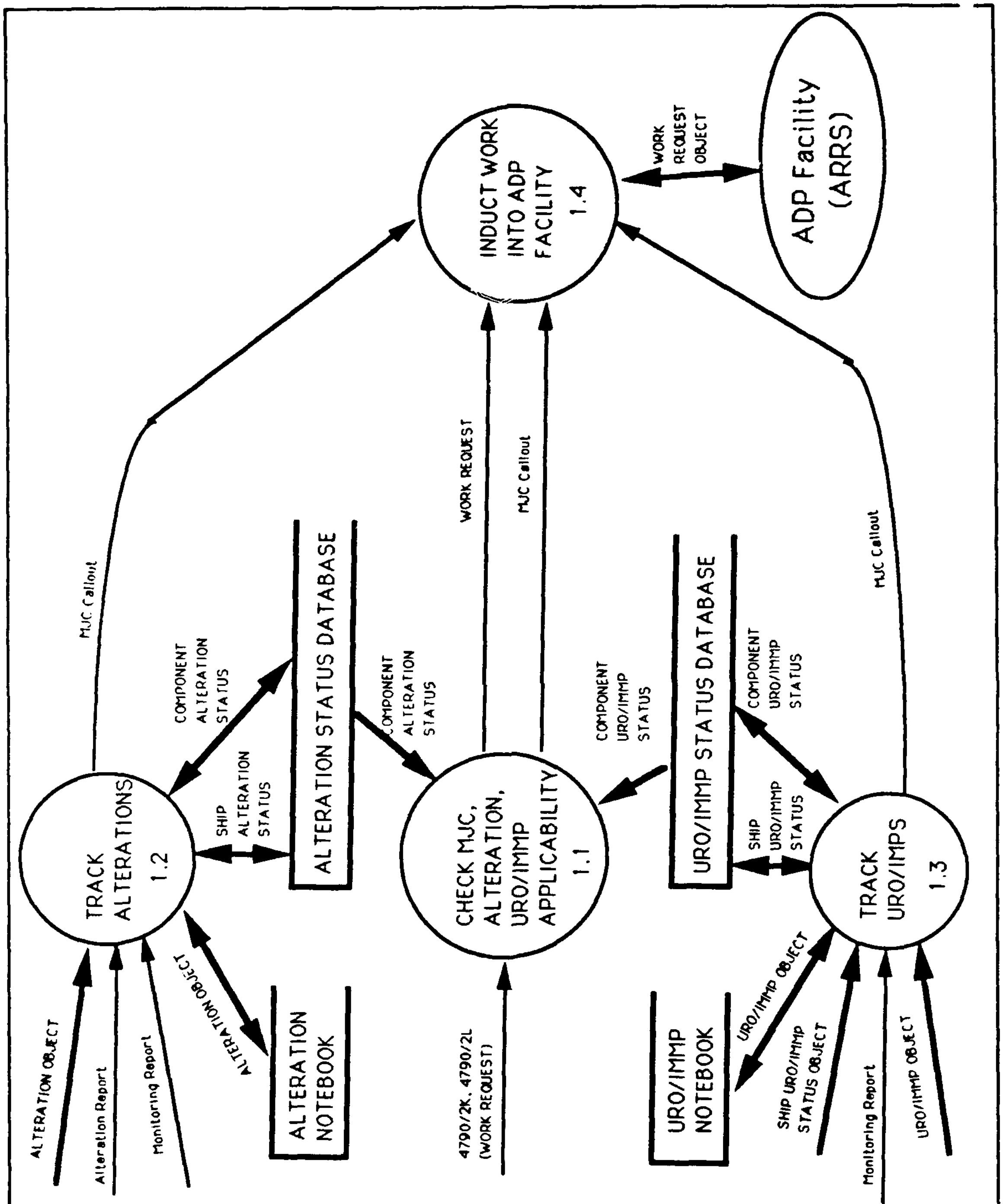


Figure 8 Work Identification Data Flow Diagram

These are inducted into the ADP facility by function 1.4, and stored in a CSMP file.

In function 1.1, Evaluate 4790/2K for Alteration or URO/IMMP Applicability, each 4790/2K is evaluated to determine whether the maintenance requirement can be satisfied by, or would facilitate, the performance of an outstandin· alteration or URO/IMMP. On USS McKEE, no physical records of component alteration or component URO/IMMP status are maintained, but in making this evaluation, alteration and URO/IMMP status are considered, looking for an alteration or URO/IMMP applicable to the Ship Component from the 4790/2K. [6]

Functions 1.2, Track Alterations, and 1.3, Track URO/IMMPs, are similar in that they both maintain databases containing the status of accomplishing a finite set of maintenance requirements. Printed alteration (and URO/IMMP) descriptions are provided by NAVSEA or the TYCOM and filed in notebooks. For each alteration, a record is made in the Alteration Status Database for each ship to which the alteration applies. Then, for each applicable ship, a record could be made for each component affected by that alteration. When an alteration is to be performed on a specific ship, and if that alteration has already been performed by the IMA, a Master Job Catalog number might exist for use by the work induction function to generate an automated work request (4790/2R). Monitoring reports, from the Reporting and Monitoring

[6] The databases for component URO/IMMP and alteration status are conceptually maintained through experience, "corporate memory", or other methods.

function, and TAMS Alteration Reports provide information which can be used to update the database. The database can also be used to reconcile TAMS Alteration Reports.

Function 1.3 is nearly identical to 1.2, except new URO/IMMP requirements are infrequently received and there is no external reporting interface. URO/IMMP records, however, are periodically audited by outside activities.

Function 1.4, Induct Work into ADP Facility, is straightforward data entry, and merits no further discussion.

b. Screening

Figure 9 is a more detailed view of the screening function. The TYCOM Rep, assisted by the MDCO, screens work requests, assigning maintenance responsibility and establishing the general method of repair. The PMA accepts or rejects the work for the IMA, and determines the need for special requirements, additional planning, and assigns the appropriate lead work center.

In function 2.1, Select Method of Repair, the TYCOM Rep attempts to balance effectiveness of repair, availability of resources, and the ship's schedule to achieve a given level of operational readiness for the lowest total maintenance cost. The bases for this decision are the work request description, personal experience and judgement, and technical guidance from technical support activities such as NAVSEA. Supplemental information concerning price and availability of repair parts may also be used when a repair under

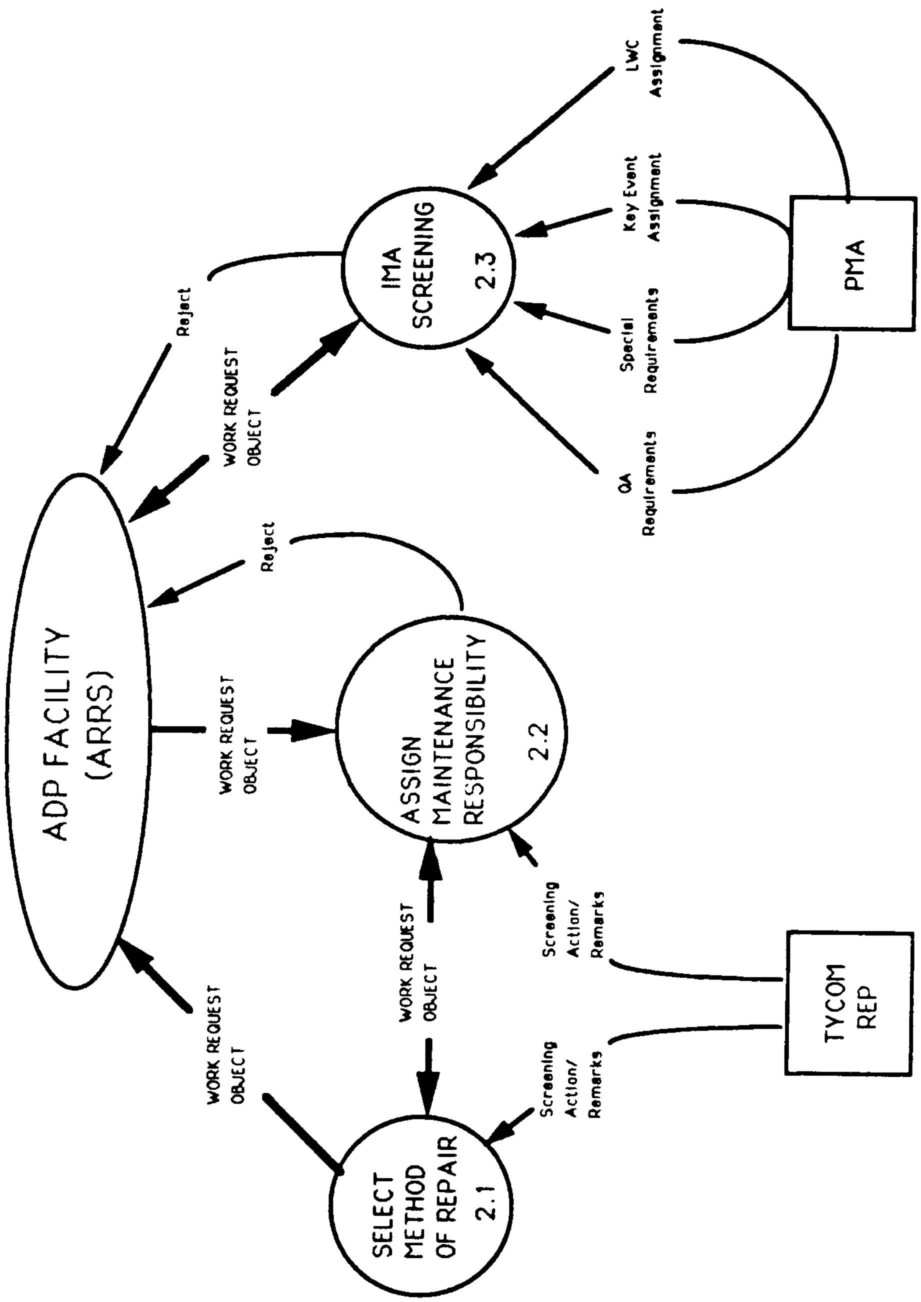


Figure 9 Screening Data Flow Diagram

consideration is known to be costly or time consuming. Most of the information used to select a method of repair is subjective. Providing the capability to make and test factually based decisions could reduce the number of iterations of the planning process required to arrive at an acceptable upkeep schedule.

In function 2.2, Assign Maintenance Responsibility, the TYCOM Rep again reviews each work request's remarks/description section. Based on his experience, the chosen method of repair, and judgement of the capability and capacity of the various maintenance activities, the work request is assigned to either the ship (organizational level maintenance), the IMA, or a depot level maintenance activity. An integrated priority, relative to other work to be performed on the ship submitting the work request, may also be assigned.

In function 2.3, IMA Screening, the PMA also reviews the remarks/description section of each work request, as well as the TYCOM Rep's screening action. Based on this review, personal experience, and judgement, the PMA assigns a lead work center and flags the work request for additional planning and any special requirements. The PMA also determines the key event for which the maintenance must be completed.

c. *Planning and estimating*

Figure 10 shows a detailed planning and estimating data flow diagram. IMMS does not provide computer based support for breaking down work requests into tasks and worksteps. These functions are shown as linked to the ADP facility, however, because MRMS does support them.

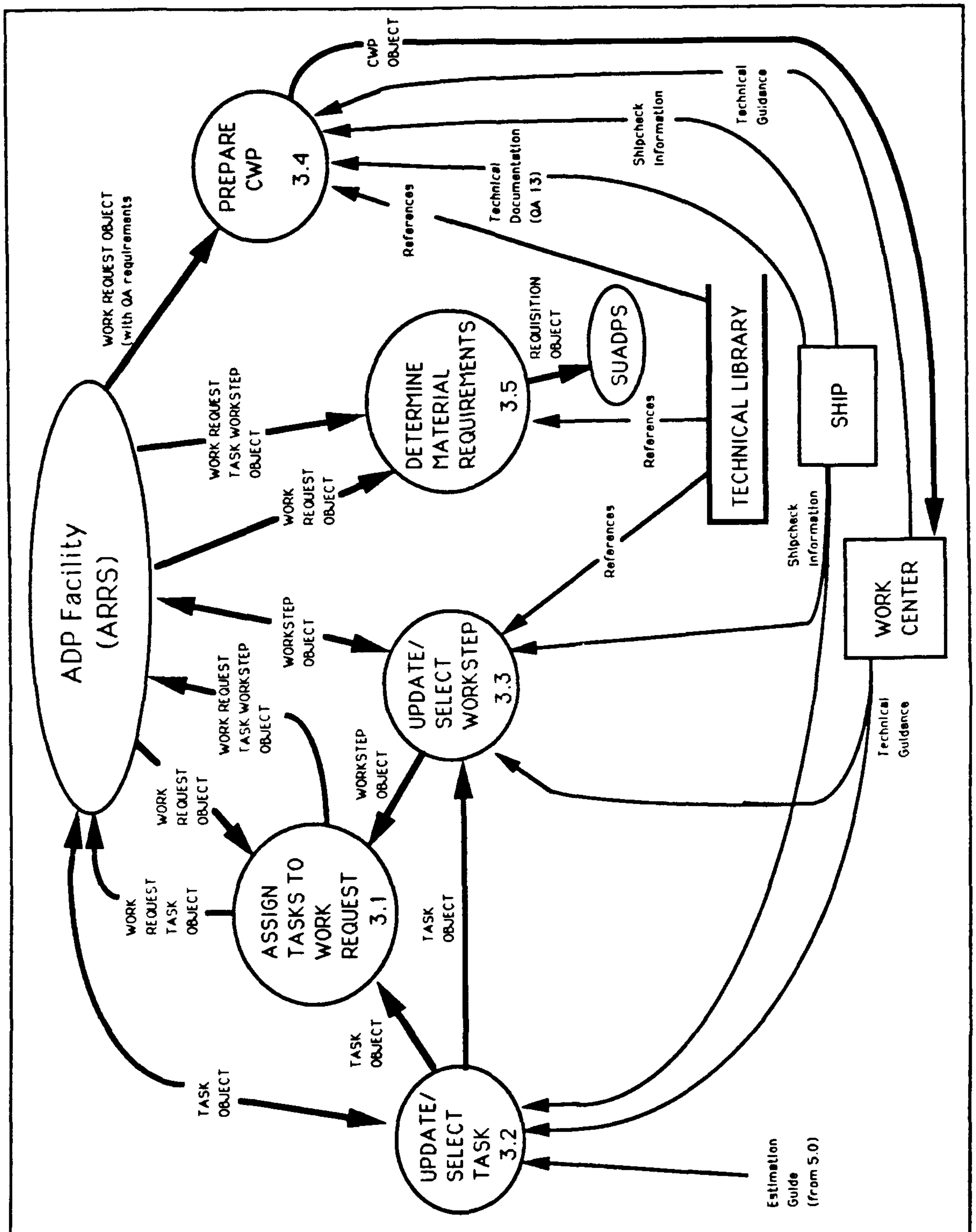


Figure 10 Planning and Estimating Data Flow Diagram

In function 3.1, Assign Tasks to Work Requests, P&E's estimator reviews each work request to be planned. The work request deficiency description, the screening action code, and the TYCOM Rep's and PMA's comments are all considered by the estimator. Following review, the estimator conceptually breaks each work request up into a series of tasks. The resources required to accomplish each task are then estimated. If start and due dates for work request tasks are not assigned by the estimator, they are assigned later in the scheduling function.

Functions 3.2 and 3.3 represent two methods of estimating resources required to accomplish tasks. The first considers only the set of tasks able to be performed by the work centers. The second method expands on the first, using Engineered Time Value concepts to further decompose tasks, and more precisely estimate the required resources.

In function 3.2, Update/Select Task, the estimator selects the tasks which correspond to the conceptual breakdown of the total job from function 3.1. An estimate of the labor resources required to complete each task may be made. This estimate is based on a statistical report of performance of a similar task on various ship components (an estimation guide), shipcheck information, and technical guidance from the work center.

In function 3.3, Update/Select Workstep, each task, from function 3.2, is further broken down into its basic steps, called worksteps. Worksteps are based on equipment type, size, and applicable references from the technical library. Estimates of labor resources required for each workstep are based on a combination of technical guidance from the work center, shipcheck information, and perhaps, some form of time-motion analysis. The estimate of the labor resources required to accomplish a given task becomes the sum of the estimates from the worksteps which make up that task.

Function 3.5, Determine Material Requirements, can be performed once a work request has been planned in detail, either explicitly by the estimator or implicitly by the assigned work center. Necessary repair parts are identified based on the physical requirements of each workstep, technical references, and supply information from the work request and the technical library. A requisition is used to order each part from the Supply Support Center, which uses the SUADPS system for requisition processing and tracking.

Work requests with QA and other special requirements must be documented in detail, describing how the work is to be done. Figure 11 shows how function 3.4, Prepare CWP, is accomplished.

In function 3.4.1, Internal Screening, the lead planner reviews each work request flagged for QA or special requirements. Work deemed not requiring a CWP is rejected. The lead planner assigns an informal, internal priority to each work request based on the work request's key event date, integrated priority, TYCOM Rep's and PMA's comments, and the internal priority of other work requests already part of the CWP workload. The lead planner assigns a planner (worker) based on the type of ship system involved, individual planner experience, and planner workload. Following screening, the work request represents a

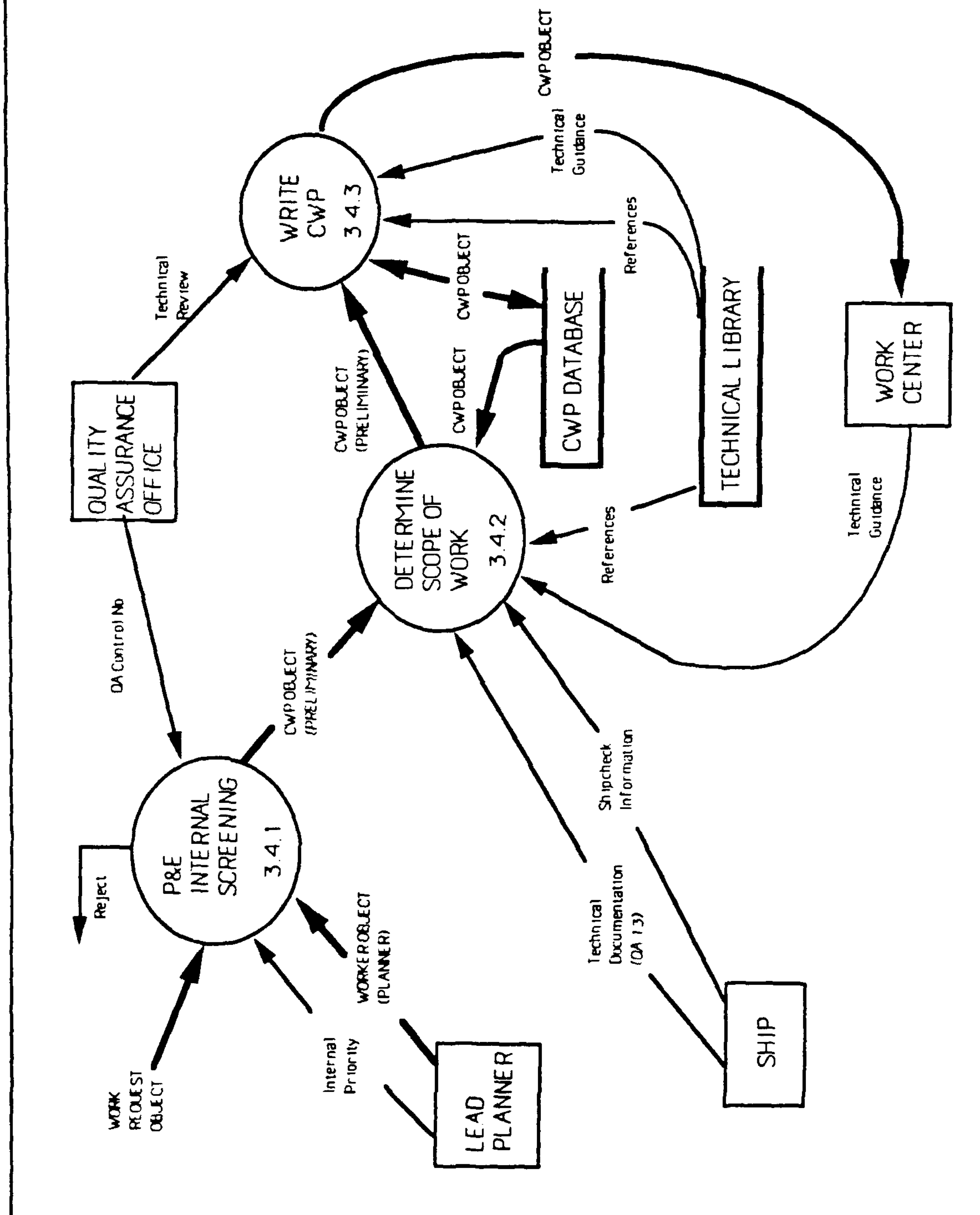


Figure 11 Prepare CWP Data Flow Diagram

preliminary CWP. For audit purposes, and as part of the internal screening process, the QA office assigns a control number to each CWP.

Following assignment, a planner performs function 3.4.2, Determine Scope of Work. Shipcheck information is obtained to verify the ship system and ship component to be repaired. Based on the ship component deficiency, technical documentation provided by the ship (QA form 13), references from the technical library, and technical guidance from the work centers, the planner determines the scope of the repair, and also, the technical and procedural references which govern that repair. To save time in researching references, the planner may check the CWP database for a pre-existing CWP on a similar component.

In function 3.4.3, Write CWP, the planner checks for a pre-existing CWP which might be modified, rather than writing a completely new CWP. Using the references identified in function 3.4.2, and additional guidance from the work centers, the planner writes a CWP to accomplish the repair called for in the work request. To save time, planners store and use computer generated QA forms as templates. Writing a CWP consists of free text entry of lists of references and enclosures, prerequisites, precautions, shop responsibilities, step-by-step instructions, and QA signature requirements. Better utilization of word processing software capabilities and features could save even more time.

Before a CWP is released to the lead work center, the QA Office conducts an independent review. The QA review ensures the CWP meets requirements for documentation of objective quality evidence for repairs conforming to specifications. Following review and approval, a copy of the CWP is delivered to the lead work center, and work may commence.

d. *Scheduling*

Figure 12 shows the scheduling function in more detail. In function 4.1, Maintain Key Event Schedule, the TYCOM Rep updates the Key Event Date object. If a key event date is changed, function 4.2 is triggered to change the due dates of incomplete work request tasks, related to the key event, so they are not later than the key event date. The start dates are also changed, to keep the task duration constant.

In function 4.2, Schedule Work Request Tasks, work request task schedules are checked and work request tasks without due dates or start dates are scheduled. The default task start date is the availability starting date. The default task due date is the associate key event date. Assigning a start date to a work request task issues the task to the assigned work center. Issued work requests appear on various progress monitoring reports.

If a work request task's due date is found to be later than the associated key event date, the due date is changed to the key event date. The start date is adjusted to maintain a constant task duration. Not all work requests are associated with a key event. For work requests without key events the limiting date for scheduling is the availability ending date.

Scheduling by key event is a major part of Program Evaluation and Review Technique (PERT). PERT, Critical Path Method (CPM), and Gannt charts are effective graphic tools for identifying and avoiding scheduling conflicts

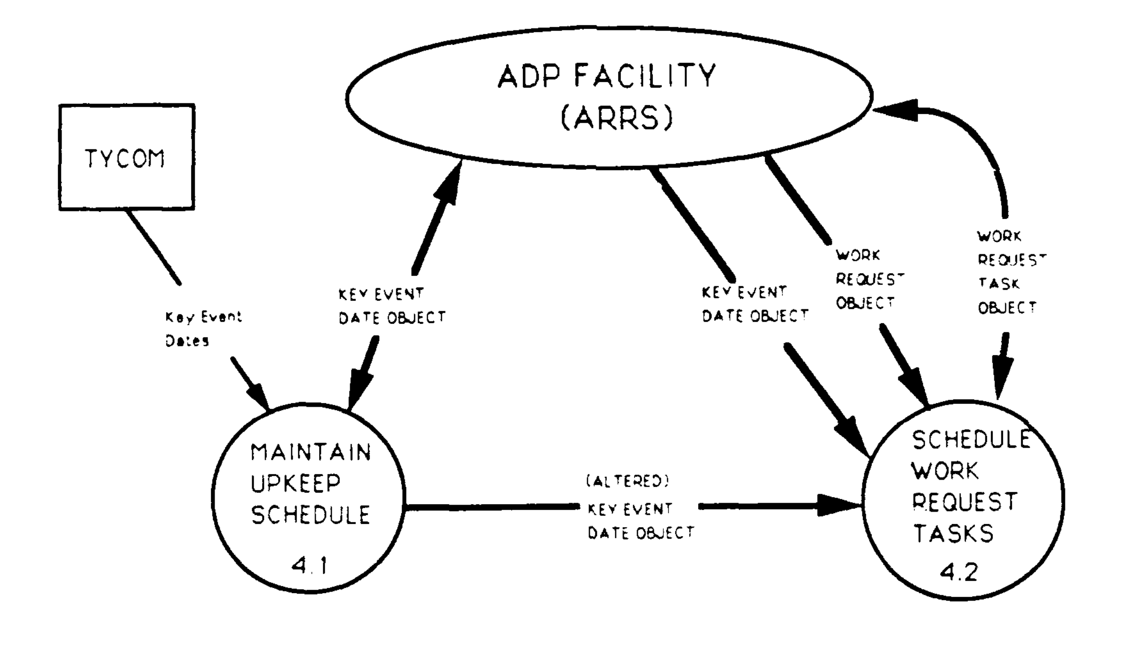


Figure 12 Scheduling Data Flow Diagram

and for project management. Surprisingly, none of these tools are used in the IMA maintenance planning process.

E. SUMMARY

IMA maintenance planning is essentially a serial process. Work proceeds through identification, screening, planning and estimating, and scheduling in sequence. Dependencies between the screening, planning, and scheduling functions, however, can result in repetitions of the planning process. For each upkeep, iterative screening, planning, and scheduling of work requests is performed until senior IMA managers agree an acceptable balance between resource utilization, maintenance effectiveness, and schedule is achieved. IMMS and MRMS support this effort through transaction processing, structured reporting, and measurement of resource utilization.

Some planning iterations could be avoided through use of decision support tools within the screening and scheduling functions. Ability to analyze different maintenance alternatives and model their impact on the upkeep schedule would facilitate optimal decision making without wasting planning effort. Scheduling aids such as PERT, CPM, and Gannt charts could identify scheduling conflicts earlier in the upkeep planning cycle.

The preceding analysis of the IMA maintenance planning process provides a basis for evaluating how computer support for maintenance planning contributes to the problems experienced by USS MCKEE's P&E section. Evaluation of support provided by IMMS and MRMS is the subject of the following chapter.

IV. COMPUTER SUPPORT FOR IMA MAINTENANCE PLANNING

This chapter evaluates the computer support provided for maintenance planning by IMMS and MRMS. The emphasis of the evaluation will be how the use of these systems relates to the problems identified earlier in this paper. Summarized, these problems are:

1. Lack of timely access to meaningful MDS data.
2. Inability to accurately estimate resource requirements.
3. Frequent, heavy use of overtime labor.
4. Inefficient and uncoordinated planning.
5. Late identification of work to P&E.
6. Delay in CWP preparation.

A. A MODEL FOR ORGANIZATIONAL COMPUTER SUPPORT

The traditional pyramid model, shown in Figure 13, depicts the roles and functions of information systems in organizations and is therefor a useful tool for evaluating computer support for maintenance planning. The pyramid model, developed by Ralph Sprague and Eric Carlson in the early 1980's, is an extension of the triangle model introduced by Robert Head in the late 1960's [Ref. 9:pp. 8-9]. The vertical dimension of the pyramid represents management levels, the horizontal dimension represents the functional areas of a business, and the depth dimension represents the different levels of computer support for management activities. In Head's triangle model, the level of computer support

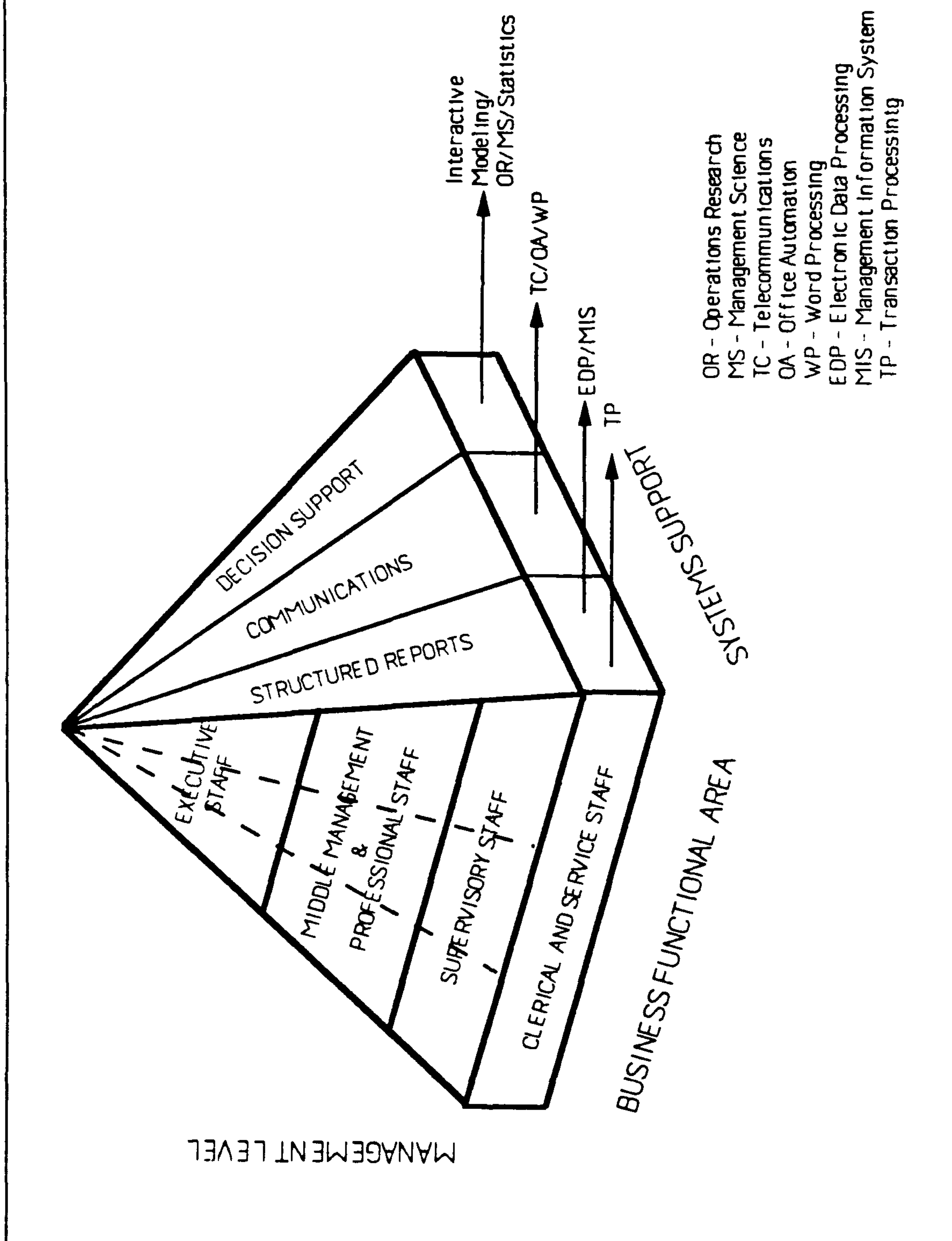


Figure 13 Theoretical View of Information Systems in Organizations

is a function of the management level. Transaction processing systems are appropriate for clerical and service staff, management information systems and electronic data processing systems are for supervisory staffs and middle level management; executive information systems and decision support systems are for executive level management. The depth dimension added by Sprague and Carlson, however, emphasizes that although transaction processing systems form the base of the organization's information system structure, all managerial levels have requirements for a full range of computer support.

The IMA maintenance planning organization is represented by the middle management, supervisory, and clerical levels of the pyramid information systems model. For these levels, the structured reports provided by transaction oriented systems like IMMS-II and MRMS, installed on USS McKEE (AS-41) and USS DIXON (AS-37) respectively, are valuable management control tools. Even so, middle level managers and supervisors in the IMA maintenance planning process also require communications and decision support. The problems previously identified can be explained as a result of inadequate computer support in one or more of the areas of reports, communications, or decision support.

B. LACK OF ACCESS TO MDS DATA

The problem of untimely access to MDS data is symptomatic of communications deficiencies, and is a problem usually encountered when planning maintenance. An example of how a need for access to data for planning might arise illustrates the problem and serves as a vehicle for evaluating IMMS and MRMS communications support.

1. An Example

During a ship's life, repairs are sometimes accomplished which alter the configuration of a component, but erroneously, are not reported as a configuration change. As a result, various references and logistics support for the affected component are not updated. Later, when that component again requires repair, the disparity between the existing component configuration and its documentation and repair parts support can bring planning and production work to a halt. The IMA must resolve the discrepancy quickly or the upkeep and ship's operational schedule will be jeopardized.

Because submarines report all corrective and alteration maintenance via the 3-M system, the IMA's CSMP file and the 3-M Central Data Bank represent a complete material history of every component on each submarine. To resolve the discrepancy in a component configuration's documentation, the IMA could check the MDS database. Unfortunately, neither IMMS nor MRMS facilitate this process.

2. IMMS Support

IMMS provides no direct link to the 3-M Central Data Bank. An IMA with IMMS has no recourse other than an urgent request to NAVSEALOGCEN (NAMSO) for a report on the affected component. The report could take several days to reach the IMA from Mechanicsburg and may be only a first step in resolving the component documentation discrepancy.

3. MRMS Support

One of the basic objectives of MRMS is to provide the capability for electronic transfer of ship maintenance data between 3-M ADP facilities. Based on the MRMS functional description [Ref. 5], upline reporting will make use of the Defense Data Network to electronically transmit periodic IMA performance reports and CSMP files. Although MRMS recognizes a functional requirement for data sharing between geographically separated facilities, it is not an objective of MRMS to provide for on-line query and retrieval directly from the 3-M Central Databank. Such a capability may eventually be realized through maintenance organizations requesting increased electronic access to all sources of MDS data. In any case, the MRMS installation onboard USS DIXON is not significantly different from IMMS in its ability to provide timely access to archived MDS data.

C. INACCURATE ESTIMATION OF RESOURCE REQUIREMENTS.

The ability to accurately predict the amount of resources required to complete assigned repairs is at the heart of the maintenance planning process. Consequently, inability to accurately estimate resource requirements leads to multiple planning problems. Maintenance planning decisions which commit IMA resources, such as work acceptance, job scheduling, and personnel assignment, are jeopardized when the decision maker is uncertain of the true capacity previously committed.

1. IMMS Support

IMMS provides marginal support for accurate resource estimation. Support consists of the Job Estimation Guide, a report of limited utility. The Job Estimation Guide is a report of the IMA's historical labor expenditures on repairs, broken down by categories of equipment or component configurations. The report is of limited utility because it omits the man-hour expenditure standard deviation statistic and also does not include a breakdown by scope of repair.

The scope of repair (whether the affected component was repaired, replaced, etc.,) should be included because the amount of effort required to accomplish a repair depends largely on the scope of repair.

The missing statistic in the IMMS Job Estimation Guide is standard deviation. The IMMS Job Estimation Guide reports only the number of repairs by APL/AEL or EIC and the high, low, and average number of man-hours expended. Failure to include standard deviation denies the estimator the ability to judge the uncertainty associated with the average man-hour expenditure. For example, a standard deviation greater than 20 percent of the range might indicate a large uncertainty in the reported average labor expenditure. In such cases, additional technical research to obtain a better estimate might be warranted.

2. MRMS Support

The use of ETV standards for resource estimation by MRMS is a substantial improvement over IMMS. The ETV methodology provides an on-line library of tasks and worksteps for logical decomposition of work and more accurate estimation of resource requirements. The estimate of the labor resources required to accomplish a given task becomes the sum of the estimates from the worksteps which make up that task. The resources required to complete a work request are the sum of the estimates for the tasks. The use of ETV standards should greatly improve the accuracy of P&E estimates and provide a sound basis for subsequent planning decisions.

The author is concerned that the method used by P&E to revise the workstep ETV library may reduce the accuracy of job estimates. In telephone interviews, planners on USS DIXON indicated the MRMS workstep library required a substantial number of additions during the startup period of its operation. The predominant method of obtaining estimates for the new worksteps was to ask the most experienced work center personnel available for *their* estimate of resource requirements. If USS DIXON's experience is typical of MRMS start up operation, MRMS ETVs are based neither on the maintenance data collected and analyzed in the course of many years of nuclear submarine maintenance, nor are they based on objective time-motion studies. Rather, even though based on inputs from experienced and highly skilled individuals, new MRMS ETVs appear to be the subjective evaluations of a few individuals.

D. FREQUENT USE OF OVERTIME LABOR

Frequent use of overtime is partly a result of inaccurate estimates of resource requirements and partly a result of a pervasive attitude among supervisory personnel that routine overtime is an acceptable use of labor resources. Improving accuracy of resource estimates should reduce the number of situations where overtime is necessary by precluding overcommitment of IMA resources.

E. INEFFICIENT AND UNCOORDINATED PLANNING

Lack of communications and decision support for the TYCOM Rep and PMA in the screening and scheduling functions contribute to problems of inefficient and uncoordinated planning.

1. Lack of Communications Support

In order to manage resource limitations, one requirement of the screening function is to communicate priorities. When a work center is overloaded, some work cannot progress until resources are made available by completion of other work. Unless priorities are communicated, the decision of which work to progress and which to put on hold is left to the work center supervisor alone. For P&E's planners, uncoordinated decisions concerning subsequently cancelled CWPs have contributed to waste of between 20 and 40 percent of the division's total efforts.

The 3-M system provides some capability for communicating priorities. The form 4790/2K work request contains two blocks used to indicate priority.

Block 41 is a one digit priority code entered by the submitting ship, which indicates the mission criticality of correcting the reported deficiency. Deficiency correction is either mandatory, essential, highly desirable, or desirable. Block 43, an optional five digit entry, can be used to indicate the priority of the work request relative to other work requests. Alternatively, the TYCOM Rep and PMA can use the remarks blocks to indicate priorities. Unfortunately, neither IMMS nor MRMS make the use of these priority indicator fields convenient and the TYCOM Rep and PMA do not routinely use them.

a. IMMS Support

IMMS provides a series of printed reports for monitoring work request planning. However, reports which include integrated priority and TYCOM Rep/PMA supplemental remarks are not routinely issued until too late to assist in coordinating advance planning.

The Ad Hoc report provides both integrated priority and supplemental remarks, but as a verbose listing of Forms 4790/2K and 4790/2P, it contains too much detail for routine use. The Ad Hoc report is issued only when specifically requested.

The integrated priority field also appears on Selected Job Management (SJM) reports which are issued daily and used to monitor work progress. However, work requests do not appear in the SJM report series until several days before the start of their associated upkeep. This is usually too late to be of much assistance in coordinating advance planning.

As a further inconvenience, changes to priority and remarks data fields must be manually entered. IMMS does not automatically reorder priorities when duplicate priorities exist. Because relative priorities of work can change frequently, it is cumbersome to keep integrated priorities manually ordered. For these reasons, maintenance planning personnel rarely use the integrated priority block. Relative priorities of work are sometimes not communicated until the start of the upkeep, and then only by verbal communications or via informal memorandums.

b. MRMS Support

In handling integrated priorities, MRMS is similar to IMMS. The process of updating integrated priorities is manual, and like IMMS, integrated priority fields are unlikely to be used. MRMS does provide, however, a "hot" flag to indicate jobs of great importance, high cost, high risk, or otherwise of interest to senior IMA management. According to the MRMS user's manuals, the "hot" designation is part of the screen display for subsequent planning activities and is thus another indicator of work priorities. However, since only a handful of jobs are "hot" at any time, the "hot" flag does little to indicate to a backlogged work center, such as P&E's planning section, which jobs will probably be worked and which are likely to be cancelled.

2. Lack of Decision Support

An optimal maintenance program is one which seeks to achieve exactly the best balance between corrective and preventative maintenance. An optimal program, because it is based on facts, will result in the lowest total maintenance costs for a given level of ship availability. Determining the optimal level of preventative maintenance requires an ongoing data collection and analysis effort. Optimizing the performance of the resulting corrective maintenance requires analysis as well, using graphic displays, Operations Research techniques, and statistical models. [Ref. 10:pp. 21-26]

The 3-M system provides the framework of an optimal maintenance management program through continuing data collection and analysis effort. Various activities analyze MDS data to validate the established levels of preventative maintenance and determine optimal operation and repair procedures. Analysis by technical authorities alone, however, is not enough because not all decision situations can be anticipated. Two examples of recurring but distinctive problems facing IMA managers are production scheduling and determining repair cost limits. Unfortunately, neither IMMS nor MRMS provide IMA managers with the analytical tools to optimally solve such problems.

a. Production Scheduling

In most cases, upkeeps are scheduled by assigning the availability start date as the start date of all work and a key event date as the target completion date. This method of scheduling, however, ignores dependencies between jobs, such as incompatible ship conditions, the same shipboard job site, or special tool and support requirements. Such dependencies might prevent one job from starting until another is finished even though both jobs have the same completion key event. The production scheduling method provided by IMMS and MRMS (grouping work requests by their terminating key event), does not facilitate recognition of job inter-dependencies. When identification and resolution of these types of scheduling anomalies are left to the work centers, planning and production effort may be uncoordinated and result in wasted resources.

Using Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) for project management could provide a tool for displaying and managing job interdependencies, and would fit in well with the key event emphasis of IMMS and MRMS. PERT charts and Gannt charts can be very powerful tools for conceptualizing schedule/resource constraint problems. PERT and CPM are discussed as functional requirements in the MRMS functional description and may be implemented in future versions.

b. Cost Limit of Repair

To make efficient and effective use of maintenance resources, the screening process should allow evaluation of repair alternatives of varying scope and method. The motivation for evaluating alternatives is to optimize the balance between long term maintenance effectiveness, ROV costs, and ship operational readiness. For example, if a work center is overloaded, one repair alternative might be to reduce man-hour expenditures by replacing a defective component rather than repairing it. In this example, the TYCOM Rep (responsible for controlling ROV fund expenditures) would want to know both the additional cost and the expected reduction in labor expense, to decide whether the effectiveness of repair and resulting change in workload/schedule would be worth the extra cost of replacement.

Some of the data needed for a repair versus replace decision are in the Job Estimation Guide report. As previously discussed, however, information concerning the scope of work and cost is omitted. Data for both job scope and cost are collected by MDS ADP systems and SUADPS. Job scope may be indicated by the Final Action Code (Block 102) posted by the lead work center when the work request is completed. Total cost of material for each job is recorded by SUADPS, but may not be posted to the work request.

Since all required data for repair versus replace decisions is recorded and archived, a statistical report of man-hour and ROV fund expenditure, broken down by equipment and job scope, could conceivably be produced. Neither IMMS, MRMS, nor the 3-M Databank, however, advertise the availability of this type of report.

F. LATE IDENTIFICATION OF WORK TO P&E

The problem of late identification of work to P&E is more a procedural issue than a computer support issue. COMSUBPAC has clearly defined objectives for work identification. If the work request history for an upkeep shows established policy is not being followed, it is the squadron's responsibility to take appropriate corrective action. There are, however, certain characteristics of IMMS and MRMS which impact the routing and identification delays experienced by the P&E section.

The serial nature of the maintenance planning process makes any routing delay a serious problem, especially when work is already late to be identified. Surprisingly, automation of data entry has occasionally made existing routing delays worse. As maintenance ADP programs become more interactive, the amount of paper documentation required is reduced and the problem of paperwork lost in routing is diminished, but a new electronic delay is taking its place.

Paper work requests allowed a certain degree of parallel action in the maintenance planning process. Since the vast majority of work requests are approved and accepted, it has been acceptable for P&E to plan a work request in parallel with TYCOM Rep and PMA screening. Apart from the previously discussed problems in communicating relative priorities, there is only a small risk the eventual screening action will nullify P&E's planning effort, and the benefit of avoiding a routing delay is large. The MDCO, as a document routing coordinator, is in a position to note any incongruities and take corrective action if required.

On-line 3-M processing systems enforce a serial planning process by preventing execution of a planning function until all prerequisite functions have been performed by authorized personnel. Relatively minor paper routing delays are replaced by larger electronic routing delays because key planning personnel may have only short and infrequent access to data entry terminals. Paper work requests are portable; computer terminals are not. Shop workers claim the reduced flexibility of on-line systems has made it unremarkable for an emergent repair to be completed before the associated work request is screened. Although such occurrences are well intentioned, they represent a breakdown in controls for use of manpower and material resources.

G. DELAY IN CWP PREPARATION

Delays in CWP preparation have been previously discussed in Chapter II. Of the delays occurring within P&E, the delay associated with difficulty in locating existing CWPs relates to inadequate computer support for communications.

Of IMMS and MRMS, only MRMS is implemented with a CWP application program. It is essentially a line editor the planner uses to write the steps of a CWP as free-form text. MRMS also provides a QA Support File which contains a limited number of general use statements, entered and categorized by the user as safety precautions, prerequisites, or general notes.

It is arguably inappropriate to implement a word processing application like CWP writing on hierarchical, menu-driven systems like MRMS. Such systems are slow and inflexible. Most P&E divisions already use a variety of excellent, commercial word processing software and personal computers for CWP writing. Planners on USS DIXON stated they did not use the CWP application of MRMS because they were unable to incorporate QA signature requirements and special requirements symbols into the resulting procedures. More probably, the planners do not want to use MRMS because they like their microcomputers better and want to continue to use existing CWP files. MRMS does not support file transfer or conversion from microcomputer applications.

The inability to exchange data between IMMS or MRMS and other computers is a large part of the communications support problem. The hypothetical situation below explores some of this issue from the viewpoint of CWP preparation.

Onboard USS McKEE, the planners have trouble finding existing CWPs due to an inadequate CWP indexing and filing system. Another submarine tender, USS DIXON, is normally close by and may not have the same difficulty retrieving pre-existing CWPs. What if instead of searching for USS McKEE CWPs, the planner tries to use a CWP written and stored by USS DIXON's planners? This prompts a series of questions which suggests additional consideration for this aspect of maintenance planning may be warranted. For instance, should CWPs even be able to be shared among maintenance activities? If so, how will the desire to share CWPs be communicated? What transfer media should be used? What file format? If file formats are different, how will they be converted? Integrating the IMA maintenance planning effort will require answering these types of questions.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Late identification of work and inadequate administrative controls are principle causes of untimely CWP preparation at one heavily loaded IMA. Untimely CWP preparation,, however, is symptomatic of a more widespread problem of inadequate communications and decision support in the IMA maintenance planning process. Although MRMS' ETV standards methodology provides significant improvement in resource estimation accuracy over IMMS, the transaction processing and structured, upline reporting emphasis of both IMMS and MRMS (version 0) does not provide tools necessary for optimal decision making to IMA maintenance supervisors. Inadequate communications and decision support capability at the IMA level prevents achievement of an optimal maintenance program.

1. Lack of Decision Support

The most significant finding of this study is that in supporting the 3-M system, data relevant to maintenance planning is captured by IMMS and MRMS. Their transaction processing and structured reporting emphasis, however, does not allow IMA maintenance planners to retrieve and analyze the data captured. Lack of tools for decision support at a management level where significant decisions are made prevents achievement of an optimal maintenance program.

Providing data access, modeling, and analysis capabilities would improve maintenance planning and performance effectiveness by providing an ability to analyze maintenance alternatives and subsequent maintenance performance. Examples of proven modeling and analysis tools are:

1. graphic displays such as X-Y plots, line graphs, and pie and bar charts for improved identification and understanding of data and trends,

2. Operations Research techniques for optimizing resource allocation or scheduling decisions,

3. statistical analysis for predicting Mean Time to Failure, Mean Time to Repair, Mean Cost of Repair, etc., for use in evaluating repair alternatives, and

4. Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM), which are effective visual aids for evaluating scheduling and resource allocation decisions.

2. Lack of Communications Support

IMA maintenance supervisors have both *internal and external* communications requirements which are largely unmet by IMMS and MRMS. To properly control and coordinate planning efforts, IMA maintenance supervisors must provide guidance on the relative importance of many jobs to many work centers. IMMS and MRMS provide limited capabilities for communicating priorities for only the highest priority work. Extensive supplemental use of verbal communications and "hot job" memoranda has proven insufficient to allow supervisors of overloaded work centers to efficiently and effectively allocate resources.

For work identification, problem resolution, and routine reporting, IMA maintenance supervisors interface with numerous external activities and ADP systems. IMMS and MRMS are primarily designed to meet upline reporting requirements. Acceptance and processing of information from the 3-M Central Databank or TAMS, for example, is largely a manual process, frequently resulting in delays and errors.

B. RECOMMENDATIONS

It is not an objective of this study to propose a replacement for the 3-M system or its supporting ADP programs. Rather, the recommendations below are extensions of established systems and methods.

1. MRMS Development

The MRMS functional description proposes system capabilities which, though not yet implemented, address the fundamental problems of inadequate communications and decision support in the IMA maintenance planning process. According to the functional description, communications with other maintenance activities would be provided by modem/mainframe host links to the Defense Data Network (MILNET). Tools for decision analysis are also envisioned, although unspecified. The recent decision by the SNAP program coordinator to incorporate MRMS in the SNAP III procurement provides an opportunity for development and implementation of needed communications and decision support capabilities.

One possible form of decision support might be the ability to model the resources required and resulting upkeep schedule for a set of work requests.

The TYCOM Rep would specify the scope/method of repair for a unit's work requests. From each work request, the ADP facility would use the component APL/AEL or Equipment Identification Code and the scope/method of repair specified by the TYCOM Rep to retrieve historical material cost and man-hour expenditures required to accomplish that repair. The material cost and man-hour expenditure would be an aggregate of historical expenditures reported for that combination of component and scope of repair. By associating each work request with a preceding and succeeding key event and using the historical estimate (or P&E's estimate if the work has already been planned) a predicted upkeep schedule could be generated. As an aid to evaluation of this schedule, work requests which might provide opportunities for significant cost, labor, or schedule reductions if the scope of repair were changed might also be indicated. The ability to model the impact of changes in job scope or work assignment could reduce iterations in the planning process.

Some decision analysis, such as evaluating a repair cost limit decision, might involve interactive processing of data using several different graphing or modeling applications. For these types of analyses, a dedicated processor such as a stand-alone or networked microcomputer might be more effective than timesharing on a minicomputer or mainframe. Microcomputer procurement under various umbrella contracts has established a hardware base to support such a computer configuration. Various activities have also demonstrated the ability to transfer data from 3-M ADP systems to microcomputers. For example, NAVSEA (PERA (CRUDES)), at Philadelphia Naval Shipyard, has developed the Fleet

Management System-Real Time (FMS-RT), a microcomputer based program which accesses CSMP databases for end-user processing. According to the point of contact, Mr. H. Dawson, FMS-RT has been used on more than 80 surface ships.

2. CWP Preparation

a. Earlier Identification of Controlled Work

While it does not address productivity issues within the P&E section, identification of controlled work at least two weeks prior to the start of an upkeep would go far in allowing CWP preparation to be complete by then. The TYCOM Rep and IMA supervisors should continue to monitor patterns of work identification, and ensure tended units submit requests for controlled work as early in the upkeep cycle as possible.

b. Administrative Controls

The current methods used by USS McKEE's P&E section for CWP storage, indexing, and tracking cause unnecessary delays in reuse of existing CWPs. USS McKEE's P&E section is not able to rapidly determine if a pre-existing CWP is applicable to another work request, and if so, where it is stored. P&E should establish and maintain a CWP index database, accessible by every planner, containing key (and foreign key) attributes of the CWP object as shown in Appendix B.

Many organizations have found the best way to provide access, back up, and security to a common body of data is to establish a Local Area

Network (LAN). Although LANs require more support than stand-alone computers, networking the planners' computers would:

1. Speed access to existing CWPs,
2. Optimize use of a faster, quieter laser printer,
3. Facilitate planner access to CWP index files, and
4. Facilitate security and back up of stored data.

3. Planner Productivity

One aspect of planner productivity able to be addressed by computers is typing speed. Few of the P&E's planners are strong typists. Since CWPs are written using a computer keyboard, procedure writing is slow. The word processing software used by the planners has several features which, by reducing the required number of keystrokes, could improve typing efficiency. Commonly used prerequisite, precaution, and shop responsibility statements, for example, might be saved as separate files. Macro functions would be used to retrieve an appropriate file into a second document screen, and selected steps copied into the CWP document. The planners on USS McKEE already use macro functions in a similar manner to retrieve QA form templates into CWP documents. To keep track of what various macro functions do, the planners use a simple help (Alt-h) macro to review an index of macro functions.

Another time saving possibility for future implementation is to make component, component installation, and process references from the technical library available on electronic storage media. Computer aided reference searches could reduce the time required to research maintenance and documentation requirements. Ability to copy appropriate sections from references directly into the body of a CWP would also reduce typing time.

In conclusion, the perpetual scarcity of financial, material, and personnel resources dictates pursuit of a maintenance management program which optimizes maintenance decisions. IMA managers are faced with significant numbers of non-trivial maintenance planning decisions. Without factually based analysis, even the best efforts of IMA maintenance managers will not consistently result in optimal decisions. Accordingly, automated tools for structured report analysis, communications, and decision support are appropriate for the IMA level of maintenance management. The Office of the Deputy Chief of Naval Operations for Logistics, Ship Maintenance and Modernization Division (OP-043), the functional sponsor for MRMS, is probably the best office to take the lead in developing such tools.

LIST OF REFERENCES

1. Smith, Lt. USN, "Problems in R-7," report to the Repair Department Officer, USS McKee (AS-41), 7 March 1989.

2. Commander Submarine Force Pacific Fleet, COMSUBPACINST 4790.7B Vol. IV (*SUBPAC Maintenance Manual*), 13 August, 1987.

3. Office of the Chief of Naval Operations, OP-325, OPNAVINST 4700.7H, *(Policies and Procedures for Maintenance of Ships)*, 30 October, 1987.

4. Office of the Chief of Naval Operations, OP-325, OPNAVINST 4790.4B (*Ship's Maintenance and Material Management (3-M) Manual*), 13 August, 1987.

5. Commander in Chief, U.S. Pacific Fleet, *Functional Description, Maintenance Resource Management System (MRMS),* December 1986.

6. Moe, C.M., *Generic Obstacles and Difficulties Associated with the Measurement and Enhancement of Productivity in Shore Intermediate Maintenance Activity (SIMA), Norfolk, Virginia,* Master's Thesis, Naval Postgraduate School, Monterey, California, December 1985.

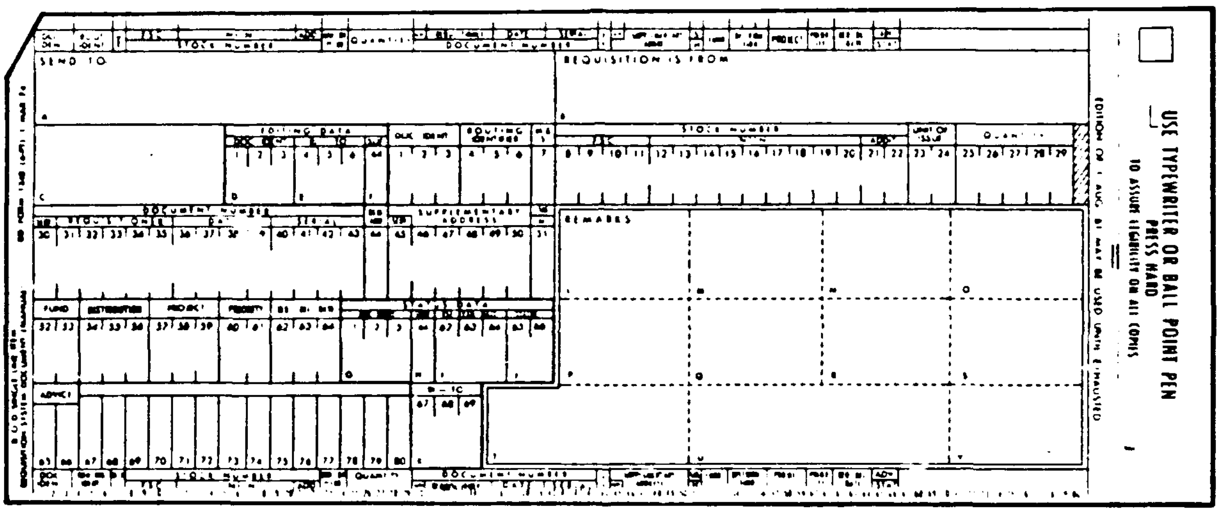
7. Whitten, J.L., Bentley, L.D., and Ho, T.I.M., *Systems Analysis and Design Methods.* Times Mirror/Mosby College Publishing, 1986.

8. Kroenke, D.M., and Dolan, K.A., *Database Processing: fundamentals, design, implementation* 3rd ed.,Science Research Associates, Inc., 1988.

9. Sprague, R.H., and Carlson, E.D., *Building Effective Decision Support Systems,* Prentice-Hall, Inc., 1982.

10. Shields, S., Sparshott, K.J., and Cameron, E.A., *Ship Maintenance; a quantitative approach,* Marine Media Management Ltd., London, 1975.

APPENDIX A. 3-M MAINTENANCE PLANNING FORMS


SEND TO
REQUISITION IS FROM
STOCK NUMBER
DOCUMENT NUMBER
REMARKS
USE TYPEWRITER OR BALL POINT PEN
PRESS HARD
TO ASSURE LEGIBILITY ON ALL COPIES

DD Form 1348, DOD Single Line Item Requisition System Document

SHIP'S MAINTENANCE ACTION FORM (2-KILO)

SECTION I IDENTIFICATION

JOB CONTROL NUMBER

1 SHIP'S UIC | 2 WORK CENTER | 3 JOB SEQ NO. | 4 APL/AEL

5 SHIP'S NAME | 5 EQUIPMENT NOUN NAME

8 HULL NUMBER | 13 IDENT/EQUIPMENT SERIAL NUMBER | 14 EIC

SAFETY HAZARD | 16 LOCATION (Compartment/Deck/Frame/Side)

CONFIGURATION CHANGE | FOR INT RA USE

18 ALTERATIONS (SHIPALT, ORDALT, Fld Chg, etc.) | 20 INSURV NUMBER | SUFFIX

SECTION II DEFERRAL ACTION

S/F MHRS EXP | DEFER DATE YR DAY | S/F MHRS REM | DEADLINE DATE YR DAY

SECTION III COMPLETED ACTION

FOR SELECTED EQUIPMENTS ONLY

ACT TKN | S/F MHRS | COMPLETION DATE YR DAY | METER READING

SECTION IV REMARKS/DESCRIPTION

35 REMARKS/DESCRIPTION

37 CSMP SUMMARY

FIRST CONTACT/MAINT MAN (Print) | DATE | SECOND CONTACT SUPERVISOR (Print)

COMMANDING OFFICER'S SIGNATURE | TYCON AUTHORIZATION

SPECIAL PURPOSE

SECTION V SUPPLEMENTARY INFORMATION

47 BLUEPRINTS TECH MANUALS PLANS ETC. | AVAILABLE ON BOARD YES NO

SECTION VI REPAIR ACTIVITY PLANNING/ACTION

REPAIR W/C | 50. EST. MHRS | 51. ASST. REPAIR W/C | ASST. EST. MHRS | SCHED. START DATE YR DAY | SCHED COMP. DATE YR DAY

REPAIR ACTIVITY UIC | 57 EST. MANDAYS | EST. MATERIAL COSTS $

EST. TOTAL COST $ | 61 JOB ORDER NUMBER | LEAD PAC CODE | DATE OF EST YR DAY

FINAL ACT | MHRS EXPENDED | DATE COMPLETED YR DAY | COMPLETED BY (Signature - Rate) | ACCEPTED BY (Signature - Rate/Rank)

OPNAV 4790/2K, Ship's Maintenance Action Form

SUPPLEMENTAL FORM (2 LIMA)

SECTION I IDENTIFICATION

A. SHIP'S NAME	B. HULL NUMBER	JOB CONTROL NUMBER		
		C. SHIP'S UIC	D. WORK CENTER	E. JOB SEQ NO
		F. CONTINUATION FOR ☐ 2K ☐ 2L ☐ 2P		

SECTION II REMARKS/SKETCHES

G

SECTION III AUTHENTICATION

H. FIRST CONTACT MAINTENANCE MAN (Print)	I. DATE YR DAY	J. SECOND CONTACT/SUPERVISOR (Print)	K. DATE YR DAY

OPNAV 4790/2L, Supplemental Form

OPNAV 4790/2P (5-84) MAINTENANCE PLANNING & ESTIMATING FORM (P & E)

SECTION I PLANNING

JOB CONTROL NUMBER

A. SHIP'S NAME	B. HULL NUMBER	1. SHIP'S UIC	2. WORK CENTER	3. JOB SEQ NO.
USS WHITE PLAINS	AFS 4	Ø5835	EEØ1	16Ø8

4. PERIODIC MAINTENANCE REQUIREMENT	5. PERIODICITY	6. YYMM ISSUED	7. SPECIAL DATA

8. SCREENING ACTION (IUC / TYCOM)

- a. [ ] b. [ ] DEPOT ACCOMPLISH
- a. [X] b. [X] IMA ACCOMPLISH
- a. [ ] b. [ ] TSU/NAVSEC/NOSSO/ETC
- a. [ ] b. [ ] SHIPS FORCE (IMA) (DEPOT) ASSIST
- a. [ ] b. [ ] SHIP TO SHOP
- a. [ ] b. [ ] ACCOMPLISH WITH MODIFICATIONS
- a. [ ] b. [ ] DISAPPROVE

9. QUALITY ASSURANCE REQUIREMENTS

- a. [ ] SUB SAFE
- b. [ ] LEVEL I
- c. [ ] NUCLEAR LEVEL I
- d. [ ] NON DESTRUCT TEST
- e. [ ] NUCLEAR WORK PROCEDURES
- f. [ ] SUBMARINE ANTENNA ENGINEERING DIVISION
- g. [ ] SPECIAL CLEANING
- h. [X] SPECIAL TESTING
- i. [ ] SPECIAL IDENTIFICATION
- j. [ ] NOISE CRITICAL
- k. [ ] RADIOLOGICAL CONTROL
- l. [ ] OTHER CONTROLS

10. SPECIAL REQUIREMENTS

- a. Ø3 KEY EVENT
- b. [ ] SPECIAL INTEREST
- c. [ ] DRY DOCK REQUIRED
- d. [X] PRE OVERHAUL TEST REQUIRED
- e. [X] POST OVERHAUL TEST REQUIRED
- f. [ ] DEPARTURE TEST REQUIRED

C. IUC SIGNATURE	D. TYCOM SIGNATURE	11. NORMALLY DONE BY
		a. [ ] SF b. [ ] IMA c. [ ] DEPOT

SECTION II SCHEDULING

WORK CENTER	SCHED START DATE (YR DA)	SCHED COMP DATE (YR DA)	EST MHRS	KEY OP	TASK
12. LEAD WORK CENTER: 38A	13. 6245	14. 626Ø	15. Ø14Ø	16.	17.
18. ASST WORK CENTER: 51A	19. 6247	20. 6258	21. ØØ4Ø	22.	23.
24. ASST WORK CENTER: 52A	25. 6245	26. 6259	27. Ø1ØØ	28.	29.
30. ASST WORK CENTER	31.	32.	33.	34.	35.
36. ASST WORK CENTER	37.	38.	39.	40.	41.
42. ASST WORK CENTER	43.	44.	45.	46.	47.

SECTION III TECHNICAL DOCUMENTATION

48. (ON BOARD YES / NO)

SECTION IV IUC/REPAIR ACTIVITY/TYCOM REMARKS

49. IMA LIMIT REPAIRS TO 6ØØ $ ROV MATERIAL

SECTION V SUPPLEMENTAL PLANNING

50. EST MANDAYS	51. EST MANDAYS COST $	52. EST MATERIAL COST $	53. EST TOTAL COST $	54.

S/N 0107-LF-770-3079

OPNAV 4790/2P, Maintenance Planning and Estimating Form

AWR
OPNAV 4790/2R

AUTOMATED WORK REQUEST

SECTION I IDENTIFICATION

JOB CONTROL NUMBER

Ship's UIC	Work Center	JCN Number	APL/EIC
Ø5835	EEØ1	16Ø8	6738201134

Ship's Name: USS WHITE PLAINS — Equipment/Nomenclature: COMPRESSOR MTR — Serial No.: NO2 25HP

Hull Number	EIC	Location	Compartment	Deck	Frame	Side
AFS-4	T5Ø5	REEFER RM 6	96	2	E	

SECTION II DEFERRAL ACTION

Defer Date	Est Manhours Remaining	Deadline Date	Defer Reason
6Ø22	ØØØ6		6

SECTION III COMPLETED ACTION

SECTION IV REMARKS/DESCRIPTION

Remarks/Description: NOTED TEMP INCREASE DRIVE END. SOUND ANALYSIS REVEALED SHARP INCREASE DB LEVELS, UNIT SECURED. S/F OPENED/INSPECTED. ROTOR SHAFT SCORED/UNDERSIZED. REMOVE MTR FRM SHIP. REPAIR SHAFT/ BEARING SURFACE, BALANCE, ASSBL, REINSTALL, ALIGN, AND TEST.

Comp Summary: SHAFT SCORED/UNDERSIZED

First Contact Maintenanceman: FAYNE MM1 — Second Contact: HARRIS ENC — 1 — 2

Commanding Officer's Signature — TYCOM Authorization — R/C Screening — TYCOM Screening

SECTION V SUPPLEMENTARY INFORMATION

Pre-Arrival Conferences Action: IMA LIMIT REPAIRS TO 6Ø2 $ ROV MATERIAL

Remarks

SECTION VI PLANNING

SECTION VII REPAIR ACTIVITY PLANNING SCHEDULING ACTION

W/C	Sched Start	Sched Comp	Est Mhrs
Lead 38A	6245	626Ø	Ø14Ø
Asst 51A	6247	6258	ØØ4Ø
Asst 52A	6245	6259	Ø1ØØ

OPNAV 4790/2R, Automated Work Request (AWR)

APPENDIX B. MAINTENANCE PLANNING OBJECTS

The focus of Appendix B is the maintenance planning view of the objects. Attributes unrelated to maintenance planning are omitted. Also, data elements and domain definitions do not necessarily conform to any set of standardized Navy data elements which may exist in compliance with the Data Element Standardization Program. Objects not directly used in maintenance planning are presented only in enough detail to clarity relationships between objects.

The following conventions are used in presenting objects, attributes, and relationships:

1. When listed as attributes of other objects, object names are **bold faced**;
2. "MV" stands for multi-valued; more than one instance of a multi-valued attribute may exist for each instance of the object it belongs to;
3. Attributes which comprise the key of a relation are underlined;
4. Attributes which are alternate (candidate) keys are italicized, but not underlined;
5. Attributes which are keys, or parts of keys, of another relation are followed by an asterisk;
6. The symbol, "┼", indicates a mandatory relationship between object instances;
7. The symbol, " ɸ ", indicates an optional relationship between object instances.

ALTERATION

Alteration Type
Alteration Number
Alteration Revision
Summary/Description
Fiscal Year
Priority
Master Job Catalog Number
Ship Applicability MV
Affected Component MV
Material MV
WORK REQUEST MV
SHIP ALTERATION STATUS MV
COMPONENT ALTERATION STATUS MV

COMPONENT ALTERATION STATUS

SHIP COMPONENT
ALTERATION
Status
Configuration Change Report Status
Selected Record Drawing Update

COMPONENT URO/IMMP STATUS

SHIP COMPONENT
URO/IMMP
Completion Date
Due Date

APL/AEL

APL/AEL Number
SHIP COMPONENT MV
REPAIR PART MV
COSAL LINE ITEM MV

COSAL LINE ITEM

SHIP
APL/AEL
REPAIR PART
Item Allowance

CONTROLLED WORK PROCEDURE

CWP Number
Revision
Revision Date
Due Date
Re-entry Control Number
File Location
Material List
Reference MV
Precaution MV
Prerequisite MV
Work Center Responsibility MV
Procedure Step MV
Retest Requirement MV
WORK REQUEST
WORKER

KEY EVENT DATE

KEY EVENT
SHIP
WORK REQUEST MV
Date

REPAIR PART

National Stock Number
Manufacturer's Part Number
Noun Name
Unit of Issue
Unit price
APL/AEL
SHIP APL/AEL ITEM MV
REQUISITION MV

KEY EVENT

Key Event Code
Description
KEY EVENT DATE MV

SHIP URO/IMMP STATUS

SHIP
URO/IMMP
Status

REQUISITION

Document Number
Urgency
Quantity
Total Price
Estimated Delivery Date
Issue Date
REPAIR PART
WORK REQUEST
WORK CENTER

SHIP

Unit Identification Code
Hull Number
Name
Ship Class
SHIP SYSTEM MV
SHIP COMPONENT MV
SHIP ALTERATION STATUS MV
SHIP URO/IMMP STATUS MV
COSAL LINE ITEM MV
WORK REQUEST MV
KEY EVENT DATE MV

SHIP ALTERATION STATUS

SHIP
ALTERATION
Status
TAMS Status

SHIP SYSTEM

System Name
Abbreviation
Reference MV
Function MV
SHIP
SHIP COMPONENT MV

SHIP COMPONENT

SHIP

Component ID

Noun Name

Function

Location

Equipment Identification Code

National Stock Number

Manufacturer's Part Number

Reference MV

APL/AEL

SHIP SYSTEM

WORK REQUEST MV

COMPONENT ALTERATION STATUS MV

COMPONENT URO/IMMP STATUS MV

TASK

WORK CENTER

Task Number

Task Summary

WORKSTEP MV

WORK REQUEST TASK MV

URO/IMMP

URO/IMMP Number

Master Job Catalog Number

Description

Periodicity

WORK REQUEST MV

SHIP URO/IMMP STATUS MV

COMPONENT URO/IMMP STATUS MV

WORKER

- Worker ID
- Rate
- Qualifications
- **CONTROLLED WORK PROCEDURE** MV
- **WORK CENTER**

WORK REQUEST TASK

- **TASK**
- **WORK REQUEST**
- Est. Man-hours (Earned Value)
- Start Date
- Due Date
- Task Status
- **WORK REQUEST TASK WORKSTEP** MV

WORK CENTER

- Work Center Code
- Work Center Function/Specialty
- **WORKER** MV
- Production Worker Total
- Support Worker Total
- Week
- Production Man-hours Available MV

WORK REQUEST TASK WORKSTEP

- **WORK REQUEST TASK**
- **WORKSTEP**
- Sequence Number
- No. of Repetitions

WORK REQUEST
Job Control Number
Special Requirements
Priority Code
Integrated Priority
Screening Code
Scope/Method of Repair
Description/Remarks
Lead Work Center
WORK REQUEST TASK MV
KEY EVENT DATE
SHIP COMPONENT
REQUISITION MV
CONTROLLED WORK PROCEDURE
ALTERATION
URO/IMMP

WORKSTEP
Equipment/Process
Size
Step Number
Step Description
Number of Workers, Shipboard
Est. Shipboard Man-hours
Number of Workers, Shop
Est. Shop Man-hours
Total Est. Step Man-hours
TASK
WORK REQUEST TASK WORKSTEP MV

OBJECT DEFINITIONS

ALTERATION OBJECT

Alteration Type; Alteration_Types
Alteration Number; Ship_Types and Alteration_Numbers
Alteration Revision; Revision_Numbers
Summary/Description; Free_Text
Fiscal Year; Serial_Numbers
Priority; Serial_Numbers
Master Job Catalog (MJC) Number; MJC_Numbers and Serial_Numbers
Ship Applicability; MV; Ship_Types and Ship_Numbers
Affected Component; MV; System_Abbreviations and Component_IDs
Material; MV; Federal_Supply_Codes_for_Mfgs. and
Navy_Item_Control_Numbers and Noun_Names and Numbers
WORK REQUEST; WORK REQUEST object; MV
SHIP ALTERATION STATUS; SHIP ALTERATION STATUS object; MV
COMPONENT ALTERATION STATUS; COMPONENT ALTERATION STATUS object; MV

APL/AEL OBJECT

APL/AEL Number; APL/AEL_Numbers
SHIP COMPONENT; SHIP COMPONENT object; MV
REPAIR PART; REPAIR PART object; MV
COSAL LINE ITEM; COSAL LINE ITEM object; MV

COMPONENT ALTERATION STATUS

Status; Alteration_Status_codes
Configuration Change Report Status; Status_descriptions
Selected Record Drawing Update; Status_descriptions
SHIP COMPONENT; SHIP COMPONENT object; SUBSET [Hull Number, Component ID]
ALTERATION; ALTERATION object; SUBSET [Alteration Type, Alteration Number, Alteration Revision]

COMPONENT URO/IMMP STATUS

Completion Date; Calendar_Dates
Due Date; Calendar_Dates
SHIP COMPONENT; SHIP COMPONENT object; SUBSET [Hull Number, Component ID]
URO/IMMP; URO/IMMP object; SUBSET [URO/IMMP Number]

CONTROLLED WORK PROCEDURE (CWP) Aliases: Re-Entry Control (REC)

CWP Number; Control_Numbers
Revision; Revision_Numbers
Revision Date; Calendar_Dates
Due Date; Calendar_Dates
Re-entry Control Number; Control_Numbers
File Location; File_Locations
Material; MV; Federal_Supply_Codes_for_Mfgs. and Navy_Item_Control_Numbers and Noun_Names and Numbers
Reference; MV; References
Precaution; MV; Free_Text
Prerequisite; MV; Free_Text
Work Center Responsibility; MV; Work_Center_Codes and Free_Text
Procedure Step; MV; Free_Text
Retest Requirement; MV; Free_Text
WORK REQUEST; WORK REQUEST object; SUBSET [JCN, Component ID, APL Number, Manufacturer's Part Number]
WORKER; WORKER object; SUBSET [Worker ID]

COSAL LINE ITEM

Item Allowance; Numbers
SHIP; SHIP object; SUBSET [Unit Identification Code]
APL/AEL; APL/AEL object; SUBSET [APL/AEL Number]
REPAIR PART; REPAIR PART object; SUBSET [National Stock Number, APL/AEL Number]

KEY EVENT

Key Event Code; Key_Event_Codes
Description; Key_Event_Descriptions
KEY EVENT DATE; KEY EVENT DATE object;

KEY EVENT DATE

Date; Julian_Dates
KEY EVENT: KEY EVENT object; SUBSET [Key Event Code]
SHIP; SHIP object; SUBSET [Unit Identification Code]
WORK REQUEST; WORK REQUEST object;

REPAIR PART Aliases: Component, Equipment, Material, assembly, sub-assembly

National Stock Number (NSN); Federal_Supply_Codes_for_Mfgs. and Navy_Item_Control_Numbers
Manufacturer's Part Number; Navy_Item_Control_Numbers
Noun Name; Noun_Names
Unit of Issue; Issue_Codes
Unit price; Prices
APL/AEL; APL/AEL object; SUBSET [APL/AEL Number]
COSAL LINE ITEM; COSAL LINE ITEM object;
REQUISITION; REQUISITION object; MV

REQUISITION Aliases: Supply chit, DD 1348

Document Number; UICs and Julian_Dates and Serial_Numbers
Urgency; Priority_Codes
Quantity; Numbers
Total Price; Prices
Estimated Delivery Date; Julian_Dates
Issue Date; Julian_Dates
REPAIR PART; REPAIR PART object; SUBSET [National Stock Number, Noun Name, Unit of Issue]
WORK REQUEST; WORK REQUEST object; SUBSET [Job Control Number]
WORK CENTER; WORK CENTER object; SUBSET [Work Center Code]

SHIP Aliases: Submarine, Unit

Unit Identification Code; UICs
Hull Number; Ship_Types and Ship_Numbers
Name; Ship_Names
Ship Class; Ship_Types and Ship_Classes
SHIP SYSTEM; SHIP SYSTEM object; MV
SHIP COMPONENT; SHIP COMPONENT object;MV
SHIP ALTERATION STATUS; SHIP ALTERATION STATUS object; MV SHIP
URO/IMMP STATUS; SHIP URO/IMMP STATUS object; MV
COSAL LINE ITEM; COSAL LINE ITEM object; MV
WORK REQUEST; WORK REQUEST object; MV
KEY EVENT DATE; KEY EVENT DATE object; MV

SHIP ALTERATION STATUS

Status; Alteration_Status_Codes
TAMS Status; Alteration_Status_Codes
SHIP; SHIP object; SUBSET [Hull Number]
ALTERATION; ALTERATION object; SUBSET [Alteration Type, Alteration Number, Alteration Revision]

SHIP COMPONENT Aliases: Equipment, assembly, sub-assembly

Component ID; System_Abbreviations and Component_IDs
Noun Name; Noun_Names
Function; MV; Free_Text
Location; Shipboard_Locations
Equipment Identification Code (EIC); EICs
National Stock Number; Federal_Supply_Codes_for_Mfgs. and Navy_Item_Control_Numbers
Manufacturer's Part Number; Navy_Item_Control_Numbers
Reference; MV; References
SHIP; SHIP object; SUBSET [Hull Number]
APL/AEL; APL/AEL object; SUBSET [APL/AEL Number]
SHIP SYSTEM; SHIP SYSTEM object; SUBSET [Abbreviation]
WORK REQUEST; WORK REQUEST object; MV
COMPONENT ALTERATION STATUS; COMPONENT ALTERATION STATUS object; MV
COMPONENT URO/IMMP STATUS; COMPONENT URO/IMMP STATUS object; MV

SHIP SYSTEM

System Name; System_Names
Abbreviation; System_Abbreviations
Reference; MV; References
Function; MV; Free_Text
SHIP; SHIP object; SUBSET [Hull Number]
SHIP COMPONENT; SHIP COMPONENT object; MV

SHIP URO/IMMP STATUS OBJECT

Status; Status_Codes
SHIP; SHIP object; SUBSET [Hull Number]
URO/IMMP; URO/IMMP object; SUBSET [URO/IMMP Number]

TASK Aliases: Key Operation (Key Op)

Work Center; Work_Center_Codes
Task Number; Serial_Numbers
Task Summary; Short_Text
WORKSTEP; WORKSTEP object; MV
WORK REQUEST TASK; WORK REQUEST TASK object; MV

URO/IMMP Aliases: Period Maintenance Requirements (PMRs)

URO/IMMP Number; Ship_Types and Ship_Classes and URO/IMMP_Numbers
Master Job Catalog (MJC) Number; MJC_Numbers and Serial_Numbers
Description; Free_Text
Periodicity; Numbers
WORK REQUEST; WORK REQUEST object; MV
SHIP URO/IMMP STATUS; SHIP URO/IMMP STATUS object; MV
COMPONENT URO/IMMP STATUS; COMPONENT URO/IMMP STATUS object; MV

WORK CENTER Aliases: Shop, Repair Center

Work Center Code; Work_Center_Codes
Work Center Function/Specialty; Work_Center_Functions
Production Worker Total; Numbers
Support Worker Total; Numbers
Week; Calendar_Date
Production Man-hours Available; Numbers
WORKER; WORKER object; MV

WORK REQUEST Aliases: 2K, 4790/2K, 4790/2R, Job

Job Control Number (JCN); UICs and Work_Center_Codes and Serial_Numbers
Special Requirements; Requirements_Flags
Priority Code; Priority_Codes
Integrated Priority; Serial_Numbers
Screening Code; Screening_Codes
Scope/Method of Repair; Short_Text or Action_Codes
Description/Remarks; Free_Text
Lead Work Center (LWC); Work_Center_Codes
WORK REQUEST TASK; WORK REQUEST TASK object; MV
KEY EVENT DATE; KEY EVENT DATE object; SUBSET [Key Event Code]
SHIP COMPONENT; SHIP COMPONENT object; SUBSET [Hull Number, Component ID]
REQUISITION; REQUISITION object; MV
CONTROLLED WORK PROCEDURE; CONTROLLED WORK PROCEDURE object;
ALTERATION; ALTERATION object; SUBSET [Alteration Type, Alteration Number, Alteration Revision]
URO/IMMP; URO/IMMP object; SUBSET [URO/IMMP Number]

WORK REQUEST TASK

Est. Man-hours; Decimal_Numbers
Start Date; Julian_Date
Due Date; Julian_Date
Status; Task_Status_Codes
TASK; TASK object; SUBSET [Work Center Code, Task Number]
WORK REQUEST; WORK REQUEST object; SUBSET [Job Control Number]
WORK REQUEST TASK WORKSTEP; WORK REQUEST TASK WORKSTEP object; MV

WORK REQUEST TASK WORKSTEP

Sequence Number; Serial_Numbers
No. of Repetitions; Numbers
WORK REQUEST TASK; WORK REQUEST TASK object;
SUBSET [Job Control Number, Work Center Code, Task Number]
WORKSTEP; WORKSTEP object;

WORKER Aliases: Planner

Worker ID; Worker_IDs
Rate; Ratings
Qualifications; MV; Short_Text
CONTROLLED WORK PROCEDURE; CONTROLLED WORK PROCEDURE object; MV
WORK CENTER; WORK CENTER object; SUBSET [Work Center Code]

WORKSTEP

Equipment/Process; Short_Text
Size; Short_Text
Step Number; Serial_Numbers
Step Description; Short_Text
Number of Workers, Shipboard; Numbers
Est. Shipboard Man-hours; Decimal_Numbers
Number of Workers, Shop; Numbers
Est. Shop Man-hours; Decimal_Numbers
Total Est. Step Man-hours; Decimal_Numbers
TASK; TASK object; SUBSET [Work Center Code, Task Number]
WORK REQUEST TASK; WORK REQUEST TASK object; MV
WORK REQUEST TASK WORKSTEP; WORK REQUEST TASK WORKSTEP object; MV

DOMAIN DEFINITIONS

Action_Codes
Text 2
Used in block 102 of OPNAV 4790/2R, or block 64 of OPNAV 4790/2K; FINAL ACT. Codes found in OPNAVINST 4790.4B (3-M Manual) para. 12.5.3.h.(2).
Final action taken to complete a work request; repair, replaced, adjusted, etc.

Alteration_Numbers
Text 4, mask XNNN,
where X is any digit or letter, NNN is any three digits.
NAVSEA and TYCOM designations for alteration numbers.

Alteration_Status_codes
Text 1,
either A, B, C, D, E, N, P, or X,
Alteration status codes from OPNAVINST 4790.4B (3-M Manual) para. 11-5.3.d.(4).(a).

Alteration_Types
Text 2, Mask SA or TY.
SA indicates alterations initiated within the Fleet Modernization Program. TY indicates alterations initiated by the TYCOM.

APL/AEL_Numbers
Text 11, mask; for APL NNNNNNNNN, for AEL N-NNNNNNNNN,
where N is any digit.
The number of the Part or Equipage list applicable to the Ship Component being reported. Alternatively, a Mfg. Model number, such as for Marotta valves.

Calendar_Dates
Text varies; may be YYMMDD, MM/DD/YY, DD-MM-YY, MMYY, etc., where YY is last two digits in year
MM is two digits of month
DD is two digits of day.
A date expressed in some combination of day, month and year.

Component_IDs
Text 12,
Identifying description of a component within a system; eg. pump #1, (valve) 103, flask #4.

Control_Numbers

Text 10, mask AAA NNN-YY,

where AAA is either "REC" or "CWP", NNN is any three digits, YY is last two digits in a year

Numbers to provide auditability of QA Re-entry work or other Controlled work.

Decimal_Numbers

Numeric 5, mask NNN.N, where N is any digit.

Decimal numbers to the nearest tenth.

EICs

Text 7,

System, subsystem, and category codes for equipment, from the EIC master index (NAMSO 4790.E2579).

Federal_Supply_Codes_for_Mfgs.

Text 5,

Supply code number for a manufacturer which provides repair parts to the Federal Government.

File_Locations

Text varies,

Computer pathname specification for CWP files; ie. drive:\directory\subdirectory\...\filename.

Free_Text

Text up to 1196 characters,

Narrative text, such as block 35 on OPNAV 4790/2K.

Issue_Codes

Text 2,

Unit of issue of repair parts, eg. EA = each.

Julian_Dates

Numeric YNNN,

where Y is last digit of year, NNN is a numbered day of the year.

Key_Event_Codes

Numeric 2,

Number of a key event; from COMSUBPACINST 4790.4B Vol. IV (SUBPAC Maintenance Manual), Appendix 6D.

Key_Event_Descriptions

Text 15,

Description of a key event; from COMSUBPACINST 4790.4B Vol. IV (SUBPAC Maintenance Manual), Appendix 6D.

MJC_Numbers

Text 4,

"Made up" work center codes for repetitive use automated work requests (from OPNAVINST 4790.4B (3-M Manual) paras. 11-5.1.a.(2) to 11-5.a.(4), and 12-10.2.a., and COMSUBPACINST 4790.4B Vol. IV (SUBPAC Maintenance Manual), para. IV-11.7.3)

Navy_Item_Control_Numbers

Text 10,

Numbers of parts identifiable by the Navy Supply system through Navy assigned numbers or Manufacturer assigned numbers.

Noun_Names

Text 16,

Equipment or part nomenclature/description; from EIC master index (NAMSO 4790.E2579) or repair part index description.

Numbers

Numeric 4,

Whole numbers up to 9999.

Prices

Numeric 7, mask DDDDDCC,

where DDDDD is any five digits representing Dollars, CC is any two digits representing cents.

Priority_Codes

Numeric 1, either 1, 2, 3, or 4

Priority categories from OPNAVINST 4790.4B (3-M Manual) para. 9-5.2.4.g.

Ratings

Text 4,

Ratings of Navy enlisted personnel.

References

Text varies, usually less than 20,

Alpha-numerics identifying various technical manuals, drawings, plans, blueprints, etc.

Requirements_Flags

Boolean,

Check marks to indicate QA and special requirements from blocks 9 and 10 of OPNAV 4790/2P form.

Revision_Numbers

Text 1,

Numbered or alphabetic sequence.

Screening_Codes

Text 2, mask NX,

where N is a digit, X is a character

Codes indicating what action is to be taken on a work request, from OPNAVINST 4790.4B (3-M Manual) paras. 9-5.2.4.h, 9-5.3.1.c, and from COMSUBPACINST 4790.4B Vol. IV (SUBPAC Maintenance Manual), para. IV-6-7.3.1.a.

Serial_Numbers

Numeric 999,

Sequential numbers.

Ship_Classes

Text 3,

Hull numbers of the lead ships of classes of submarines, ie 594, 616, 637, 640, 688, etc.

Ship_Names

Text 20,

Names of U.S. Navy submarines.

Ship_Numbers

Text 3,

Hull numbers of U.S. Navy submarines.

Ship_Types

Text 4, either SS, SSN or SSBN,

U.S. Navy designations for types of submarines.

Shipboard_Locations

Text 20, mask:

Compartment, Level or Deck, Frame, and Side.

Shipboard locations of ship components.

Short_Text

Text, varies, usually less than 20,

Short, narrative descriptions, usually of codes.

Status_codes
Numeric 2,
Numbers representing a descriptive status.

Status_descriptions
Text varies, usually less than 20,
Narrative description of status.

System_Abbreviations
Text 4,
Abbreviations for ship systems, eg. HMV for Main and Vital Hydraulics, MLO for Main Lube Oil, EHF for Electrical Hull Fitting.

System_Names
Text 20,
Names of ship systems.

Task_Status_Codes
Numeric 2,
Two digit progress status codes from OPNAVINST 4790.4B (3-M Manual) para. 12-9.1.i.

UICs
Numeric 5,
Unique number of a Naval activity (unit).

URO/IMMP_Numbers
Text 16, mask XXXX-NNN TTTT MM,
where XXXX is a ship type, NNN is a ship hull number, TTTT is "URO" or IMMP", and MM is any two digits.
URO and IMMP periodic maintenance requirements.

Work_Center_Codes
Text 4,
Three or four character codes for IMA work centers (COMSUBPACINST 4790.4B Vol. IV (SUBPAC Maintenance Manual), Appendix 11B) or shipboard work centers;

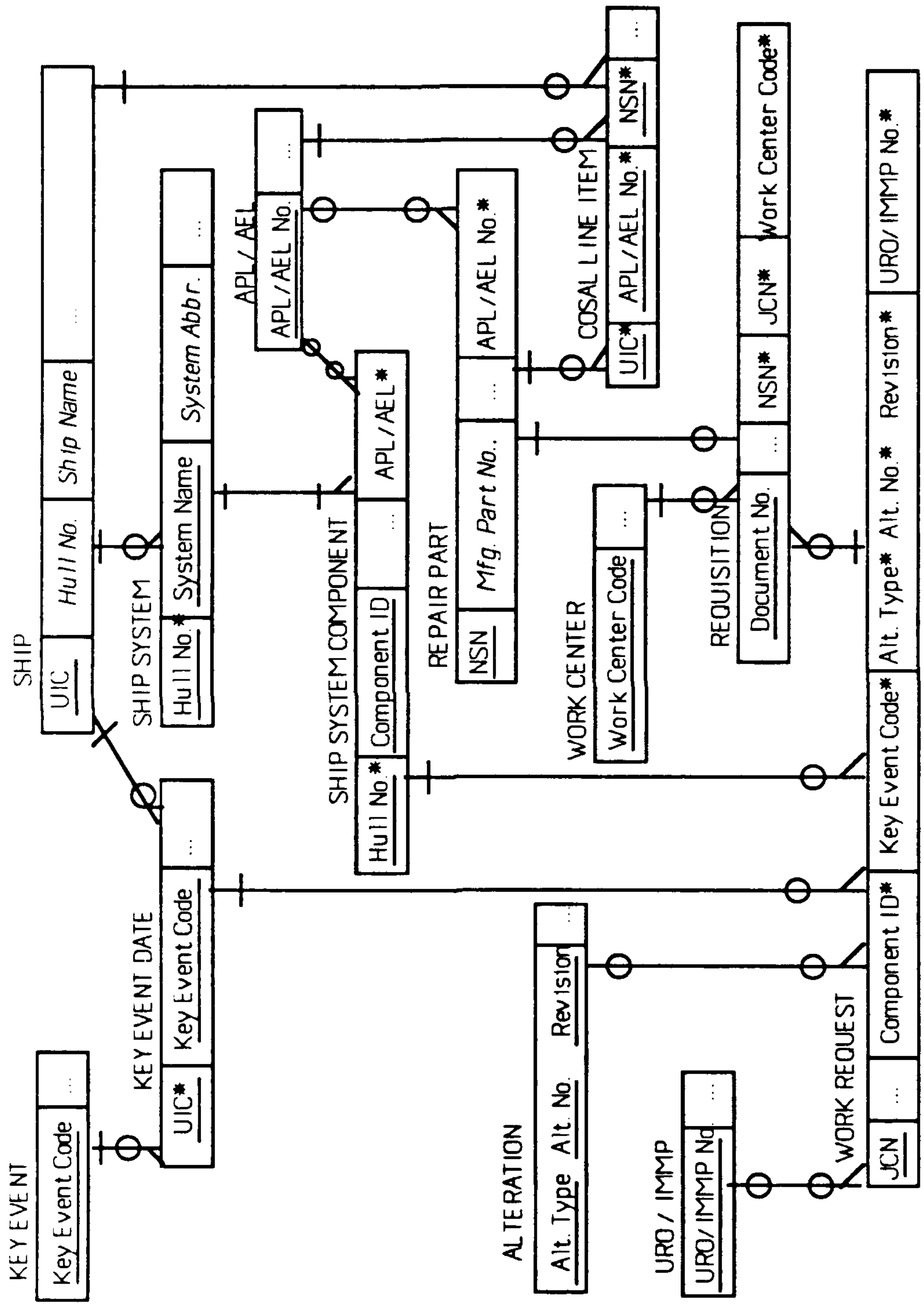
Work_Center_Functions
Text 21,
IMA work center names from COMSUBPACINST 4790.4B Vol. IV (SUBPAC Maintenance Manual), Appendix 11B.

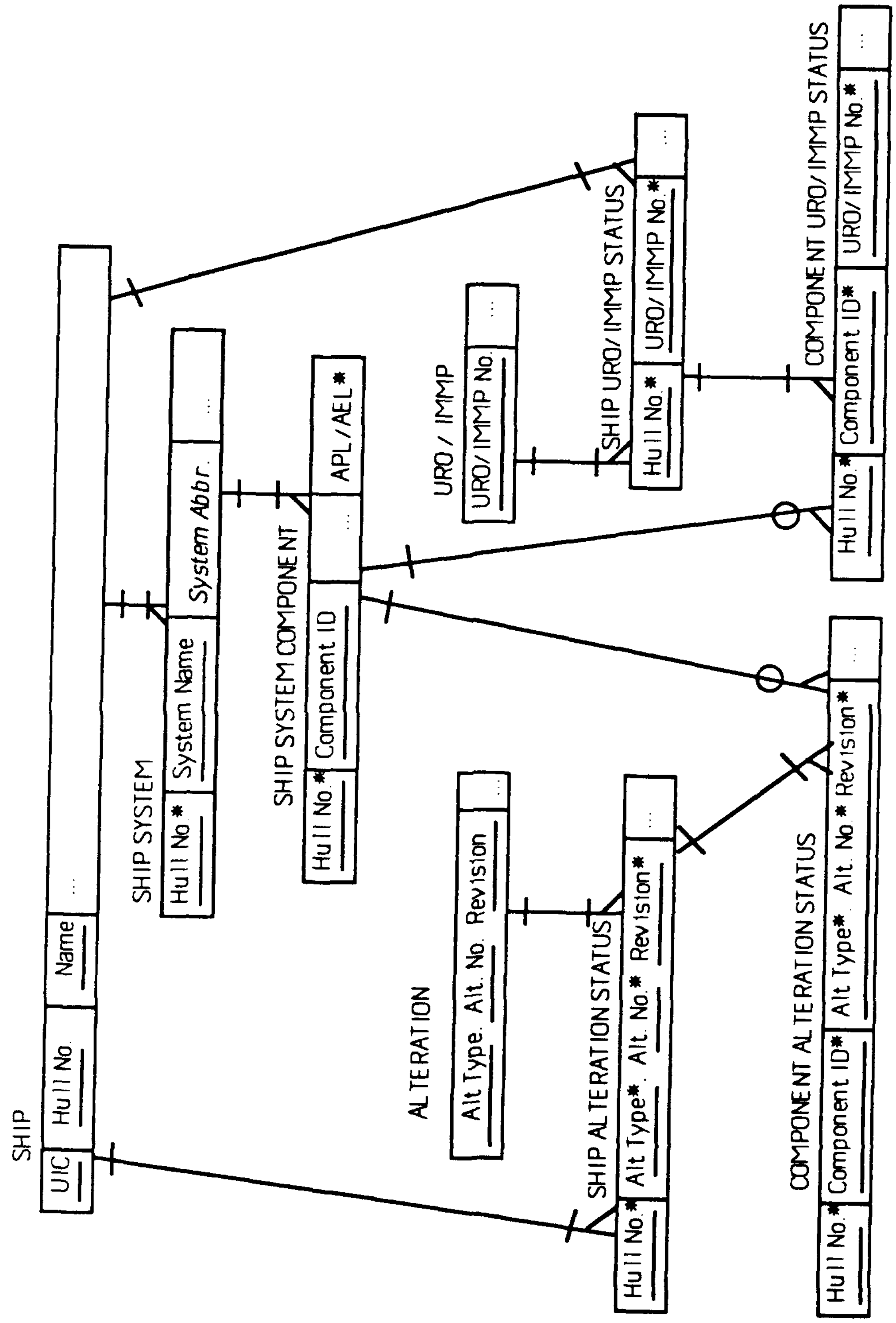
Worker_IDs

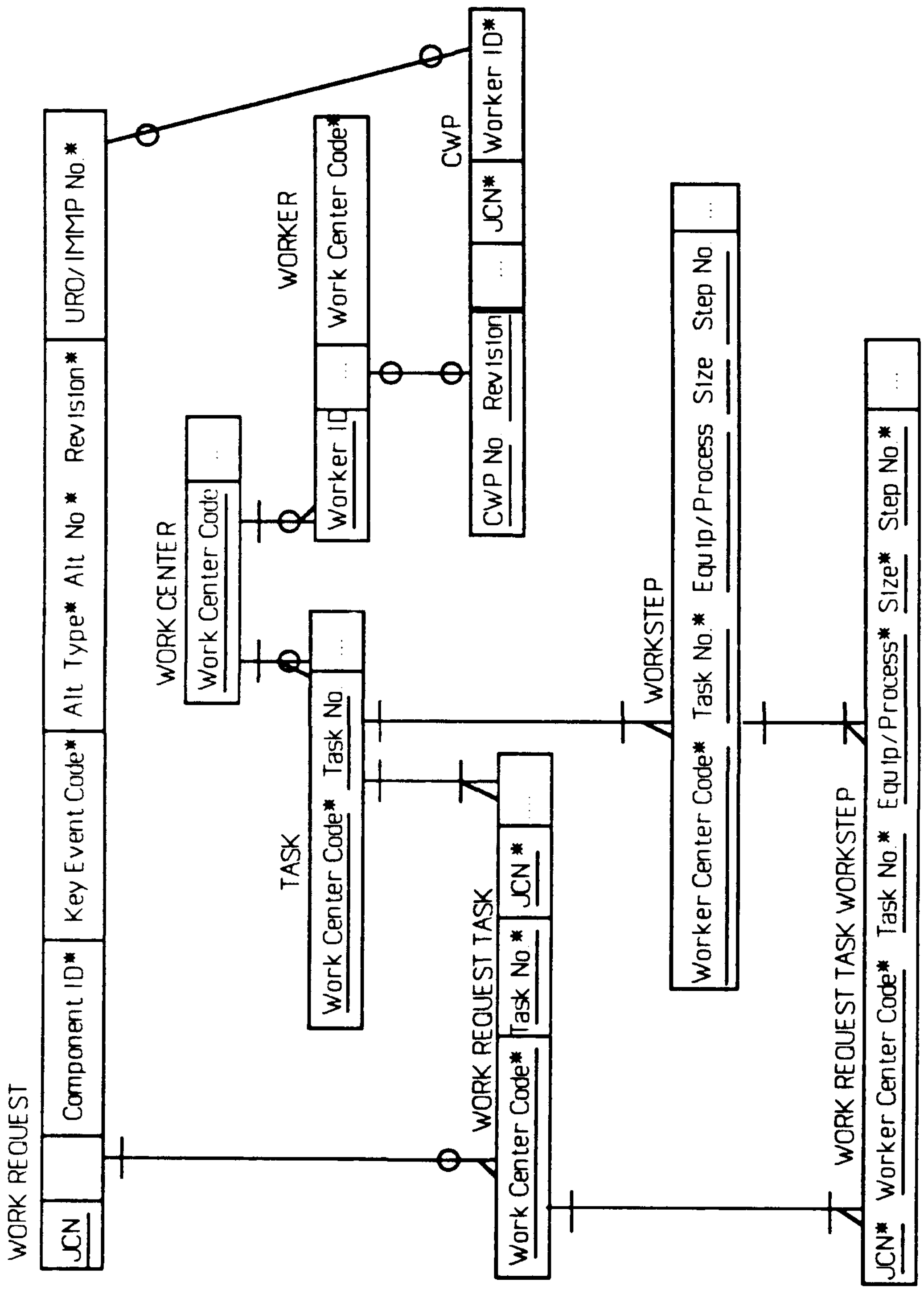
Text 9,

Unique identifier of a worker; perhaps all or part of his or her Service Number.

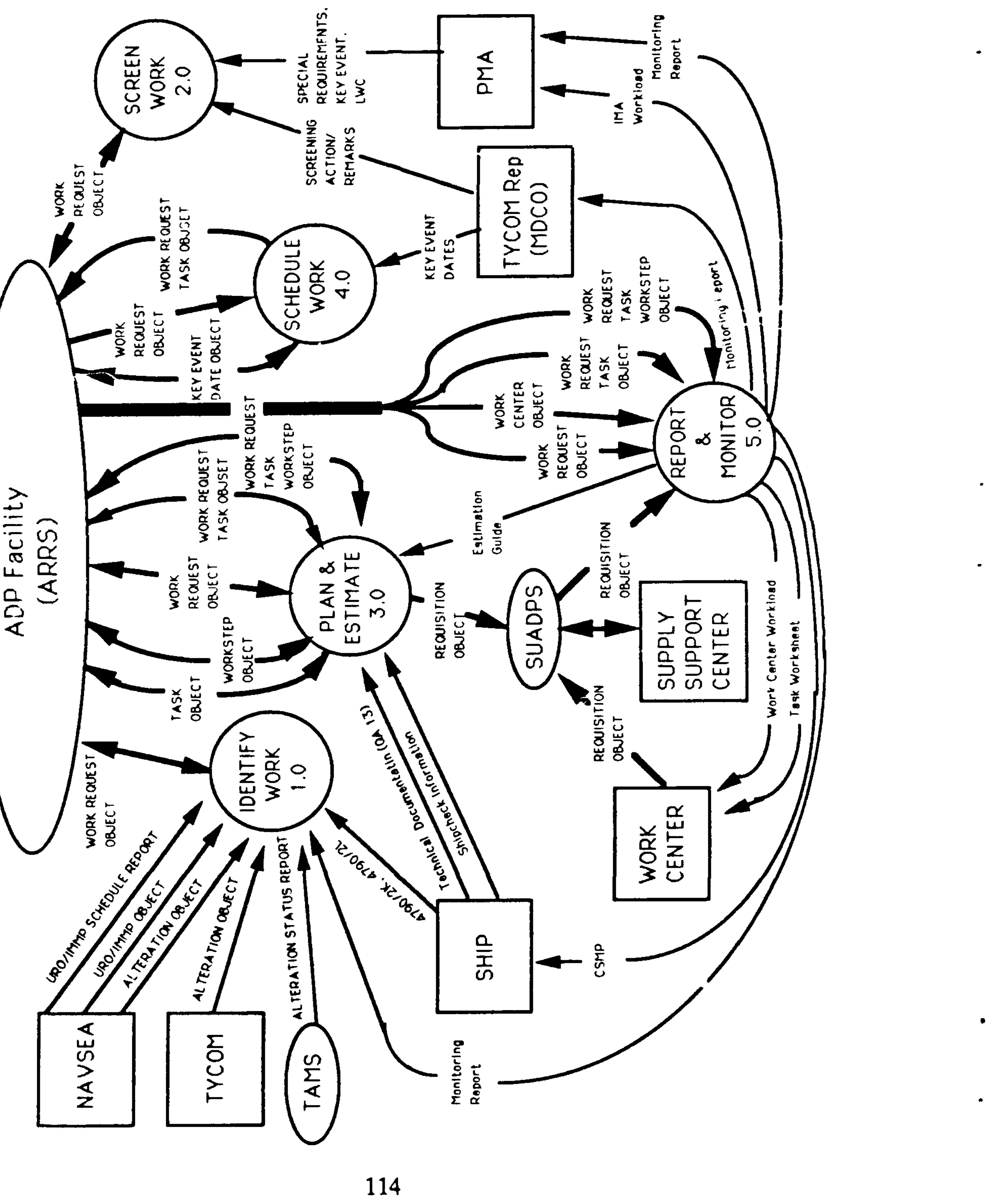
ENTITY RELATIONSHIP DIAGRAMS

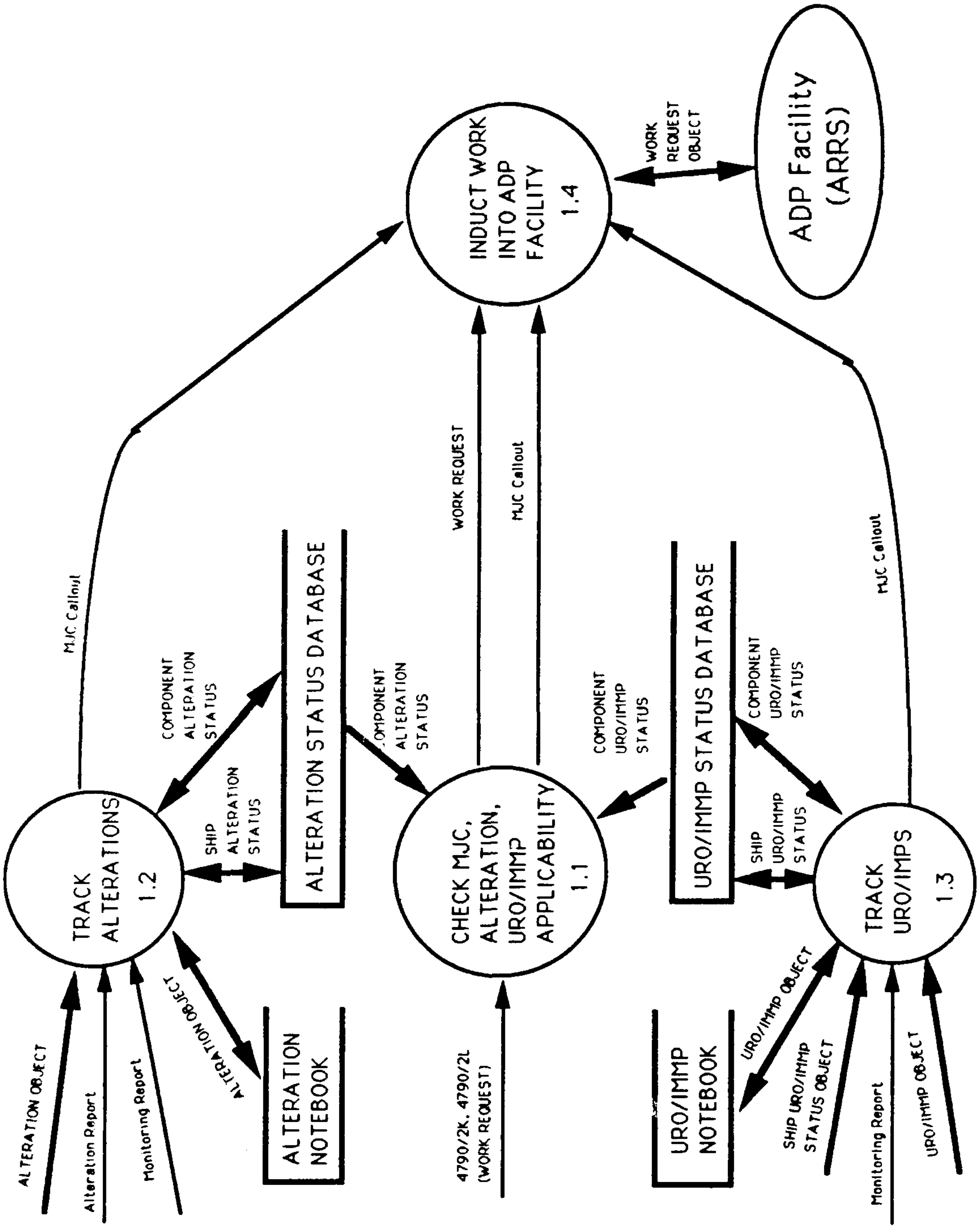


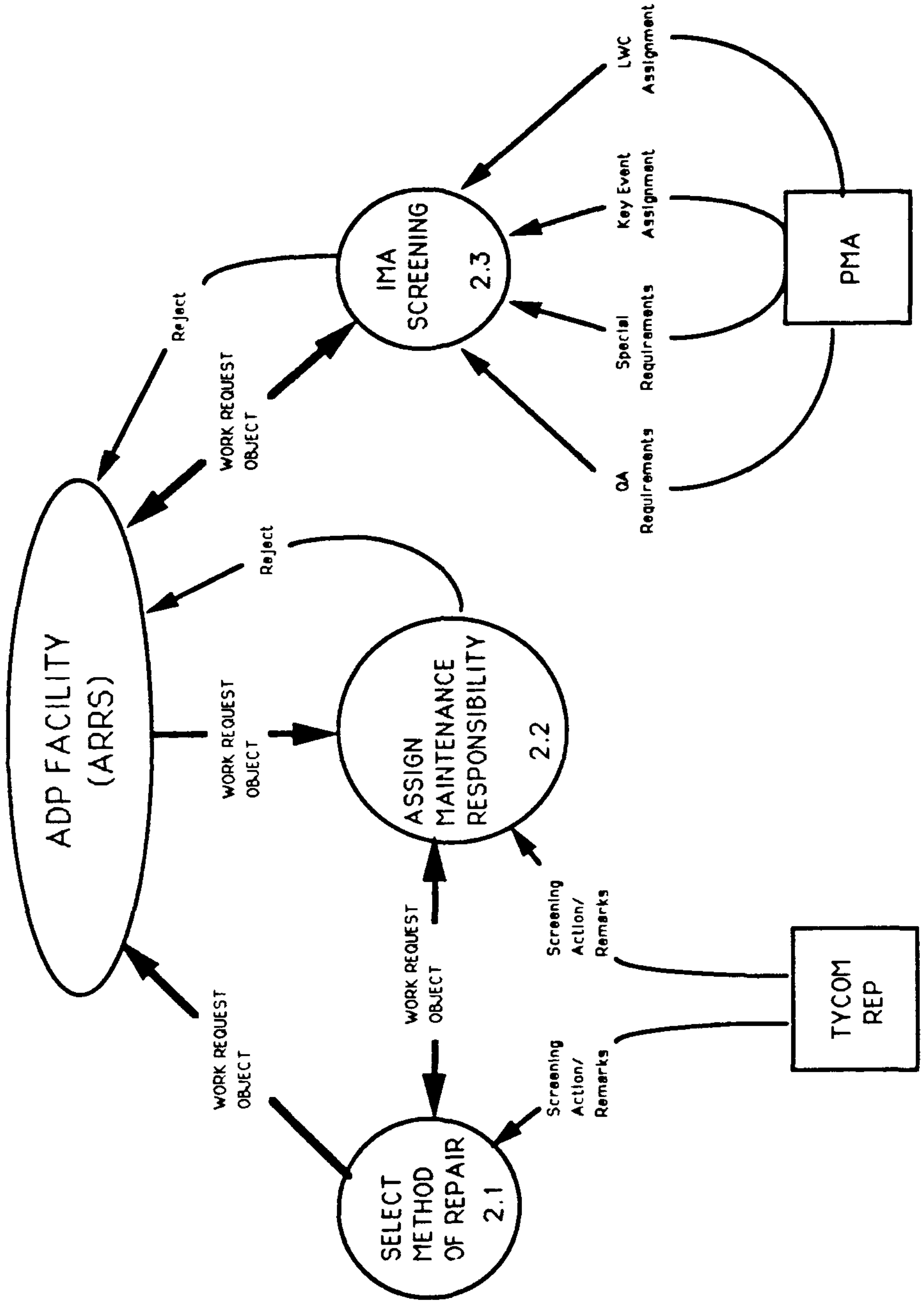

SHIP
UIC
Hull No.
Name
SHIP SYSTEM
Hull No.*
System Name
System Abbr.
SHIP SYSTEM COMPONENT
Hull No.*
Component ID
APL / AEL*
URO / IMMP
URO/ IMMP No.
SHIP URO/ IMMP STATUS
Hull No.*
URO/ IMMP No.*
COMPONENT URO/ IMMP STATUS
Hull No.*
Component ID*
URO/ IMMP No.*
ALTERATION
Alt Type.
Alt. No.
Revision
SHIP ALTERATION STATUS
Hull No.*
Alt Type*.
Alt. No.*
Revision*
COMPONENT ALTERATION STATUS
Hull No.*
Component ID*
Alt Type*
Alt. No.*
Revision*


WORK REQUEST
JCN
Component ID*
Key Event Code*
Alt Type*
Alt No *
Revision*
URO/IMMP No.*
WORK CENTER
Work Center Code
TASK
Work Center Code*
Task No
WORKER
Worker ID
Work Center Code*
CWP
CWP No
Revision
JCN*
Worker ID*
WORK REQUEST TASK
Work Center Code*
Task No *
JCN *
WORKSTEP
Worker Center Code*
Task No.*
Equip/Process
Size
Step No
WORK REQUEST TASK WORKSTEP
JCN*
Worker Center Code*
Task No.*
Equip/Process*
Size*
Step No.*

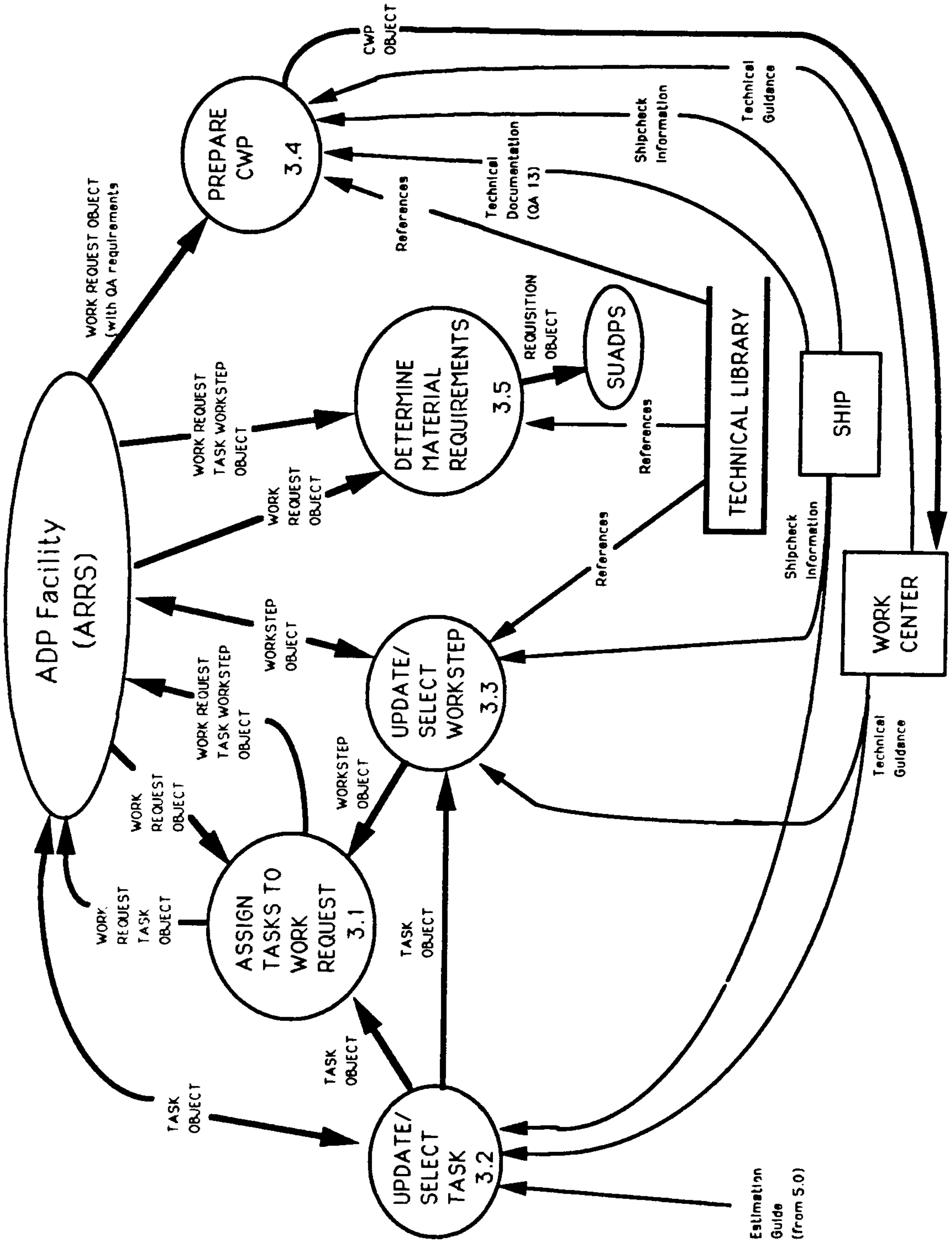
APPENDIX C. MAINTENANCE PLANNING PROCESS

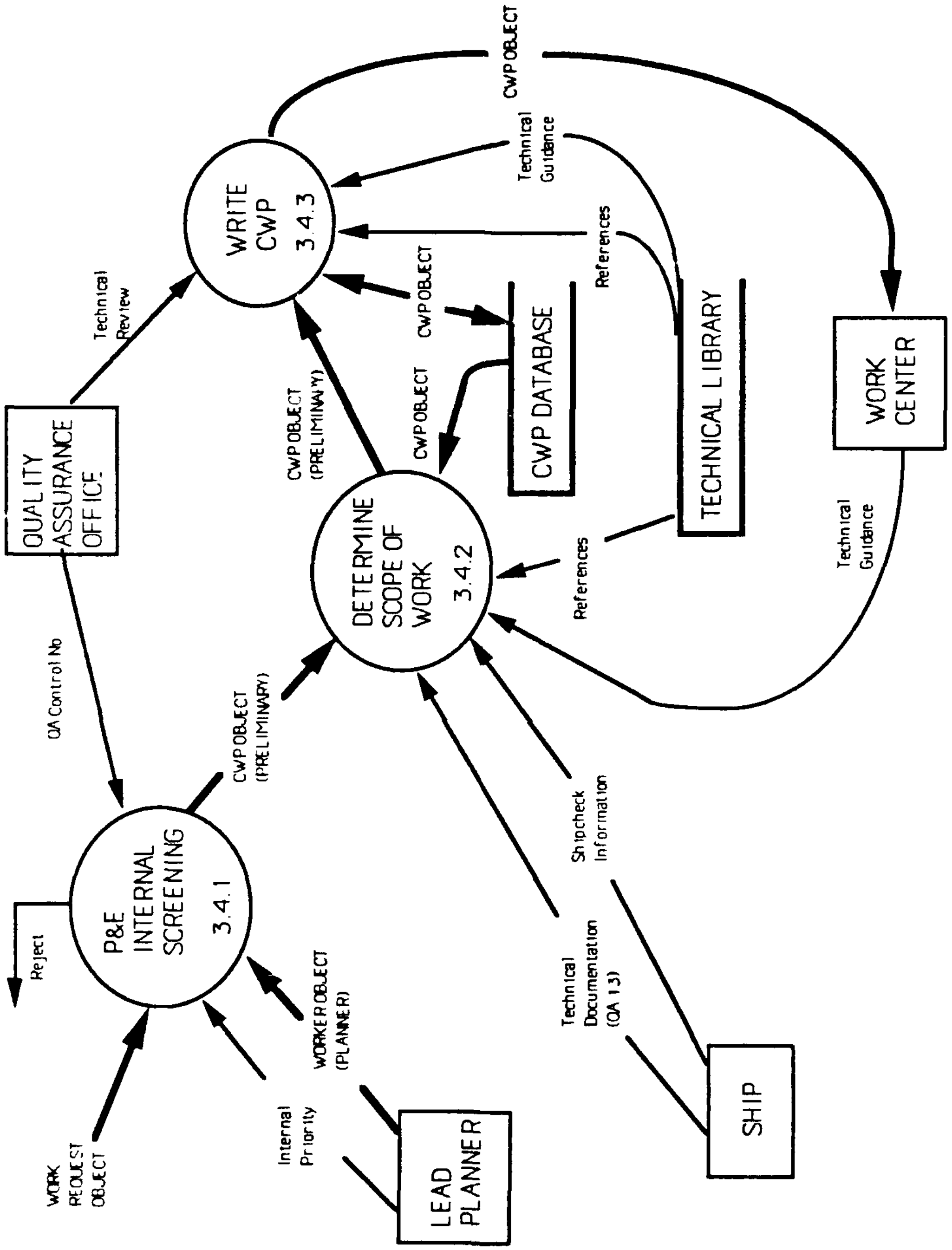


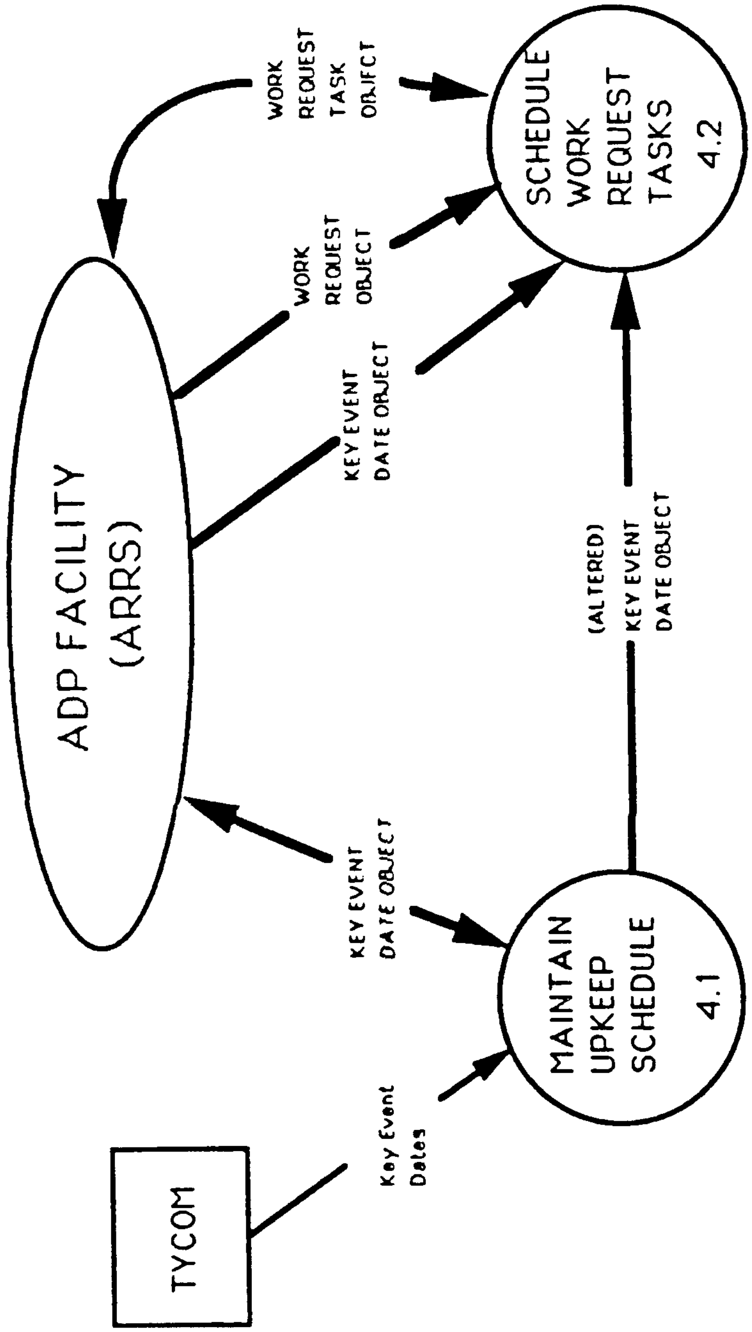

INDUCT WORK INTO ADP FACILITY 1.4
ADP Facility (ARRS)
WORK REQUEST OBJECT
TRACK ALTERATIONS 1.2
CHECK MJC, ALTERATION, URO/IMMP APPLICABILITY 1.1
TRACK URO/IMPS 1.3
ALTERATION STATUS DATABASE
URO/IMMP STATUS DATABASE
ALTERATION NOTEBOOK
URO/IMMP NOTEBOOK
MJC Callout
WORK REQUEST
MJC Callout
MJC Callout
COMPONENT ALTERATION STATUS
SHIP ALTERATION STATUS
COMPONENT ALTERATION STATUS
COMPONENT URO/IMMP STATUS
COMPONENT URO/IMMP STATUS
SHIP URO/IMMP STATUS
ALTERATION OBJECT
ALTERATION OBJECT
Alteration Report
Monitoring Report
4790/2K, 4790/2L (WORK REQUEST)
URO/IMMP OBJECT
SHIP URO/IMMP STATUS OBJECT
Monitoring Report
URO/IMMP OBJECT



ADP FACILITY
(ARRS)
SELECT
METHOD
OF REPAIR
2.1
ASSIGN
MAINTENANCE
RESPONSIBILITY
2.2
IMA
SCREENING
2.3
PMA
TYCOM
REP
WORK REQUEST
OBJECT
WORK REQUEST
OBJECT
WORK REQUEST
OBJECT
WORK REQUEST
OBJECT
Reject
Reject
Screening
Action/
Remarks
Screening
Action/
Remarks
QA
Requirements
Special
Requirements
Key Event
Assignment
LWC
Assignment


ADP Facility (ARRS)
ASSIGN TASKS TO WORK REQUEST 3.1
UPDATE/ SELECT TASK 3.2
UPDATE/ SELECT WORKSTEP 3.3
PREPARE CWP 3.4
DETERMINE MATERIAL REQUIREMENTS 3.5
SUADPS
TECHNICAL LIBRARY
SHIP
WORK CENTER
WORK REQUEST OBJECT (with QA requirements
WORK REQUEST TASK WORKSTEP OBJECT
WORK REQUEST OBJECT
WORKSTEP OBJECT
WORK REQUEST TASK WORKSTEP OBJECT
WORK REQUEST OBJECT
WORK REQUEST TASK OBJECT
WORKSTEP OBJECT
TASK OBJECT
TASK OBJECT
TASK OBJECT
REQUISITION OBJECT
References
References
References
CWP OBJECT
Technical Documentation (QA 13)
Shipcheck Information
Technical Guidance
Shipcheck Information
Technical Guidance
Estimation Guide (from 5.0)


WRITE CWP 3.4.3
CWP OBJECT
Technical Guidance
References
CWP OBJECT
CWP DATABASE
TECHNICAL LIBRARY
WORK CENTER
Technical Review
QUALITY ASSURANCE OFFICE
CWP OBJECT (PRELIMINARY)
CWP OBJECT
DETERMINE SCOPE OF WORK 3.4.2
References
Technical Guidance
QA Control No
CWP OBJECT (PRELIMINARY)
Shipcheck Information
P&E INTERNAL SCREENING 3.4.1
Reject
Technical Documentation (QA 13)
WORKER OBJECT (PLANNER)
SHIP
Internal Priority
WORK REQUEST OBJECT
LEAD PLANNER


ADP FACILITY
(ARRS)
SCHEDULE
WORK
REQUEST
TASKS
4.2
MAINTAIN
UPKEEP
SCHEDULE
4.1
TYCOM
WORK
REQUEST
TASK
OBJECT
WORK
REQUEST
OBJECT
KEY EVENT
DATE OBJECT
(ALTERED)
KEY EVENT
DATE OBJECT
KEY EVENT
DATE OBJECT
Key Event
Dates

APPENDIX D. PROBLEMS IN R-7

A Report by Lt. SMITH,
USS MCKEE Repair Department

1. The informal review of Planning and Estimating, R-7, of the Repair Department of the USS MCKEE (AS 41) (Conducted 21-28 February 89) yielded concrete observations and generated complex recommendations for increasing the effectiveness in the following areas: Manning, Training, Space Engineering, Office Systems and Organization Issues. The scope of the review has been discussed with the Repair Officer, PMA, R-7 Division Officer and R-7 LPO.

2. The basic problem, formulated by the review process, is that R-7 does not consistently meet the demands of package preparation placed on it by the repair department through the units tended by USS MCKEE. This demand can be separated into two basic areas.

3. The first area is the preparation of Controlled Work Packages (CWP) to support repairs to tended units. The second area is the identification, package preparation, and material procurement for the timely accomplishment of SHIPALTS and A&Is. While the first area is getting accomplished under crisis management, the second area is significantly behind power curve with little recent progress made in accomplishing the approximately 500 outstanding SHIPALTs and A-Is. While this report deals specifically with the lack of CWP preparation for the accomplishment of submarine repairs, following this report's recommendations should also improve the management of the second area.

4. USS MCKEE wrote 629 CWPs last year. Figure 1 provides a breakdown by year and tended unit for the last three years of CWP demand. 1986 package requirements were higher than 1987 and 1988 due to three units conducting SRAs. COMSUBRON ELEVEN long range plan shows two 688 Class submarines in SRA per year through 1991 Based on the 637 Class submarines transferred, with the exception of USS DRUM and only having to work six 688's and the USS BLUEBACK regularly, the level of CWP generated for submarine repair should not increase significantly.

Figure 1

UNIT	1986	1987	1988	DISPOSITION
USS WILLIAM H. BATES	68	93	44	Trans. to ROH MAR 89
USS BLUEBACK	30	36	151	
USS CHICAGO	0	0	6	
DOLPHIN	0	0	6	DEVGRU 1 UNIT
DRUM	0	0	23	ARRIVED CSS 11 '88
ELK RIVER	0	1	0	VISITOR
USS FLASHER	1	0	0	CSS 3 UNIT
FLORIKAN	0	0	3	
USS GUITARRO	1	0	0	CSS 3 UNIT
USS GURNARD	1	0	0	CSS 3 UNIT
USS HOUSTON	152	31	50	
USS LA JOLLA	79	69	39	DMP MINSY til 1990
USS LOUISVILLE	0	0	26	
USS PASEDENA	0	0	0	Arrive 1989
PIDGEON	0	0	2	Visitor
USS PINTADO	139	111	91	Trans. ROH AUG 89
USS POGY	129	120	55	Trans. ROH APR 89
USS PORTSMOUTH	60	23	33	
USS SALT LAKE CITY	35	61	19	
SAN ONOFRE	16	4	0	
TOTAL COMPLETED	712	549	548	
CANCELLED PKG.	181	186	81	
TOTAL PKGS WRITTEN	893	735	629	

DMP IMPACT

5. While the number of CWPs generated for submarine repair should remain constant, the impact from shifting required maintenance from the Shipyard to the IMA will tend to increase the number of CWPs required. This effort, designed to reduce the overall costs of Submarine Force maintenance, will significantly increase the workload of the IMA, especially in the planning and estimating area.

SHIPALT AND A-I PROBLEMS

6. While R-7 is significantly behind in preparing CWP for sub- marine repair, the division is further behind in the planning and material acquisition for the accomplishment of approximately 500 overdue SHIPALTs and A&Is. The reason for this problem is related to being in a crisis management mode in preparing CWPs for submarine repair, despite having four people dedicated to SHIPALT and A&Is. By combining the jobs being planned with the overdue SHIPALTs and A&Is into R-7's currently existing Management Information System, R-7 management can assess the current situation and decide if resources need to be shifted to SHIPALTs and A&Is or to CWPs preparation. While the problem will not disappear overnight, tracking the overdue SHIPALTs and A&Is will help to recognize the problem and to manage its size and scope.

CWP WORKLOAD

7. The current situation in R-7 can not handle the current level of CWP requirements. Based on an estimated expenditure of 30 man-hours to prepare a repair package, R-7 manning supports only 335 repair packages a year. Enclosure (1) details man-hour allocation of R-7. To meet the current demand, R-7 personnel are forced to work longer hours and manage in a crisis mode more often than is required. This mode of operation requires significantly more manpower due to the higher level of attention, reduces divisional morale and generally results in a poorer package. Late planning also delays proper material procurement and shop load planning. It is difficult, if not impossible, to fix the problem when you are behind. With the man-power in R-7 forced to work longer hours, thought should be given to leveling out the workload of R-7. Up to 10 days is required to prepare and route a CWP. Currently, CWPs are not started until after the pre-arrival conference. To even out the work load, the planning of a CWP could begin as soon as the job is received by the IMA. If a job is cancelled or deferred to the next upkeep, then the work already accomplished on the CWP should be saved so when the planning starts again, R-7 does not have to start from scratch.

MANNING

8. When a shop is behind in production as R-7 is, the common tendency is to supply man-power to fix the problem. This idea is a temporary way to increase the production of R-7, but due to critical rate shortages on the MCKEE, the supply of quality man power is simply not available. The 141 HTs and 86 MMs are significantly below manning levels of the 171 HTs and 103 MMs required by NMPC. These two rates are further drained by NMPC undermanning of nuclear welding, shop 38N, which is assigned 3 people by NMPC. It would be very difficult to perform all the nuclear welding required today with only two welders and one supervisor. The current manning level of 38N is 5 HTs and 5 MMs. Quality Assurance Inspectors, shop 93C, is not even mentioned in the NMPC manning levels. This shop requires an additional 3 HTs and 7 MMs. This brings the total deficit to 38 HTs and 29 MMs. R-7 requires experienced personnel in these two rates to write the majority of their CWPs.

MAN-HOURS

9. The manning level of R-7 has been reduced from 40 down to 26 people over the last 18 months while the number of work packages has remained relatively constant. R-7 will lose an additional 6 people by the end of 1989 without any personnel gains being identified. The yearly requirements for R-7 is expected to be about 700 to 750 work repair packages. The available man-hour for the R-7 planners to write these packages is sufficient for 335 packages annually. Transferring more personnel to R-7 would certainly help, but with the overall shortage of personnel in the Repair Department, this idea may not be the best solution. Enclosure (1) provides a break down of R-7 man-hour usage and possible ways to increase R-7 productive man-hours.

TRAINING

10. While R-7 meets its current training requirements, man power problems and the constant turnover of personnel result in informal job planning training. Since there is currently no formal qualification training for the planners, it is recommended that a formal training program be put in place, including the use of civilian planners from other IMAs to effectively train the R-7 personnel. Enclosure (2) provides more details in this area.

SPACE LAYOUT

11. The planners' office layout provides limited desk top space for the numerous references that are required to prepare a work package. By using long counters with a computer positioned under the counter top, printers in a different area, and monitors on a shelf, the desk top area would increase,

thereby increasing the efficiency of the planner. Enclosure (3) provides more information in this area.

INFORMATION MANAGEMENT

12. Increasing the efficiency of the planners will also require a different approach as to how the CWPs are tracked and stored. Currently, the planners use 5 micro-computers, each with it's own printer, to type out a work package. This system reduces the available desk top space, and raises the noise level with several dot matrix printers all going at once. The sharing of work packages from planners to planner is reduced since old work packages are "locked up" in a particular computer's hard disk and may not be known to another planner. The solution to this is to install a centralized storage unit for work packages with a keyboard, screen and dumb terminal for each planner. This arrangement would reduce the desk space used by the equipment and increase work procedure sharing by centralized storage of work procedures. Printing would be accomplished by one or two laser printers which will increase the number of pages per minute printed, reduce the noise level in the work place, and improve the quality of the printed product. Enclosure (4) gives more detail in this area.

ORGANIZATIONAL ISSUES

13. The final area of concern deals with organizational issues. Currently, there are 4 independent databases maintained by the planners to keep track of what repair jobs require packages. Tracking this redundant data takes time away from package writing. This administrative task could easily be handled by the divisional administrative assistant. In addition, the database should be compatible with the one used by the ship supervisors and R-10 personnel. This would increase data transfer and reduce redundant typing. Another organizational issue is there is no effective way to find an old work procedure. The current way is to go through the computer directory and see if it's there. This requires a lot of looking, remembering what is there, and hoping the file name tells you what the work package is. The development of a simple look up table to cross references such items as ship class, hull number, component name, APL and component identification will upgrade the ability to find existing or similar packages. Another administrative item for consideration is that as packages are routed for approval, the routing often takes up to 5 days to get completed. During this process, some comments are made which deal with style rather than technical accuracy. Finally, when defects in the package are pen and ink corrected,the correction rarely make it back to the planner so he can learn from his mistakes and update the electronic version of the CWP.

CONCLUSION

14. Solving the overall problem of getting packages to the shop in a timely manner to support a tended unit's scheduled upkeep will continue to be a demanding management problem for R-7. The standard of 12 hours per CWP should be established as an achievable longterm goal. In the short term, I recommend the following (in priority order):

(1) Use augment personnel to beef-up the R-7 division to assist in the technical library or as directed, by the R-7 division officer.

(2) Develop one Management Information System to track CWPs, SHIPALTs, A&Is, UROs and IMMPs. Ensure this system will "talk" to the system currently used by the SHIPSUPS, and is maintained by the R-7 administrative assistant. An annual savings of 300 man-hours is estimated.

(3) Build computer aided cross reference table to enable the planner to easily find packages already written.

(4) Ensure the tended units submit work requests (2-Kilo) with a QA-9 or QA-13 in a timely manner to support their upkeep.

(5) Follow recommendation A & C of enclosure (1) to increase the number of productive man-hours available.

For the longterm, I recommend the following (in priority order):

(1) Follow up effort by Naval Postgraduate Students concerning improved workspace layout, administrative MIS for Repair Department and advanced package writing tools.

(2) Redesign the layout of R-7 to reduce the background noise level and improve the workspace environment.

(3) Implement a well-designed training course to improve the planners ability to do their job.

(4) Obtain a centralized computer system so each planner can obtain a screen and Keyboard without having a noisy printer in his office.

(5) Evaluate an effective alternate to the "Controlled Work Procedure Generator" prepared for Naval Submarine Support Facility New London, CT by Life Cycle Engineering, Inc. Enclosure (5) gives more detail on this CWP development tool.

ENCLOSURE (1)
R-7 MAN-HOUR USAGE

Given:

- Each year has 2000 man-hours available, including ten holidays.
- Each week is 40 hours long.
- Each man gets 20 work days of leave.

Divisional functions/Supply Berthing Space Cleaners:

- 1 male every other month,	1080 MH.
- 1 Petty Officer (male) supervisor quarterly,	540 MH.
- 1 female cleaner every other month,	1080 MH.
- 1 Petty Officer (female) supervisor quarterly,	540 MH.
Total man-hours for berthing in one year (Cleaning):	3240 MH.
Quarter Deck Watches:	
- 1 man, 4 hours per day,	1000 MH.
	=======
DIVISIONAL TOTAL:	4240 MH.

22 people in R-7 to share this 4240/22 = 193 per person for each man in R-7.

	Man-Hours
Divisional functions	193
Drills about 4 hrs/week, 48 weeks	192
Field day, 4 hrs/week, 48 weeks	192
Training, 3 hrs/week, 48 weeks	144
Leave, 4 week per year	160
	881

Man-hours of productive time.	2000-881 = 1119 MH
Productive time to plan jobs.	9 planners X 1119 man-hours = 10,071 MH

Current time to prepare a package planner time only:

Check prints/drwg in Tech Library	8
Ship check	5
Complete package	17
	30

Package/year with 9 planners. 10071 MH / 30 MH per CWP = 335.6

To reach the level of 623 packages last year, planners would have to work (623-335 CWP) X 30 MH per CWP / 9 planners / 48 weeks = 20 more hours per week.

1. QA recorded 551 packages in 1988. The maximum number of packages was 893 in 1986. LPO estimates about 20 packages per upkeep x 4 per year x 12 boats = 960 packages which is probably high.

   9 planners can do 335 packages.
   15 planners should do 551 packages.
   26 planners should do 950 packages.

2. This is a straight ratio and does not take into account working space limits, typing limits and surge volumes.

3. Based on the above manning estimates, 21 planners (26 plus 15 divided by 2 = 21) is determined to be the ideal number. This gives 7 planners per specialty area. These areas are: Mechanical; Hull and Mast/Antenna.

4. Seven planners per area gives one per section with one left over to cover for training, schools, leave and crisis management.

5. Increasing the manning level of R-7 will be difficult due to the below normal level of Repair Department manning on the USS MCKEE. Other ways to increase man-hours available to plan jobs are discussed below.

   a. Eliminate the Quarter Deck and Berth cleaning duties for R-7. This would add 4240 MN or the equivalent of (4240/30) = 141 packages.

   b. Use Augment crew members in the technical library to assist in pulling references and prints. This should reduce the time to prepare a package by 8 hours (10071/22) - 335 = 123 package increase.

   c. Increase the work day of the planner by one hour. By using man-hours, the adverse effect on morale was not included: (250 MN x 9 planners) 30 = 75 packages (100 packages if step b was also used).

Cleaning and Quarterdeck watches	(4240)/22	= 193
Use Augment crew in Tech Library	123	= 123
Work one additional man-hour a day	(250 x 9)/22	= 102
	additional packages:	418

6. This level of production increase assumes no other duties are assigned to R-7 personnel. The increase in production should last until either morale decreases due to longer working hours or until the planned loss of 6 people from R-7 further reduces it's workforce.

ENCLOSURE (2)
TRAINING AND QUALIFICATIONS

1. Currently, there is no formal qualification program for planners in R-7. The normal rotation of knowledgeable Petty Officers results in a constant turn over of personnel. There are several training issues to address.

2. First, the Petty Officer writing a package is a slow typist. The use of inexpensive computer run self pace typing courses will increase the speed of a planner's typing. It is purposed that a minimal speed of 30 words per minute (wpm) be set before qualifying a planner. By using "Typing Tutor III", a popular self-pace, inexpensive typing teacher, a planner's typing speed could increase to 30 wpm with about 15 hours of independent study.

3. Second is the absence of a qualification card. This card must be resolved. This card should include the following items:

   a. Reference Locations.
   b. References Available.
   c. Drawings Available.
   d. Type at 30 words/minute.
   e. Assist in preparing 2 packages.
   f. Prepare one package for qualifications.
   g. Submarine system familiarization.
   h. Resolving specification, differences in references.
   i. How to read/interpret a drawing.

4. While the above items are recommended to be included in a qualification card, the card should be developed with a civilian planner from another IMA (Pearl Harbor). This would give one of the key factors missing from the planning office, experience.

5. This brings up the third training issue, the use of civilian/military experience to train all the current planners. The use of civilian experience to train Naval personnel is used regularly by the USS MCKEE for technical repairs such as valve body repair. By using the experience of civilian planners from another submarine IMA, the MCKEE planners would be brought up to step with the rest of the planners in the Submarine Force. Then using the civilian planners and vast training program development knowledge available in R-7, qualification guidelines would be developed.

6. The qualification guidelines would reflect the items selected in qualification card maintain a high standard level to ensure that new planners are effectively trained. The guidelines should be straight forward and as condensed as possible.

ENCLOSURE (3)
R-7 FACILITIES

1. The current layout of the planning section of R-7 is ineffective to efficiently write CWPs. Figure 3.1 provides a 30:1 scale drawing of the floor plan in the planning section. One problem is the position of the three computers near the rear of the office. Around these computers, there is no area to put the drawings and prints required to effectively plan a job. The planner is forced to hold the references in his lap while trying to type out a quality CWP. The second problem noted is the high ambient noise level in the office. The 5 printers and copy machine along with a 15 second beep from the Emergency Power Supply produce a disturbing amount of noise. The final significant problem noted is that since there are no room dividers in the area, people are disrupted often by visitors to the office. Planning CWPs is a time consuming thought intensive activity. Efforts should be taken to enhance the work environment.

2. Figure 3.2 shows one proposed plan to improve the effectiveness of the planners. The floor plan shows places for 8 planners and one supervisor. If more planners are required, then the cubicals would be shared in a shift work arrangement. The maximum effective number of planners would be limited to 32 with 4 supervisors. This would fill a 4 shift rotation and definitely exceed any foreseeable requirement by the USS MCKEE. The advantage of this floor plan arrangement is it provides a relatively low cost way to provide a quiet, well organized work place to prepare CWPs with sufficient room to spread out the required references next to the tool used to write the CWP. It is recommended that the optimum floor plan be determined with help of thesis students from Naval Postgraduate School in Monterey. In the mean time, it is recommended that the proposed floor plan be utilized to upgrade R-7.

(FIGURES 3.1 AND 3.2 ARE OMITTED)

ENCLOSURE (4)
INFORMATION MANAGEMENT

1. R-7 currently uses five micro-computers to prepare CWPs. R-7 also maintains four separate databases to track CWPs and no database for SHIPALTs and A&Is. R-1O uses one database to track SHIPALTs and A&Is. R-10's database will also talk to the SHIPSUPS database. While this real-time administrative tool is useful in tracking jobs and significantly reducing the man-hours producing numerous required reports, it is a parallel system with the IMMS system.

2. To reduce the number of man-hours involved in administratively tracking CWPs, SHIPALTs and A&Is, R-7 should go to using the IMMS system. If the number of required reports justifies a local database, then a parallel database capable of communicating with the SHIPSUPs and the C0MSUBPAC SHIPALT and A&I database could be developed. The updates to this database, if justified, should be accomplished by the R-7 administrative assistant, not the planners since it is a waste of their manpower.

3. Improving the tool used to prepare CWPs will involve getting a 32 bit micro-computer with up to 32 work stations. This would give a keyboard screen to each planner, one to the Head planner, one or two to R-10 if desired, one to the R-7 division officer, one for PMA, one for Repair Officer, couple for the SHIPSUPs and several more left over for future use. The purpose of this system would be to prepare CWPs. Status of CWPs, Work package reviews, work assignments and various reports could easily also be produced from this system. More importantly, it would provide a central location for the electronic storage of CWPs. The cost of the system described with a good tape back up system is approximately $25,000.00.

4. Central storage of CWPs would increase the availability of CWP to all planners. As with any filing system, a good cross-reference system would be essential for efficiently retrieving CWPs previously written. This cross-reference system would be a simple database capable of using the unit's hull number, class, component, APL or general class to list CWPs previously written. This cross-reference table would greatly reduce the time to find a previously written CWP. Since finding CWPs would be easier, the use of old CWP would increase which would reduce the time required to produce a CWP.

5. While sufficient experience exists in C0MSUBR0N ELEVEN to effectively size the right system (both hardware and software) it has been determined that the proper approach s to research this issue with help from Naval Postgraduate School. Students can use this topic for their thesis and produce top quality research for travel costs to and from San Diego.

6. The proper management of information will not write packages faster. Having the best tools economical available and the status of your workload with an easy to use information system will make the management of the problem easier. A centralized computer to write packages will reduce the time to write CWPs and is highly recommended.

ENCLOSURE (5)
CONTROLLED WORK PROCEDURE GENERATOR

1. The Controlled Work Procedure Generator (CWPG) is a tool designed to assist a planner in writing a CWP. The CWPG can be used by the planner to standardize the format, references, shop guidelines, safety precautions, enclosures and other inserts normally contained in a CWP. The advertised advantage of CWPG is by producing packages that look alike, the time to review a work package would be reduced. The time to write a CWP is not greatly reduced. By using the CWPG, a planner can save typing time by using preformatted statements concerning references, joints material specifications and other items frequently used in writing a CWP. While saving typing time is certainly important, another advantage is that the CWPG forces the planner to layout the CWP prior to typing one word. This feature would tend to increase the quality of the CWP.

2. The design of the CWPG is very poor. This program pieces together different Word Perfect 4.2 files. The calling up of Word Perfect 4.2 multiple times in the generator slows down the package writing and consumes the entire 640KB of computer random access memory. The CWP references and other Word Perfect macros are written with COMSUBLANT references, not COMSUBPAC. This means each COMSUBPAC IMA must redo the program to conform to their guidelines. The file maintenance section of CWPG, which is designed to modify these macros, does not work and R-7 has not been able to get any technical support to fix the problem. While the automatic numbering system and ease of importing information are important features, the complex codes used to callout the macros, difficulty encountered in changing the macros, and the general poor man-machine interface results in a poor package writing tool which does not encourage R-7 planners to use it.

3. The sharing of work packages between IMAs is currently almost nonexistent. What is needed to truly get the full intended benefit from CWPG is a means to expeditiously transfer CWPs between submarine IMAs. This would involve an electronic bulletin board listing CWPs written with CWPG that are available for sharing with other submarine IMAs. A cross-reference table similar to the one mentioned in enclosure (4) would have to be used to increase access speed. This way, a CWP written by one submarine IMA could be used by all other submarine IMAs. Update control and security issues would certainly have to be addressed before this system could be implemented.

INITIAL DISTRIBUTION LIST

1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943-5002	2
3.	Director of Information Systems (OP-945) Office of the Chief of Naval Operations Navy Department Washington D.C. 20350-2000	1
4.	Superintendent, Naval Postgraduate School Computer Technology Programs, Code 37 Monterey, California 93943-5000	1
5.	Commander, Submarine Force U.S. Pacific Fleet Attn: Mr. Ed Sproat, Code 4011 Pearl Harbor, Hawaii 96860-6550	2
6.	Department of the Navy Chief of Naval Operations Attn: Mr. Steve Michaluk Pentagon OP-432D1, Room 4B521 Washington, D.C. 20350-2000	2
7.	Commander, Submarine Squadron Eleven Attn: Material Officer Naval Submarine Base San Diego, California 92132-5200	2
8.	Superintendent, Naval Postgraduate School Chairman, Code 54 Department of Administrative Sciences Monterey, California 93943-5004	1

INITIAL DISTRIBUTION LIST (cont.)

9. Superintendent, Naval Postgraduate School — 4
   Attn: Robert Knight, LCDR, USN(SC), Code 54Kt
   Department of Administrative Sciences
   Monterey, California 93943-5004

10. Superintendent, Naval Postgraduate School — 1
    Attn: James Suchan, Code 54Sn
    Department of Administrative Sciences
    Monterey, California 93943-5004

11. Superintendent, Naval Postgraduate School — 1
    Attn: Tom Moore, Code 54Mr
    Department of Administrative Sciences
    Monterey, California 93943-5004