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IWHS ELEVATOR CONTROLLER STUDY.(U)

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Final Report
IWHS Elevator Controller Study

ROBERT L. COX

Search and Inspection Group
Ocean Technology Division

LEVEL II

November 24, 1978

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A study has been performed to determine the optimum replacement for the present automatic controller of the IWHS Elevators on Aircraft Carriers CV 59 through CV 64. The task of selecting a replacement controller was precipitated by the lack of spare parts for, and the poor maintenance of, the present controller. Design approaches based on relay logic, semiconductor logic, and programmable controllers were evaluated with respect to reliability, maintainability, equipment supportability, standardization, human interface, failsafe operation, and life cycle

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20. Abstract (Continued)

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cost. It was determined that a controller based on electromechanical relays rated highest with respect to reliability, maintainability, equipment supportability, standardization, human interface, and life cycle cost. With respect to failsafe operation, the relay based controller had a respectable rating. The unexpected high rating of relay logic compared to semiconductor logic and programmable controllers is attributed to two factors: the usage rate of the IWHS elevators is compatible with relay reliability, and the relay controller has been demonstrated to be highly maintainable by the assigned maintenance personnel.

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1.0 SUMMARY

The Summary is presented first in this study in order to provide a readily available reference that indicates what situation prompted the study, what the objectives of study were, how the study was performed, and what were the more important results of the study. The reader that desires/requires additional information should read the Background (Paragraph 1.1) and the Definition of the Problem (Paragraph 1.2) of this summary before proceeding to any other section of the study.

A substantial amount of desirable, if not necessary, information is included in the Appendix of this study. Appendices A and B are concerned with the detailed reliability calculations, while Appendix H indicates fleet experience with modern relay controllers. Appendices C, D and E provide very valuable background information on the capabilities of the Electrician's Mate. Appendices F and G list the high reliability standard electronic modules and microcircuits from which a Navy static logic controller could be developed.

1.1 BACKGROUND

A recent concept in ammunition handling and stowage, called the Improved Rearming Rate Program (IRRP), is being incorporated in the newer aircraft carriers. Basically the IRRP concept consists of preassembled weapons and palletized ordnance. Under the IRRP concept, missile weapons are assembled and tested at a Naval Weapons Station, placed in a special cradle, and delivered to the carrier in an assembled configuration. Bombs and miscellaneous ordnance are delivered to the carrier on a pallet. The cradled missiles, palletized bombs and ordnance can be delivered to the carrier at shore installation or while underway. The aircraft carriers with IRRP capability have rather large weapons elevators that service several load/unload levels below and including the main deck. The carriers also feature modular stowage magazines for cradles and palletized weapons. More rapid weapon handling to, within, and from the magazines is provided by overhead handling systems in the magazine and forklifts to load and unload the elevator at each level serviced.

Note: Manuscript submitted November 14, 1978

Six older Aircraft Carriers, CV 59 through CV 64, have been modified to conform to the IRRP concept under the Improved Weapons Handling System (IWHS) program. Five of the aircraft carriers have two IWHS elevators, one of the carriers (CV 60) has one IWHS elevator with another to be installed in the near future.

1.2 DEFINITION OF THE PROBLEM

The control system for the IWHS elevators has a Manual Controller and an Automatic Controller. The logic and drive portion of the Automatic Controller presently utilizes the PDP-14 Industrial Control System previously manufactured by the Digital Equipment Corporation (DEC) of Maynard, Massachusetts. The PDP-14 was introduced by DEC in early 1969 but is no longer being manufactured and offered for sale. Many spare parts for the PDP-14 must be specially ordered from DEC at high cost and long delivery times. The maintainability of the IWHS Elevator has become a serious problem, not only due to the availability of spare parts, but also due to apparently inadequate maintenance service by the Electrician's Mate (EM). The inadequate maintenance service is generally attributed to the fact that the PDP-14 is a digital computer-like device whose sequential logical operations are completely foreign to the normal training and duties of the EM.

A solution to the spare parts problem was initiated by utilizing some modules from the Navy Standard Electronic Module (SEM) program to build a programmable controller that was functionally equivalent to, and software compatible with, the PDP-14 controller. The equipment development was accomplished by Naval Weapons Support Center (NWSC) and tested on the USS KITTY HAWK (CV 63) in 1977. The test was performed on the Lower Stage No. 3 IWHS Elevator by simply disconnecting the cables from the PDP-14 and connecting them to the new controller, referred to here as the SEM General Purpose Controller (SEM GPC). It was determined during the test that the elevator operated essentially the same with the SEM GPC as it did with the PDP-14. However, a detailed evaluation identified desirable improvements to SEM GPC in the physical, electrical, electronic, display, documentation, and software support areas. Due to the stated desirable improvements, and to a recognized need for improved maintainability by the EM, NWSC is presently developing an improved controller (MSEM GPC) using a Microprocessor SEM to replace many of the individual SEM's.

Another approach to a solution of the IWHS Elevator problem was suggested by the development of a "Modern" Relay Controller by the Puget Sound Naval Shipyard (PSNS). The Modern Relay Controller features the use of relative small electromechanical relays to perform logical operations and drive small loads. Solid State Relays are used to drive the higher loads. Light emitting diodes are used to indicate the excitation status of the relays to provide a maintenance aid for the EM. Additionally the relay controller features a built-in test socket to test the electromagnetic relays. Two controllers, referred to as the hybrid controller, were built by PSNS and one each installed on the USS SACRAMENTO (AOE-1) and the USS CAMDEN (AOE-2). Messages from these two ships (See Appendix H) indicate that the controllers have been successful.

On the later carriers (CV 66 through CV 69), the logical operations of the Automatic Controller are mechanized using semiconductor logic. The technique is referred to as Static Logic and is very similar in logical operation to relay logic. Static logic has been found to be satisfactorily maintainable by EM's. The disadvantage of presently installed Static Logic is that General Electric, whose Static Logic family is used on the USS AMERICAN (CV 66) and the USS KENNEDY (CV 67), is no longer in the static logic business, while Cutler-Hammer, whose Static Logic family is used on the USS NIMITZ (CV 68) and USS EISENHOWER (CV 69), has significantly redesigned their logic family. The Static Logic approach for the IWHS elevator is a reasonable one but any approach selected should be supportable for 20 years.

1.3 STUDY AUTHORIZATION

Because there was no obvious "best" contending solution to the problem, PERA (CV) tasked the Naval Research Laboratory (NRL) to perform an independent study to determine the optimum solution. The study was funded by PERA (CV) Project Order Numbers N00251-78-PO 00023, N00251-78-PO 00033 and N00251-79-PO 00002. The corresponding assigned NRL Problem Numbers are 84D01-22, 22A and 22B.

1.4 STUDY APPROACH

The NRL plan of approach to the IWHS Elevator Automatic Controller Study was to:

1. Systematically define the problem to the complete satisfaction of PERA (CV) and NRL (Section 2.0).
2. Define the elevator controller requirements (Section 5.0).
3. Define the capabilities of the maintenance personnel (Section 6.0).
4. Determine the appropriate criteria and sub-criteria for evaluating the candidate design approaches (Section 8.0).
5. Analyze the possible design approaches and select the most promising (Section 7.0).
6. Define the design approaches to be evaluated (Section 7.0).
7. Determine the appropriate weighting factors to be applied to the sub-criteria and the major criteria (Section 8.0).
8. Evaluate the design approaches, first according to the sub-criteria and then according to the major criteria (Section 8.0).
9. Analyze the evaluations, determine the significant conclusions and recommended course(s) of action (Section 9.0).
10. Contact cognizant naval organizations and suppliers as required to obtain pertinent information (Section 3.0 & 4.0).

The sections indicated in parenthesis are the sections of the report that correspond to the plan of approach elements. It was necessary to contact many organizations in order to perform study properly; the organizations contacted included 32 codes in 19 Navy organizations, 24 commercial control equipment manufacturers, a technical publication on control engineering, an academic institution, an engineering society, and a large industrial user of programmable controllers.

1.5 DESIGN APPROACHES EVALUATED

Six design approaches were selected for evaluation with respect to reliability. A brief description of the six design approaches is as follows:

Regular EM Relay - A design approach that uses small electromagnetic (EM) relays to interface directly with the external input devices and to perform the required logical operations. Larger EM relays are used to convert logical decisions into power signals to drive the external output devices.

Hybrid Relay - A design approach that is identical to the regular EM relay approach except that the larger power relays are replaced by so called Solid State Relays (SSR).

Static Logic - A design approach that uses semiconductor logic to perform the required logical operations. SSR's are used to drive external output devices. DC to DC converters are used to convert the high level signals from the external input devices to the low logic levels required by the semiconductor logic devices.

Non LSI Programmable Controller - This design approach uses a computer-like device; a Programmable Controller (PC), to sequentially sample the status of external input devices and to perform the logical operations to determine when to turn external output devices on and off. DC to DC converters convert the high level signals from the external input devices to the low logic levels required by the PC. The PC controls the external output devices via SSR's. The PC resembles a computer in that it contains a memory, a central processing unit (CPU), and can interface with input/output devices. The Non-LSI PC uses several Small Scale Integration (SSI) logic chips and some Medium Scale Integration (MSI) logic functional chips to perform the CPU function.

LSI Programmable Controller - This design approach is the same as the Non-LSI PC except that the CPU is a microprocessor on a Large Scale Integration (LSI) chip.

VLSI Programmable Controller - This design approach is the same as the LSI PC except that the CPU is a more advanced microprocessor on a Very Large Scale Integration (VLSI) chip.

The reliability evaluation indicated that the regular EM relay and the Hybrid Relay design approaches were similar enough that they could be considered as one basic design approach (Relay). The evaluation also indicated that the Non-LSI PC and the LSI PC were sufficiently similar and representative of commercially available equipment that they could be considered as another basic design approach (Commercial PC). The reliability evaluation indicated the desirable use of the Standard Electronic Modules (SEM) of MIL-M-28787A in a Navy designed controller. Accordingly the other basic design approaches were designed SEM Static Logic and SEM PC. The SEM PC is another name for the highest quality of VLSI PC.

1.6 EVALUATION RESULTS

The results of the evaluation of the four basic design approaches with respect to reliability, maintainability, equipment supportability, standardization, human interface, failsafe operation, and life cycle cost is given in Table 1.1. An overall evaluation figure-of-merit (FOM) was obtained by multiplying the reliability and life cycle cost individual ratings by 0.25, multiplying the other individual ratings by 0.10, and then summing the results for each design approach to render the overall FOM's indicated below

Basic Design Approach	FOM
Relay	98.0
SEM Static Logic	84.5
SEM PC	74.0
Commercial PC	63.2

It is seen that the overall evaluation indicates that the Relay design approach is the "Best" approach.

1.7 Conclusions and Recommendations

Conclusions

The overall evaluation indicated that the Relay design approach is the "Best" solution to the IWHS Elevator Controller problem. Although not rated the "Best" solution, the SEM static logic and the SEM PC approaches are considered as viable approaches. The SEM Static Logic approach would be particularly attractive if higher elevator dispatch rates should be required or if it were desireable to consider the Static Logic controllers on Aircraft Carriers CV 66 through CV 69. The

DESIGN APPROACH	RELIAB.	MAINT.	EQPT. SUPT.	STD.	HUMAN INTER.	FAIL SAFE	LCC
RELAY	100	100	100	100	100	80	100
SEM STATIC LOGIC	100	90	90	80	80	80	70
COMMERCIAL PC	90	70	10	40	40	90	63
SEM PC	100	80	80	80	40	100	44

TABLE 1.1 INDIVIDUAL EVALUATION RATINGS FOR THE AUTOMATIC CONTROLLER DESIGN APPROACHES

SEM PC is potentially an attractive approach if its capability for self test were to be properly implemented and a successful Human Interface with the Electrician's Mate demonstrated. The ommercial PC, although it has a fairly respectable FOM, should be eliminated from any real consideration because of its very poor rating with respect to Equipment Supportability.

Recommendations

It is recommended the Relay design approach be recognized as the most probable successful replacement for the PDP-14. A modern relay based controller should be installed and tested on the U.S.S. CONSTELLATION (CV 64) so that it can be compared with the PDP-14 and a commercial Static Logic Controller. CV 64 is unique among the ships having the IWHS Elevators because it has a Static Logic controller and a PDP-14, both of which can control Lower Stage Weapons Elevator No. 3. When the SEM PC, being developed by NWSC, becomes available it too should be installed and tested on CV 64. A final definitive selection of a replacement controller could be deferred until after an in-service comparative elevation; otherwise the Relay controller should be selected now.

2.0 PROJECT DEFINITION

In response to a request from PERA (CV), NRL prepared a program plan to conduct a study to indentify the optimum type of control system for the IWHS elevators. NRL's program plan identified 12 tasks to be performed under the study. The 12 tasks were:

1. Meet with PERA (CV) to review the program plan, define the problem in greater detail, and discuss information requirements.
2. Define the basic controller requirements.
3. Define the evaluation criteria.
4. Define the weighting factors for the criteria.
8. Make a preliminary report on the first four tasks.
6. Analyze present controller solutions.
7. Review the state-of-the-art of programmable controllers.
8. Define the candidate controller solutions.
9. Modify the evaluation criteria and weighting factors if required.
10. Rate the candidate solutions.
11. Analyze the results and determine recommendations.
12. Write a final report.

Task 1 constituted the project definition task and was initiated by a meeting between NRL and PERA (CV) on April 12 and 13, 1978 at Puget Sound Naval Shipyard (PSNS). PSNS personnel also attended the meeting to provide background information and to provide information regarding their controller candidate, the Hybrid Relay Controller.

The initial project definition accomplished April 12 and 13, 1978 was clarified and supplemented during the entire study by a free flow of information between PERA (CV) and NRL.

A summary of the two day meetings is as follows:

<u>PDP-14 Controller</u>

1. The PDP-14 is considered reliable, only about 15% of the controller problems are due to the PDP-14. Usually the problem lies with the external input/output devices.

2. The PDP-14 is difficult for the maintenance personnel to troubleshoot; they do not understand how it works and tend to blame it when it is not at fault.

3. The manufacturer of the PDP-14 no longer adequately supports it.

4. The PDP-14 controller was not procured to a performance specification as an elevator controller; it was procured and adapted to perform the elevator control function.

Other Controllers

1. The SEM General Purpose Controller as designed by the Naval Weapons Support Center has a much higher procurement cost than other controllers. The controller demonstrated on the USS KITTY HAWK (CV 63), like the PDP-14, was not understandable to the maintenance personnel.

2. PSNS has designed a Hybrid Relay Controller and installed on the U.S.S. SACRAMENTO (AOE-1) and the U.S.S. CAMDEN (AOE-2.) The controllers have worked well, the maintenance people understand them, and the procurement cost is relatively low.

Aircraft Carriers and Elevators

1. Six Aircraft Carriers (CV 59 through 64)have the IWHS Elevators: 5 CV's have 2 IWHS Elevators per CV, CV 60 has one IWHS Elevator with another to be installed soon. The remaining life of the CV's is approximately 20 years.

2. CV 59 through CV 64 have approximately 15 weapons elevators each, their non-IWHS Elevators have conventional relay controllers.

3. The electrical maintenance of the elevators is performed by Electrician's Mates (EM).

Plan of Approach and Related Information

1. The plan of approach is satisfactory but needs to include a task which defines the capability of the Electrician's Mate.

2. The required supportable life of the optimum controller is 20 years.

3. A procurement of 20 controllers shall be used for cost purposes.

4. NRL is authorized to investigate the external input/output devices as they see fit.

5. The evaluation criteria shall be Reliability, Maintainability, Equipment Supportability, Equipment Standardization, Human Interface, Failsafe Operation, and Life Cycle Cost.

6. The evaluation with respect to the Human Interface shall be limited to the Electrician's Mate. No other Enlisted Rate shall be considered.

7. PERA (CV) does not require a specific life cycle cost analysis procedure to be followed by NRL.

3.0 REFERENCE DOCUMENTS

The following documents provided information utilized during this study.

3.1 DRAWINGS

NAVSHIPS CV43 712 2416966 USS CORAL SEA (CV 43) Weapons Elevators

NAVSHIPS CVA 61 703 2404567B USS RANGER (CV61) 10,500 Pound Lower Stage Weapons Elevator No. 8

3.2 MILITARY HANDBOOKS

MIL-HDBK-217B Reliability Prediction of Electronic Equipment

3.3 MILITARY SPECIFICATIONS

MIL-H-24148 (SHIPS) Human Engineering Requirements for NAVSHIPS Systems and Equipment

MIL-M-28787A Standard Electronic Module Program, General Specification for

MIL-M-38510D Microcircuits, General Specification for

3.4 MILITARY STANDARDS

NAVPERS 18068D Manual of Navy Enlisted Manpower and Personnel Qualifications and Occupational Standards

MIL-STD-167 Mechanical Vibrations of Shipboard Equipment

MIL-STD-721 Definition of Terms for Reliability Engineering

MIL-STD-806 Graphic Symbols for Logic Diagrams

3.5 TECHNICAL MANUALS

NAVSEA 0916-LP-003-7010 9000 Pound Weapons and Cargo Elevators No. 1 - No. 6 USS CAMDEN AOE-2 (Volume 2 Electrical)

NAVSEA 0916-LP-045-6010 Cargo Elevator No. 7 Frame 174-177 Centerline, USS SACRAMENTO AOE-7, USS CAMDEN AOE-2

NAVSEA 0978-LP-062-7030 USS KITTY HAWK (CV63) 10,500 Pounds Lower Stage Weapons Elevator No. 6 Frame 173-178 Port (3 Volumes)

NAVSEA 0978-LP-064-4010 USS CONSTELLATION (CV64) 10,500 Pounds Lower State Weapons Elevator No. 3, Frame 84-89 Port (Three Volumes)

NAVSHIPS 0978-057-9010 SIMM Technical Manual of Operation and Maintenance for USS KITTY HAWK (CVA63) Lower Stage Elevator 3 with Tray Loader

DEC-14-GGZC-D PDP-14 Users Manual (Digital Equipment Corporation)

DEC-14-HGZB-D PDP-14 Maintenance Manual (Digital Equipment Corporation)

3.6 MISCELLANEOUS

Controller Development Proposal (Naval Weapons Support Center)

Development System for a General Purpose Controller (Naval Weapons Support Center)

Preliminary Technical Manual, Standard Electronic Module Control System (Naval Weapons Elevator Support Center)

SEM Elevator Controller Evaluation and Report (Puget Sound Naval Shipyard)

Unpublished Data - Design of the Microprocessor Based SEM General Purpose Programmable Controller (Naval Weapons Support Center)

4.0 ORGANIZATIONS CONTACTED

Many organizations were contacted to obtain information for this study. The organizations contacted included 32 Codes in 19 Navy organizations, 24 control equipment manufacturers, the Editor of a trade magazine, a Professor at a Technical Institute, an Engineering Society, and a large user of the PDP-14 controller and other Programmable Controllers (PC). The Navy contacts are listed in Table 4.1, the equipment manufacturers are listed in Table 4.2, the miscellaneous contacts are listed and discussed below:

<u>Control Engineering</u>: E. J. Kompass, Chief Editor

Control Engineering is a trade magazine published monthly by Technical Publishing Company. Mr. Kompass has been following the development of PC's since they were first introduced in response to a one page requirement specification sent to industry by General Motors in 1968. Mr. Kompass provided valuable background information and suggested that Professor Taebel at the General Motors Institute and E. Simon at The Engineering Society of Detroit be contacted for further information.

<u>General Motors Institute</u>: Professor T. Taebel

Professor Taebel has been active in the philosophy, design and application of PC's and has written several articles on the subject. He provided an excellent overview of some of the problems of PC's and suggested that M. Sottomayer of the GM Hydramatic Division be contacted for further information.

<u>The Engineering Society of Detroit</u>: E. Simon

The society has sponsored an annual PC Conference since 1972. E. Simon provided selected papers given at those conferences.

<u>Hydramatic Division of General Motors</u>: M. Sottomayer

Mr. Sottomayer provided specific information relative to the difficulties of maintaining PC's with regular plant electricians. His experience has been that repeated intensive training of electricians is required.

ORGANIZATION	CODE	PERSONNEL	MAJOR SUBJECT(S)
CNTT	81	Cmdr. Taylor	Proposed Weapon Elevator Training Plan
	N332	W. Lehto	Proposed Weapon Elevator Training Plan
	N334	Lt. Ham	*EM Capability, EM Training*
CV 60 (Saratoga)	Weap. Dept.	Cmdr. Hahn and Staff	EM Capability, PDP-14 Controller
	Ops. Dept.	Lt. Bagley, CWO2 Donnelly	Data Systems Technician (DST) Capability
	Elec. Dept.	EMC Romano and Staff	EM Capability, Relay and PDP-14 Controllers
CV 69 (Eisenhower)	Weap. Dept.	Cmdr. Gloeckner and Staff	EM Capability, Static Logic Controller
	Elec. Dept.	Enlisted Personnel	EM Capability, Static Logic Controller
DESC	ECS	N. Hauck, J. Dennis	Qualification of MIL-M-38510 Microcircuits
NAVELEX	5045	J. Wyatt	SEM (MIL-M-28787) and Microcircuit (MIL-M-38510) *Programs*
NAVMAT	09M3	H. Anderson	Life Cycle Cost Procedures
NAVPERS	5E	Cmdr. Davis	EM Training
	2102	Lt. Jennings	EM On-Job-Training and Advancement
	21213	Lt. George	EM On-Job-Training
	2123	Cmdr. Romanski	Enlisted Personnel Test Battery
NNSY	51	W. Ownby	EM Capability, PDP-14 Controller
	271	S. D'Antoni	PDP-14 Controller
NAVSEA	PERA(CV)	E. Perez, J. Williams	General Study Information

TABLE 4.1 — LIST OF NAVAL ORGANIZATIONS CONTACTED (CONTINUES)

ORGANIZATION	CODE	PERSONNEL	MAJOR SUBJECT(S)
NAVSEA (cont)	CENLANT	M. Oakley	EM Capability; Relay, Static Logic and PDP-14 Controllers
	CENPAC	R. Simpkins	EM Capability; Relay, Static Logic and PDP-14 Controllers
	01G2	J. Fetchko	Life Cycle Cost Procedures
	04G1	R. Dangel	Life Cycle Cost Procedures
	047C14	N. Skoog	Proposed Weapon Elevator Training Plan
	942W	D. Chang	Weapon Elevator Maintenance Training
	PMS 392	J. Faull	Weapon Elevator Maintenance Training
NRL	5210	Dr. Davey, G. Nelson	Future Digital Logic Interfaces
NTC	SSC 30	Lt. Gott	EM Training, ROM/Encoder Course
NTTC	N72	Chief Burrow	Underway Replenishment (UNREP) School
NWESA	84	J. Bartholomew	Life Cycle Cost Procedures
NWSC	3074	D. Winkler, R. Price	MSEM General Purpose Controller Information
	30713	D. Brown, S. Rapp	Reliability and Qualification of SEM (MIL-M-28787)
PSNS	2701	F. Mapes, D. Osgood, W. Radke, B. Dopheide	IWHS Elevator Design, EM Capability; Relay, Hybrid Relay, Static Logic, and PDP-14 Controller Design

TABLE 4.1 — LIST OF NAVAL ORGANIZATIONS CONTACTED (CONTINUED)

NO.	COMPANY	PROG. CONT.	LOGIC MOD.	OTHER
		EQUIPMENT		
1.	Allen-Bradley	x	x	
2.	Applied Systems Corporation	x		
3.	Automatic Timing & Controls Company		x	
4.	Cincinnati Milacron	x		
5.	Control Logic, Inc.		x	
6.	Cutler-Hammer		x	
7.	Digital Equipment Corporation	x	x	
8.	Dynage, Inc.	x		
9.	Ebert Engineering Company	x	x	
10.	Fisher Controls	x		
11.	General Electric Company	x	x	
12.	General Equip. & Manu. Co., Inc.			Prox. SW.
13.	Giddings & Lewis Electronics Co.	x		
14.	Gould, Modicon Division	x		
15.	Gulf & Western, Eagle Signal Division	x		
16.	Industrial Solid State Controls, Inc.	x		
17.	Kinetic Systems Corporation		x	
18.	Reliance Electrical	x		
19.	Research Inc.	x		
20.	Struthers-Dunn, Inc.	x		EM & SSR Relays
21.	Teledyne Relays			EM & SSR Relays
22.	Tenor Company, Inc.	x		
23.	Texas Instruments	x		
24.	Westinghouse	x		

TABLE 4.2 — LIST OF CONTROL EQUIPMENT MANUFACTURERS CONTACTED

5.0 BASELINE IWHS AUTOMATIC CONTROLLER REQUIREMENTS

A required equipment function can normally be met by two or more design approaches that differ significantly with respect to criteria other than their functional performance. Typical examples of such criteria are cost, reliability, maintainability, etc. A specification of the required functional performance and certain design features or attributes can be stated in a manner that allows a design approach (concept) to be developed into a specific design with a significant amount of latitude. If the design approaches have been previously demonstrated with respect to functional performance, the selection of the preferred design approach to be developed can be accomplished by comparing them with respect to other criteria.

Because a functional requirements document for the Automatic Control[illegible]HS elevator had not previously been generated, NRL, with [illegible] obtained from the Puget Sound Naval Shipyard (PSNS), developed this specification entitled "Baseline Requirements Specification for the Automatic Controller Portion of a Control System for the IWHS Elevator".

5.1 IWHS ELEVATOR CONTROL SYSTEM

The IWHS Elevator Control System consists of a Motor Controller (MC), a Manual Controller, an Automatic Controller (AC) and Door Control Circuits. The Motor Controller controls the main electrical power to the hoist motor. In the NORMAL automatic mode the MC monitors several safety circuits such as "All Doors Closed," "Up/Down Overtravel," "Over-speed Governor," etc., and provides the AC with a "Safety Circuits" signal that permits operation of the AC. When the AC is not working or the "Safety Circuits" signal is not present, the elevator platform may be operated by placing the control system in the "MANUAL-EMERGENCY" mode. Certain switches, but not the "All Doors Closed" switch, that normally constitute the safety signal may be bypassed at the MC; then the elevator may be manually operated by "Jogging" with the Manual Controller. In either mode, a door at a given level may be opened only when the elevator platform is at that level, and both modes require that all doors be closed before the platform may be moved. The AC provides the capability to automatically dispatch the platform between levels and to sequence the main deck and third deck hatches as required, and to dispatch/call the elevator to/ from the stow level by controls located at the second deck control station.

The Automatic Controller (AC) is composed of two equipment groups. The first group, referred to as the External Input/Output Devices (EIOD), includes the pushbuttons, limit switches, proximity sensors, indicator lamps, hydraulic solenoid valves, and alarm bells necessary to sense and control an IWHS Elevator. The second group of equipment is referred to as the Logic/Drive Unit (LDU). The LDU senses the signals from the input devices of the EIOD, performs the logical functions to safely control the elevator, and provides the power amplification to drive the output device of the EIOD. Figure 5.1 illustrates a block diagram of the IWHS Elevator Control System.

5.2 PURPOSE OF SPECIFICATION

The purpose of this specification is to identify the requirements of a typical IWHS Elevator Automatic Controller (AC) in order to evaluate candidate design approaches. The specification is intended to be utilized only for this study; however, it could serve as the starting basis for the generation of an "official" requirements specification. The utility of the requirements specification is that it states: the environment within which the AC must be able to operate, the interfaces the AC has with the rest of the IWHS Elevator System, the interface with the designated maintenance personnel, the required operation performance, the required failsafe provisions, the operability of the AC in terms of reliability-maintainability-supportability, and the required design and construction features of the AC.

5.3 APPLICABLE DOCUMENTS

5.3.1 MIL-STD-167	Mechanical Vibrations of Shipboard Equipment
5.3.2 NAVPERS 18068D	Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards
5.3.3 MIL-HDBK-217B	Reliability Prediction of Electronic Equipment

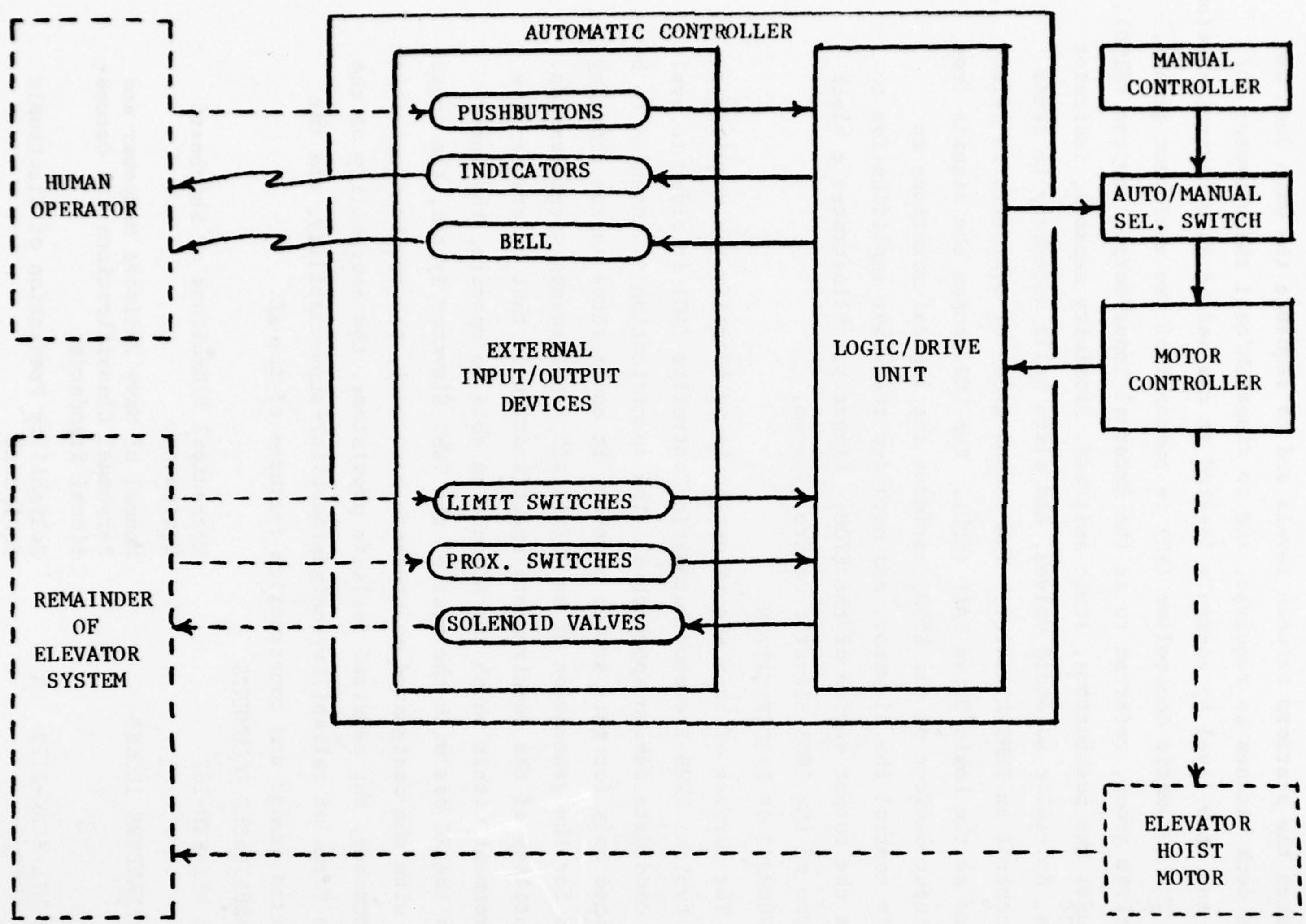

FIGURE 5.1 IWHS ELEVATOR CONTROL SYSTEM AND INTERFACE

5.3.4 MIL-STD-721	Definition of Terms for Reliability Engineering
5.3.5 MIL-STD-806	Graphic Symbols for Logic Diagrams
5.3.6 MIL-H-24148 (Ships)	Human Engineering Requirements for NAVSHIPS Systems and Equipment

5.4 ENVIRONMENTS

5.4.1 PHYSICAL ENVIRONMENT

5.4.1.1 The AC shall be capable of operating continually in an ambient temperature range of 0-50°C.

5.4.1.2 The AC shall be capable of operating continually in an ambient relative humidity of 95%.

5.4.1.3 The AC should be designed for <u>TBD</u> shock levels normally encountered in an industrial environment.

5.4.1.4 The AC shall be capable of operating in the presence of the vibration levels, up to 33 Hertz, specified by MIL-STD-167.

5.4.2 ELECTRICAL ENVIRONMENT

The AC shall be capable of operating in the presence of electrical transients on the 110 VAC nominal line having an amplitude less than 12% and a duration less than 0.5 seconds. This requirement is valid even when the 110 VAC line is experiencing a slow variation 10% below its nominal value.

5.4.3 ELECTROMAGNETIC ENVIRONMENT

The electromagnetic interference requirements for the AC are: <u>To Be Determined</u> (TBD).

5.5 SYSTEM INTERFACE

5.5.1 PHYSICAL INTERFACE

5.1.1.1 The LDU shall be installable in a NEMA 12 type enclosure. The utilized space inside the enclosure shall be limited to:

Height: 56 inches
Width: 30 inches
Depth: 8 inches

5.5.1.2 The hoist motor can operate at either of two speeds. The two loaded speeds and the corresponding rates of elevator platform travel are:

a) High Speed 1700 RPM 125 FT/MIN
b) Low Speed 260 RPM 19 FT/MIN

5.5.1.3 The average distance between levels is 10 feet.

5.5.1.4 The main deck and third deck hatches take 15 seconds (nominal) to open or close from the opposite condition.

5.5.1.5 The "Pull In" and the "Drop Out" time of the high speed contactor in the motor controller is 0.016 seconds (nominal).

5.5.1.6 The "Pull In" and the "Drop Out" time of the low speed contactor in the motor controller is 0.016 seconds (nominal).

5.5.1.7 The lockbars take 3 seconds to extend or retract.

5.5.1.8 The hatches take 3 seconds to Dog or Undog.

5.5.1.9 The hatches take 3 seconds to Latch and Unlatch.

5.5.1.10 The elevator platform takes TBD seconds to come to a full braked stop when traveling at high speed.

5.5.1.11 The elevator platform takes TBD seconds to come to a full braked stop when traveling at low speed.

5.5.1.12 The platform stow position is 3 feet above the second deck.

5.5.2 ELECTRICAL INTERFACE

5.5.2.1 The AC shall receive its electrical power from the motor controller at a nominal level of 110 VAC with slow variations of ± 10%.

5.5.2.2 The LDU shall receive a TBD signal from the motor controller that signifies that the system is safe to operate, i.e., no safety sensors are actuated.

5.5.2.3 The LDU shall receive a TBD signal from the motor controller that signifies that the high speed contactor is actuated.

5.5.2.4 The LDU shall output a power signal to the "Up Contactor" of the motor controller when it is required to move the elevator platform in the upward direction.

5.5.2.5 The LDU shall output a power signal to the "Down Contactor" of the motor controller when it is required to move the elevator platform in the downward direction.

5.5.2.6 The LDU shall output a power signal to the "Low Speed" contactor of the motor controller when it is required to move the elevator platform at low speed.

5.5.2.7 The LDU shall output a power signal to the "High Speed" contactor of the motor controller when it is required to move the elevator platform at high speed.

5.5.2.8 The four power signal signals described above shall be at 115 VAC, the inrush current capability shall be 60 amps, and the holding current capability shall be 3.0 amps.

5.5.3 HUMAN INTERFACE

5.5.3.1 The AC shall be designed so that its preventive and corrective maintenance requirements are compatible with the normal skills of an Electrician's Mate, 2nd Class as defined by section 3-c of NAVPERS 18068D, "Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards."

5.5.3.2 The Technical Manual for the AC shall be written to be compatible with the normal skills of an Electrician's Mate, 2nd Class, and shall be organized for ready access of trouble-shooting information.

5.5.3.3 General purpose tools and test equipment required for the maintenance of the AC shall be those listed in section 3-c of NAVPERS 10868D.

5.5.3.4 Special purpose tools and equipment required for maintenance of the AC shall be discussed in the Technical Manual for the AC.

5.5.3.5 Special attention shall be given to the logic diagrams of the Technical Manual for the AC:

a) The logic diagrams shall identify selected gates to indicate what signals are being processed, to permit efficient trouble-shooting procedures.

b) The logic diagrams shall reflect the systematic build-up of the circuitry. Similar inputs shall be grouped together as well as outputs. Each input and output shall be identified to its purpose and location by decks where applicable.

5.6 PERFORMANCE

5.6.1 FUNCTIONAL PERFORMANCE

5.6.1.1 The AC shall provide for dispatching the elevator from one of eight load/unload levels to any other of the eight load/unload levels.

5.6.1.2 The AC shall provide for automatic sequencing of the main deck and third deck hatches as indicated in Figure 5.2 and Figure 5.3.

5.6.1.3 The AC shall provide for unstowing the platform from the stow position to the second deck; and for stowing the platform at the stow position for the second deck.

5.6.1.4 The AC shall provide for emergency stowing of the platform and closing of the main deck hatch when it is at rest or in motion above the stowage level. The action shall be initiated by an "Emergency Override" pushbutton located at the main deck.

5.6.1.5 The AC shall provide for automatic leveling of the platform in less than TBD seconds when the platform overshoots the destination level.

5.6.1.6 The AC shall cause the lockbars to extend when the platform is stowed, and to retract the lockbars prior to the platform being unstowed.

5.6.1.7 The AC shall provide indications, at the second deck and machinery room control stations, of the level at which the platform is located.

5.6.1.8 The platform shall achieve an alignment with its destination level of plus or minus one quarter inch.

5.6.2 LOGICAL PERFORMANCE

5.6.2.1 The AC shall allow dispatch of the elevator platform only from the load/unload level at which the platform is positioned.

5.6.2.2 The AC shall allow the elevator platform to be stowed and unstowed by stow controls located only at the second deck control station. Stow controls shall permit movement of the platform only between the stow position and the second deck level.

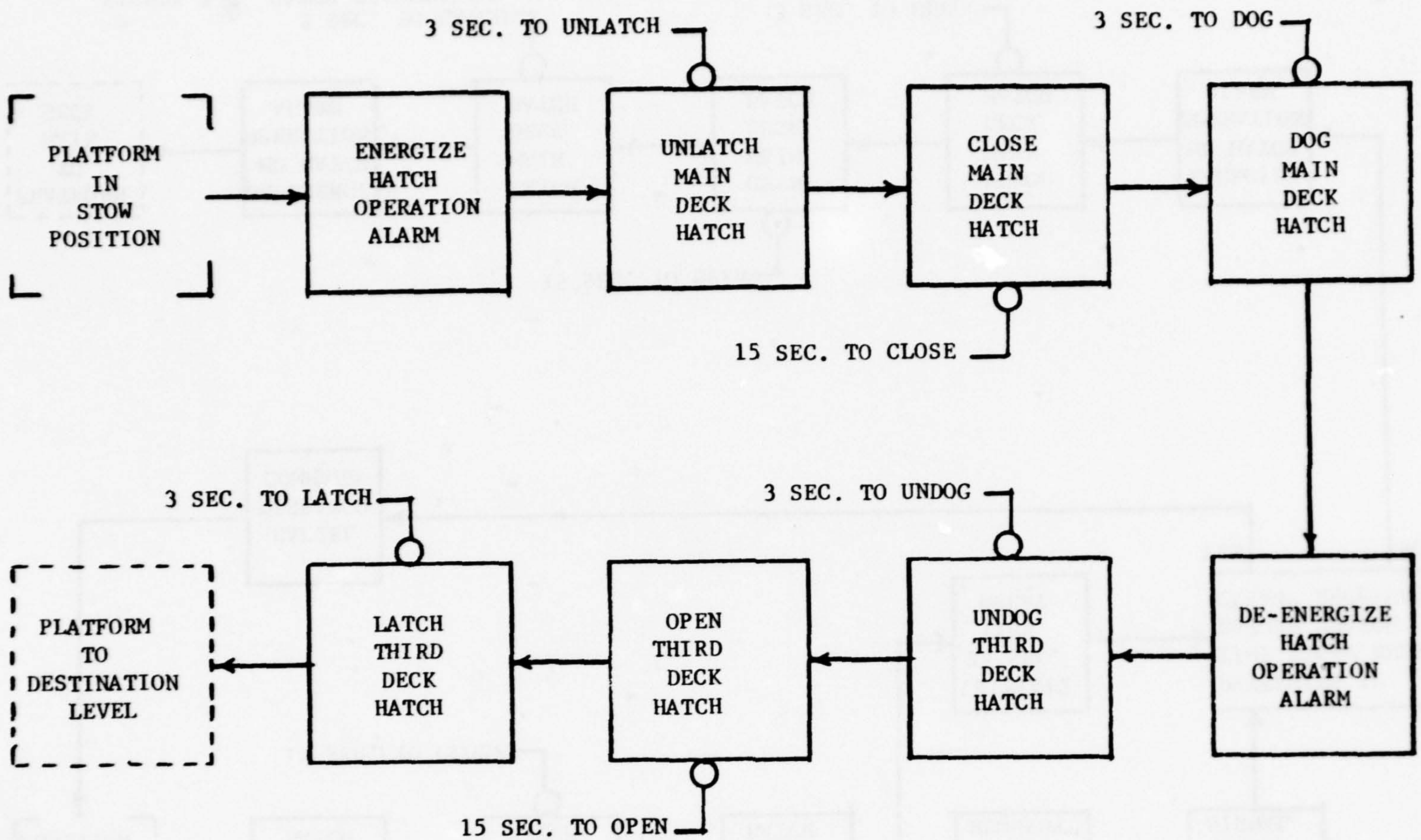

FIGURE 5.2 HATCH SEQUENCE/DOWN (PLATFORM FROM MAIN DECK TO FOURTH DECK OR BELOW)

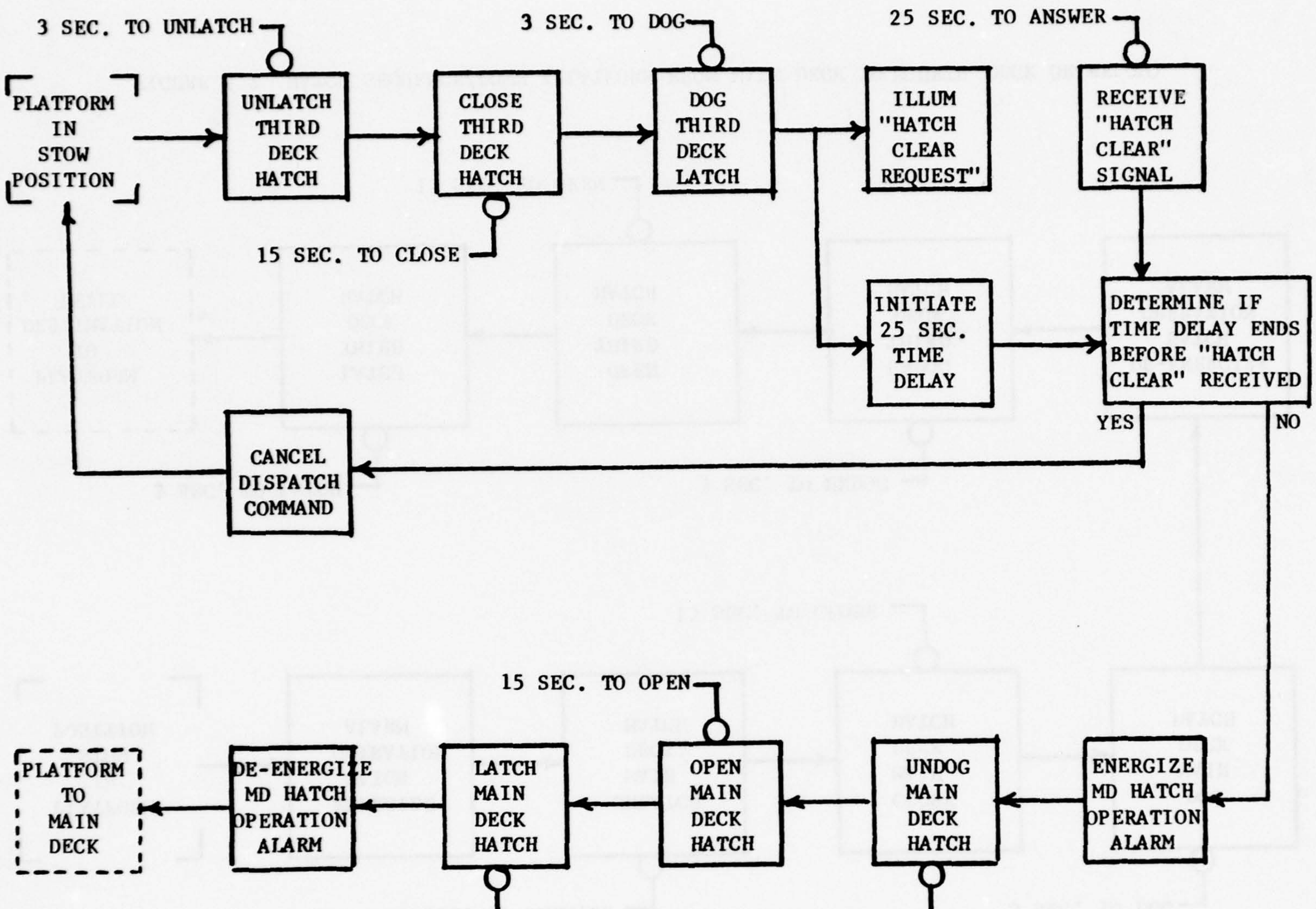

FIGURE 5.3 HATCH SEQUENCE/UP (PLATFORM TO MAIN DECK FROM FOURTH DECK OR BELOW)

5.6.2.3 The AC shall use the stow position as the platform position during hatch sequencing. The platform lockbars shall not be utilized in the hatch sequence position.

5.6.2.4 The AC shall cause dispatch between decks/platforms, but not from the stow level, to commence at high speed.

5.6.2.5 Upon approaching the destination level the AC shall cause the platform to travel at slow speed toward the destination level.

5.6.2.6 The AC shall sense when the platform is within $\pm$ 1/16 inch of the destination level and cause the platform to stop.

5.6.2.7 The AC shall sense when the elevator platform overshoots the level to which it has been dispatched. The AC shall respond by causing the platform to stop, reverse direction at low speed and achieve the required level alignment.

5.6.2.8 The AC shall indicate at the second deck and machinery room control stations when the platform is between two levels by a steady illumination of the indicators for the level above, and the level below, the platform.

5.6.2.9 The AC shall cause the platform to travel at the slow speed to/from the second deck when unstowing/stowing the platform.

5.6.2.10 The AC shall cancel any dispatch order when the platform is at rest or in motion above the stow level and the main deck hatch is not fully closed. The AC shall cause the platform to go to the stowage level at high speed after which the main deck hatch shall be fully closed and dogged, and the platform lockbars extended.

5.6.2.11 The AC shall send the platform to the stow level to permit hatch sequencing when the platform is dispatched to/from the main deck from/to the second deck and lower.

5.6.2.12 The AC shall sequence the main deck and third deck hatches as shown in Figure 5.2 when traveling toward the main deck and as shown in Figure 5.3 when traveling toward the second deck and below. Each succeeding step of the sequence requires successful completion and continuation of the action achieved by each preceding step of the sequence.

5.6.2.13 When electrical power is interrupted in the AC, the AC shall immediately de-energize all outputs. Upon restoration of power the AC shall immediately cancel the dispatch action that was in progress prior to the interruption. If the platform is stopped between levels the "MANUAL-EMERGENCY" mode must be utilized to jog the platform to an adjacent level.

5.6.3 FAILSAFE PROVISIONS

5.6.3.1 It shall not be possible, with the exception of the "Emergency Override" sequence, to initiate a new dispatch until the previous dispatch has been completed.

5.6.3.2 It shall not be possible to initiate the "Emergency Override" sequence when the main deck hatch is already fully closed.

5.6.3.3 It shall not be possible for the elevator platform to travel below the stow position when the third deck hatch is not fully open and latched.

5.6.3.4 It shall not be possible for the elevator platform to travel above the stow position when the main deck hatch is not fully open and latched.

5.6.3.5 It shall not be possible to open the main deck hatch when the third deck hatch is not closed and dogged, or when the safety circuits signal from the motor controller indicates an unsafe condition, or when the "Hatch Clear" signal has not been received.

5.6.3.6 It shall not be possible to close the main deck hatch when the platform is not positioned at the stow position.

5.6.3.7 It shall not be possible to close the third deck hatch when the platform is not positioned at the stow position.

5.6.3.8 It shall not be possible to open the third deck hatch when the main deck hatch is not fully closed and dogged.

5.6.3.9 No single failure of any component of the AC or associated wiring shall result in an accidental operation of the elevator platform or the hatches.

5.6.3.10 No single failure of any component of the AC or associated wiring shall result in complete loss of control of the elevator platform or the hatches.

5.6.4 RELIABILITY

5.6.4.1 The AC shall have a predicted probability of failure over a 24 hour period less than 0.006 when operated at the rate of 0.25 dispatches per hour (6 dispatches per day).

5.6.4.2 The AC shall have a predicted probability of failure over a 24 hour period less than 0.03 when operated at the rate of 6 dispatches per hour (144 dispatches per day).

5.6.4.3 The AC probability of failure shall be predicted on the basis of the environments of Section 5.4.1 of this specification.

5.6.5 MAINTAINABILITY

5.6.5.1 The AC shall have a TBD active Mean-Time-To Repair (MTTR). Active MTTR does not include administrative delay time.

5.6.5.2 The MTTR requirement shall be based on the utilization of the skills of an Electrician's Mate (EM) who has attended the EM Class A school and the EM Class C-7 school.

5.7 DESIGN AND CONSTRUCTION

5.7.1 EXTERNAL INPUT DEVICES

5.7.1.1 Dispatch, permissive and emergency commands momentary pushbuttons shall be used to initiate the 18 commands listed in Table 5.1.

5.7.1.2 Each of the first 14 commands of Table 5.1 shall be available at each of the 8 load/unload elevators with the exception of those commands that correspond to a dispatch to that level, e.g., "To 2D/UP" and "To 2D/DN" need not be available at the second deck (2D).

5.7.1.3 All pushbuttons that provide a given command shall be connected in parallel as indicated in Table 5.2.

5.7.1.4 The 15th and 16th commands of Table 5.1, "To SL from 2D" and "To 2D from SL," shall be located only at the second deck control station.

CMD #	COMMAND FUNCTION	CMD ABBREVIATION
1	DISPATCH ELEVATOR PLATFORM UPWARD TO MAIN DECK	MD/UP
2	" " UPWARD TO SECOND DECK	2D/UP
3	" " DOWNWARD " "	2D/DN
4	" " UPWARD TO FOURTH DECK	4D/UP
5	" " DOWNWARD " "	4D/DN
6	" " UPWARD TO FIRST PLATFORM	1P/UP
7	" " DOWNWARD " "	1P/DN
8	" " UPWARD TO SECOND PLATFORM	2P/UP
9	" " DOWNWARD " "	2P/DN
10	" " UPWARD TO THIRD PLATFORM	3P/UP
11	" " DOWNWARD " "	3P/DN
12	" " UPWARD TO FOURTH PLATFORM	4P/UP
13	" " DOWNWARD " "	4P/DN
14	" " DOWNWARD TO THE HOLD	H/DN
15	" " TO STOW LEVEL FROM SECOND DECK	SL/2D
16	" " TO SECOND DECK FROM STOW LEVEL	2D/SL
17	SIGNIFY THE MAIN DECK HATCH IS CLEAR AND PERMIT THE ELEVATOR PLATFORM TO PROCEED UPWARD FROM THE HATCH SEQUENCE POSITION	HC
18	CANCEL ANY DISPATCH COMMAND IN PROGRESS, SEND THE ELEVATOR PLAT-FROM TO THE STOW POSITION, AND CLOSE THE MAIN DECK	EMERGENCY OVERRIDE

TABLE 5.1 DISPATCH, PERMISSIVE AND EMERGENCY COMMANDS

NO.	DISPATCH COMMAND	PUSHBUTTON LOCATION MAIN DECK	SECOND DECK	FOURTH DECK	FIRST PLATFORM	SECOND PLATFORM	THIRD PLATFORM	FOURTH PLATFORM	HOLD
1	MD/UP		X	X	X	X	X	X	X
2	2D/DN	X							
3	2D/UP			X	X	X	X	X	X
4	4D/DN	X	X						
5	4D/UP				X	X	X	X	X
6	1P/DN	X	X	X					
7	1P/UP					X	X	X	X
8	2P/DN	X	X	X	X				
9	2P/UP						X	X	X
10	3P/DN	X	X	X	X	X			
11	3P/UP							X	X
12	4P/DN	X	X	X	X	X	X		
13	4P/UP								X
14	HOLD/DN	X	X	X	X	X	X	X	
15	UNSTOW		X						
16	STOW		X						
17	HATCH CLEAR	X							
18	EMERGENCY OVERRIDE	X							

TABLE 5.2 LOCATION OF PARALLEL CONNECTED DISPATCH PUSHBUTTONS

5.7.1.5 The 17th and 18th commands of Table 5.1, "Hatch Clear" and "Emergency Override," shall be located only at the main deck control station.

5.7.1.6 Electromechanical limit switches shall be mounted on the main deck and third hatches to signify their dog/undog, open/closed, and latched/unlatched status as indicated in Table 5.3 and Table 5.4.

5.7.1.7 The limit switches shall be in pairs, as indicated by the "#1 and #2" nomenclature of Tables 5.3 and 5.4, and utilized to indicate the same status redundantly.

5.7.1.8 Thirty-two proximity switches, mounted in the elevator shaft in the vicinity of the 8 load/unload levels and the stow level, shall be used to sense when the elevator platform is at the slow and stop positions given in Table 5.5.

5.7.1.9 Four proximity switches, mounted on the elevator platform, shall be used to indicate the status of the platform lockbars. Two redundant switches shall indicate when the lockbars are retracted.

5.7.2 EXTERNAL OUTPUT DEVICES

5.7.2.1 Twelve hydraulic solenoids shall be driven by the Logic/Drive Unit to control the dog/undog, open/close, latch/unlatch action of the second and third deck hatches as indicated in Table 5.6.

5.7.2.2 Two hydraulic solenoids shall be driven by the Logic/Drive Unit to control the extend/retract action of the platform lockbars as also indicated by Table 5.6.

5.7.2.3 The fourteen hydraulic solenoids shall require 115 VAC excitation, 5 amps inrush current, and 0.5 amps holding current.

5.7.2.4 Indicator lights shall be provided at the second deck control station and in the elevator machinery room to indicate the elevator status listed in Table 5.7.

5.7.2.5 The two indicator lights, one in each location, indicating a given elevator status shall be connected in parallel and driven by the Logic/Drive Unit. Each pair of lights shall require no more than 0.1 amperes at 115 VAC.

LIMIT SWITCH #	LIMIT SWITCH FUNCTION	L.S. ABBREVIATION
1	INDICATE THAT THE MAIN DECK HATCH IS DOGGED	MDHD #1
2	" "	MDHD #2
3	INDICATE THAT THE MAIN DECK HATCH IS UNDOGGED	MDHUD #1
4	" "	MDHUD #2
5	INDICATE THAT THE MAIN DECK HATCH IS OPEN	MDHO #1
6	" "	MDHO #2
7	INDICATE THAT THE MAIN DECK HATCH IS CLOSED	MDHC #1
8	" "	MDHC #2
9	INDICATE THAT THE MAIN DECK HATCH IS LATCHED	MDHL #1
10	" "	MDHL #2
11	INDICATE THAT THE MAIN DECK HATCH IS UNLATCHED	MDHUL #1
12	" "	MDHUL #2

TABLE 5.3 MAIN DECK HATCH STATUS INDICATOR SWITCHES

LIMIT SWITCH #	LIMIT SWITCH FUNCTION	L.S. ABBREVIATION
1	INDICATE THAT THE THIRD DECK HATCH IS DOGGED	3DHD #1
2	" "	3DHD #2
3	INDICATE THAT THE THIRD DECK HATCH IS UNDOGGED	3DHUD #1
4	" "	3DHUD #2
5	INDICATE THAT THE THIRD DECK HATCH IS OPEN	3DHO #1
6	" "	3DHO #2
7	INDICATE THAT THE THIRD DECK HATCH IS CLOSED	3DHC #1
8	" "	3DHC #1
9	INDICATE THAT THE THIRD DECK HATCH IS LATCHED	3DHL #1
10	" "	3DHL #2
11	INDICATE THAT THE THIRD DECK HATCH IS UNLATCHED	3DHUL #1
12	" "	3DHUL #2

TABLE 5.4 THIRD DECK HATCH STATUS INDICATOR SWITCHES

PS#	POSITION SENSING FUNCTION
1	MAIN DECK UP SLOW
2	" " UP STOP
3	STOW LEVEL UP SLOW
4	" " UP STOP
5	" " DOWN SLOW
6	" " DOWN STOP
7	SECOND DECK UP SLOW
8	" " UP STOP
9	" " DOWN SLOW
10	" " DOWN STOP
11	FOURTH DECK UP SLOW
12	" " UP STOP
13	" "" DOWN SLOW
14	" " DOWN STOP
15	FIRST PLATFORM UP SLOW
16	" " UP STOP
17	" " DOWN SLOW
18	" " DOWN STOP
19	SECOND PLATFORM UP SLOW
20	" " UP STOP
21	" " DOWN SLOW
22	" " DOWN STOP
23	THIRD PLATFORM UP SLOW
24	" " UP STOP
25	" " DOWN SLOW
26	" " DOWN STOP
27	FOURTH PLATFORM UP SLOW
28	" " UP STOP
29	" " DOWN SLOW
30	" " DOWN STOP
31	HOLD DOWN SLOW
32	" " STOP

TABLE 5.5 PROXIMITY SWITCH INDICATORS OF THE ELEVATOR PLATFORM POSITION

SOLENOID #	HYDRAULIC SOLENOID FUNCTION	SOL. ABBREVIATION
1	UNLATCH THE MAIN DECK HATCH	MDHUL SOL
2	LATCH " "	MDHL SOL
3	CLOSE " "	MDHC SOL
4	OPEN " "	MDHO SOL
5	DOG " "	MDHD SOL
6	UNDOG " "	MDHUD SOL
7	UNLATCH THE THIRD DECK HATCH	3DHUL SOL
8	LATCH " "	3DHL SOL
9	CLOSE " "	3DHC SOL
10	OPEN " "	3DHO SOL
11	DOG " "	3DHD SOL
12	UNDOG " "	3DHUG SOL
13	EXTEND THE PLATFORM LOCKBARS	PLBE SOL
14	RETRACT THE PLATFORM LOCKBARS	PLBR SOL

TABLE 5.6 HYDRAULIC SOLENOID CONTROL FUNCTIONS

IND. #	INDICATOR FUNCTION	IND. ABBREV.
1	INDICATE ELEV. PLATFORM IS AT THE MAIN DECK	MD IND
2	" " STOW LEVEL	SL IND
3	" " SECOND DECK	2D IND
4	" " FOURTH DECK	4D IND
5	" " FIRST PLATFORM	1P IND
6	" " SECOND PLATFORM	2P IND
7	" " THIRD PLATFORM	3P IND
8	" " FOURTH PLATFORM	4P IND
9	" " HOLD	H IND
10	" " STOW LEVEL AND READY TO PROCEED TO THE MAIN DECK, BUT NEEDS A PERMISSIVE SIGNAL FROM THE MAIN DECK OPERATOR TO SIGNIFY THE MAIN DECK	HCR IND
11	INDICATE THAT THE MAIN DECK HATCH IS OPENING OR CLOSING	MDHA BELL

TABLE 5.7 INDICATOR FUNCTIONS FOR THE ELEVATOR POSITION AND STATUS

5.7.2.6 A bell shall be located in the vicinity of the main deck hatch to give an alarm that the main deck hatch is in the process of opening or closing. The alarm bell shall be driven by the Logic/Drive Unit and shall require no more than 0.5 amperes at 115 VAC.

5.7.3 LOGIC/DRIVE UNIT (LDU)

5.7.3.1 The total weight of the LDU, not including the enclosure, shall be less than 500 pounds.

5.7.3.2 The weight of an individual Line Replaceable Unit of the LDU shall be less than 25 pounds.

5.7.3.3 The electrical power required by the LDU shall be less than TBD watts.

5.7.3.4 The LDU shall incorporate a 10,000 hour, non-resetting, elapsed time meter.

5.7.3.5 The LDU design shall provide sufficient design margins to compensate for normal production spread tolerances, aging, and temperature conditions.

5.7.3.6 The LDU components shall not be potted unless the potting is necessary to meet an environmental condition. If a component is potted, the potting shall be easily removable with tools and/or solvents normally included in ship supplies.

5.7.3.7 The LDU shall be designed so that Line Replaceable Units (LRU) may be removed without requiring disassembly of other LRU's.

5.7.3.8 The LDU shall provide the means to monitor the condition of all inputs and outputs and the status of important logic points within the logical portion of the controller.

5.7.3.9 The LDU design shall provide shielding and filtering of all inputs and outputs to reduce electromagnetic interferences that could cause unscheduled operation of the controller.

5.7.3.10 The LDU shall use transformers to isolate rectifier power supplies to prevent having a common circuit path with the supply lines.

5.7.3.11 High impedance and low impedance circuits of the LDU shall not be connected as to allow interaction, but shall be appropriately buffered.

5.7.3.12 High speed switching devices in the LDU shall be protected from the effects of ringing or inductive voltage spikes.

5.7.4 MAINTAINABILITY DESIGN PRINCIPLES

The Automatic Controller (AC) shall be designed, to the maximum extent possible, in accordance with the following maintainability design principles:

1) Complexity of maintenance shall be reduced by:
   a) Providing adequate accessibility, work space and work clearance.
   b) Providing for interchangeability of like components, materials and parts within the system/equipment.
   c) In choosing components for design, first choice shall be given to components that are readily available. The number of parts peculiar on a government stocking, or industrial stocking basis shall be kept to a minimum.
   d) Minimizing the number of variety of tools, accessories and support equipment.
2) Need for and frequency of design-dictated maintenance activities shall be reduced by using:
   a) Components which require little or no preventive maintenance.
   b) Tolerances which allow for use and wear throughout life.
   c) Adequate corrosion prevention/control features.
3) Maintenance downtime shall be reduced by designing for:
   a) Rapid and positive detection of malfunction or degration.
   b) Rapid and positive isolation of malfunctions.
   c) Ease of fault correction.
   d) Rapid and positive adjustment and calibration
   e) Rapid and positive verification of correction.

4) Design-dictated maintenance support costs shall be reduced by minimizing:
   a) The need for specialized maintenance tools, support equipment and facilities.
   b) The requirements for depot or factory maintenance, consistent with system/cost effectiveness.
5) Maintenance personnel requirements shall be minimized by applying human engineering principles including:
   a) Provision for identification and accessibility of parts, test points, adjustments and connections.
   b) Provision for case of handling, mobility, transportability and storability.
   c) Specification of logically sequenced maintenance tasks.
6) Potential for maintenance error shall be reduced by designing to eliminate:
   a) The possibility of incorrect connection/assembly/installation.
   b) Dirty, awkward, and tedious job elements.
   c) Ambiguity in maintenance labeling, coding and technical data.
7) Labeling, nameplate content and positioning, equipment-mounted circuit diagrams, and operating instructions shall be engineered for ready understanding and shall be placed in logical relationship to the parts of the equipment to which they refer.
8) Clearly identified and easily accessible test points shall be provided for all measurement points required by the trouble-shooting manual.
9) Guides and sockets for removable plugs and circuit boards shall be designed for easy multiple removal and replacement without jamming, distorting, or suffering undue wear.

6.0 MAINTENANCE PERSONNEL CAPABILITIES

An equipment possesses certain design features which affect its maintainability. Another factor that effects the equipment maintainability is the match between the equipment and the type and level of skills possessed by the personnel assigned to maintain the equipment. For shipboard elevator controllers, the assigned Enlisted Rate is the Electrician's Mate (EM). The general capabilities of the EM is defined here in this study to serve as a baseline against which to compare the applicable design features of the various design approaches for the IWHS Elevator Automatic Controller.

The capabilities of an individual are a function of his innate intelligence, the knowledge he has gained from training and work experience, and his motivation. This study, of necessity, focuses only on his knowledge. The training of an individual is accomplished by On-The-Job-Training (OJT) and by attending various service schools and by information contained in Rate Training Manuals. OJT can be informal in nature,e.g., the individual is trained by a more experiencedindividual, or it can be formal in nature, e.g., courses are taught on the ship by equipment manufacturers representatives or by Navy support group personnel. Examples of Navy support groups are NAVSEACENLANT, NAVSEACENPAC, Puget Sound Naval Shipyard, Norfolk Naval Shipyard, etc. Applicable service schools for the EM are the EM Class A School (Course A-662-0016), the EM Class C-7 School (Course A-662-0017),and appropriate Class C Schools such as the ROM/Encoder School (Course A-690-0018). The Rate Training Manual for the EM 3 and 2 is NAVEDTRA 10546-0.

The conventional typesof elevator controllers used by the Navy are relay controllers and static logic controllers. The present IWHS Controller, a programmable controller type, is defined here as an unconventional controller. Accordingly the maintenance capabilities of the EM aredefined with respect to conventional controllers and unconventional controllers.

6.1 CAPABILITIES FOR MAINTAINING CONVENTIONAL CONTROLLERS.

Prior to 1 October 1978 the EM Class A School was 8.6 weeks in duration, consisting of a combined total of approximately 258 hours of classroom instruction and laboratory exercises. It has been estimated that 48 hours of the training is effective in preparing the EM to perform maintenance on conventional elevator controllers. Prior to the same date the EM Class C-7 School was 26 weeks in duration, consisting of a combined total of approximately 780 hours of classroom and laboratory time. It has also been estimated that 120 hours of the training is effective in preparing the EM to perform maintenance on elevator controller. From these figures, it is seen that 16% of the total training is effective in preparing the EM for elevator controller maintenance. Relay and static logic controllers are presented in the two above courses. Similarily a review of the Rate Training Manual for the Electrician's Mate 3 & 2 (NAVEDTRA 10546-D) for general and specific information relating to relay and static logic controllers has resulted in an estimate that 15% of the manual information is effective in informing the EM in how to maintain conventional controllers.

A review of Section 1 of NAVPERS 18068D, which defines the occupational standards for Enlisted Rates, indicates that the EM is expected to be able to maintain controllers. NAVPERS 18068D does not distinguish between conventional and unconventional controllers except to indicate that Navy Enlisted Classifications (NEC's) are given when certain specialized equipment is involved. There is no NEC for the PDP-14 controller. The portion of NAVPERS 18068D that deals with the EM is reproduced in Appendix D of this report.

The Navy Occupational Task Analysis Program (NOTAP), Department of the Navy Occupational Development and Analysis Center (NODAC), has recently completed a task inventory of a representative sampling of the EM's. A subset of that task inventory (See Appendix H) includes responses from 263 EM's, in pay grades E2 to E9 stationed on CV's 59, 62, 63 and 64. The response from those EM's indicate that 140 (53.7%) of the 263 EM's work on controllers, and that those 140 EM's spend 8.6% of their time on controllers. The 8.6% corresponds to an equivalent of 12 EM's working full time on the four aircraft carriers or an average of 3 per carrier. If the total of 263 EM's is considered, it is seen that 4.6% of the total EM time is spent on controllers. A comparison of the 8.6%.

and 4.6% performing figures with the 16% effective controller training figure suggests that sufficient relative time is devoted to training the EM to maintain conventional controllers.

Discussions with cognizant personnel at NAVSEACENLANT, NAVSEACENPAC, Norfolk Naval Shipyard, and Puget Sound Naval Shipyard indicates that the EM is sufficiently capable of maintaining the Relay and Static Logic type of controllers. Additional conversations with Weapons Officers and EM's aboard one of the six aircraft carriers having Relay and PDP-14 Controllers, and one aircraft carrier having Static Logic Controllers indicates the Weapons Officers, and EM's themselves, see the EM as sufficiently capable of maintaining Relay and Static Logic Controllers.

6.2 CAPABILITIES FOR MAINTAINING UNCONVENTIONAL CONTROLLERS

The present IWHS Elevator Controller, the PDP-14, is considered an unconventional controller because it is significantly different in operation from the relay and static logic controllers. Its major point of difference is that it is a digital computer-like device. The PDP-14 was introduced about March of 1969 by the Digital Equipment Corporation (DEC). DEC was then, and still is, a well known manufacturer of small computers. The PDP-14, like a computer, has input/output interfaces, a control unit, and a memory. It differs from a general purpose computer mainly in that it uses a fixed non-volatile memory and has a very limited instruction set. It performs logical operations but does not have arithmetic capability.

The only ships on which the EM has been exposed to the PDP-14 is on the six Aircraft Carriers, CV59 through CV64. Of the approximately 15 weapons elevators on each of the six aircraft carriers, only the two IWHS Elevators per carrier have the PDP-14 controller. The USS Saratoga (CV60) presently has only one IWHS Elevator installed, the remaining one is to be installed during its Ship Life Extension Program (SLEP) yard period.

The EM Class A and Class C-7 schools do not prepare the EM to work on a digital Computer-Like Controller (CLC), and the EM rate training manual does not contain information relative to a CLC. The occupational standards for the EM (See Appendix D) do not indicate the EM should be qualified to work on CLC's, and an EM Navy Enlisted Classification (NEC) for CLC's has not been assigned.

Training to prepare the EM to maintain the PDP-14 controller is presently being accomplished by attendance at the ROM/Encoder School at the Service School Command, Naval Training Center, Great Lakes, Illinois. The two week course is given in 60 hours of combined classroom instruction and laboratory exercise time. As of 1 October 1978, 13 EM's have completed the course. The 60 hours of training just for one type of controller compares very favorably with the 120 hours of combined training in the EM Class A school and Class C-7 school for conventional controllers. Additional On-The-Job-Training is provided by NAVSEACENLANT and Norfolk Naval Shipyard on the East Coast, and NAVSEACENPAC and Puget Sound Naval Shipyard on the West Coast.

The six aircraft carriers in question have approximately 15 weapons elevators per carrier for a total of 90 elevators. Of those 90 elevators, 11 (12%) are the IWHS Elevators having the PDP-14 controller. Recall from section 6.1 that 140 EM's spent 8.6% of their time on all controllers. Assuming that they work only on weapons elevators controllers and spend their time equally on all controllers, it is seen that they would spend only 1% (.086 x .12 x 100) of their time on PDP-14 controllers. The obvious problem with such a low percentage is their knowledge gained in training is not used often enough, and is soon lost.

It could be argued that the 8.6% of the 140 EM's that work on controllers could be 12 dedicated EM's that work only on PDP-14 controllers. However, discussions with EM's aboard an aircraft carrier having the PDP-14 controller indicated that certain EM's are not dedicated to the PDP-14 controllers even when they are having problems. Four of the 13 EM's that attended the ROM/Encoder Course were from that aircraft carrier. Of the EM's on that ship that stated they worked on the PDP-14 controller, only one had attended the course. That EM stated that he did not spend most of his time on the PDP-14 controller.

Discussions with cognizant personnel at NAVSEACENLANT, NAVSEACENPAC, Norfolk Naval Shipyard, and Puget Sound Naval Shipyard indicates that with some exceptions, the EM is not sufficiently capable of maintaining the PDP-14 type of controller. Additional discussions with the Weapons Officers and the EM's aboard one of the six aircraft carriers in question, indicate that they do not think the EM is sufficiently capable of maintaining the PDP-14 controller. There is general agreement that given better/more training and better technical manuals, the EM is potentially capable of maintaining the controller i.e. the EM is sufficiently intelligent.

7.0 DEFINITION OF THE CANDIDATE AUTOMATIC CONTROLLER DESIGN APPROACHES

The Automatic Controller consists of two equipment groups as discussed in the baseline requirements specification of Section 5.0. The two equipment groups are: the External Input/Output Devices (EIOD) group, and the Logic/Drive Unit (LDU) group. The EIOD hardware is completely specified in the baseline requirements specification, thus the EIOD group is common to all the design approaches that were considered. Strictly speaking the design approaches are for the LDU which was specified only in terms of requirements.

Initially the design concepts considered for the Logic/Drive Unit (LDU) of the Automatic Controller included the present PDP-14 Controller, other commerical Programmable Controllers similar to the PDP-14, the Navy General Purpose Programmable Controller based on the use of the Navy Standard Electronic Modules (SEM), Static Logic Controllers functionally similar to the Cutler-Hammer Direct Static Logic (DSL) and the General Electric Static Control (SC), Electromagnetic (EM) Relay Controllers functionally similar to those used on the majority of shipboard elevators, and Hybrid Relay Controllers using a combination of EM Relays and Solid State Relays (SSR). The PDP-14 Controller was quickly eliminated from any further consideration since it was the source of the present controller problem, it is difficult for the assigned enlisted rate to maintain, and it is no longer in production.

Consideration of the above mentioned initial design concepts lead to the selection of six candidate design approaches for further evaluation. The selected design approaches for the LDU are presented in the following paragraphs. An estimate of the type and number of components required for each of the six design approaches for the LDU is given in Table 7.1.

7.1 REGULAR EM RELAY LDU

This design approach utilizes Low Power (signal level) Electromagnetic (EM) Relays to sense inputs, perform logical functions, and to drive low power outputs such as indicator lamps. Time delay EM Relays are also utilized to provide fixed time intervals. High Power

NO.	COMPONENT	RELAY REGULAR	RELAY HYBRID	STATIC LOGIC	PROGRAMMABLE CONTROLLER NON-LSI	PROGRAMMABLE CONTROLLER 8080	PROGRAMMABLE CONTROLLER 9900
1	LOW POWER EM RELAY (3PDT)	82	82	0	0	0	0
2	LOW POWER EM RELAY (SPST)	11	11	0	0	0	0
3	HIGH POWER EM RELAY (SPST)	18	0	1	1	1	1
4	SOLID STATE RELAY (SPST)	0	18	29	29	29	29
5	*TIME DELAY EM RELAY (DPDT)*	2	2	0	0	0	0
6	LIGHT EMITTING DIODE	113	113	113	113	113	113
7	DC/DC CONVERTER	0	0	82	82	82	82
8	SSI LOGIC CHIP (10 GATE)	0	0	49	25	25	25
9	MSI LOGIC CHIP (100 GATE)	0	0	0	10	5	5
10	SSI TIMER	0	0	2	10	10	10
11	LSI CHIP (8080 μ PROCESSOR)	0	0	0	0	1	0
12	VLSI CHIP (9900 μ PROCESSOR)	0	0	0	0	0	1
13	READ ONLY MEMORY (ROM-1024 BIT)	0	0	0	8	8	16
14	LOGIC POWER SUPPLY	0	0	1	1	1	1

TABLE 7.1 — COMPONENT TYPE AND QUANTITY UTILIZED IN ALTERNATE LOGIC/DRIVE UNIT OF ELEVATOR CONTROLLER

EM Relays are used to drive hydraulic solenoids, and motor contactors located in the Motor Controller. The EM Relays are modern type relays which plug in and can be easily removed for test and/or replacement. Each relay utilizes a Light Emitting Diode (LED) to monitor the excitation to its coil. The relay LDU includes two test sockets, one for the Low Power Relays, and one for the High Power Relays. The test sockets are connected to push buttons and additional indicator lights in a manner such that the relays can easily be tested. The Time Delay Relays are tested in the same test socket as the Low Power Relays. The relays are of relatively low cost so that they can economically be discarded instead of performing any preventative or corrective maintenance upon them.

7.2 HYBRID RELAY LDU

This design approach is essentially the same as the REGULAR EM RELAY LDU with the exception that Solid State Relays (SSR) are used instead of the High Power EM Relays to drive the hydraulic solenoids and the motor contactors. Solid State Relays utilize semiconductor technology to perform switching of AC or DC voltage. The SSR's do not plug in but since they are the equivalent of a single pole-single throw EM relay they can easily be tested in place. However, the SSR's are mounted in such a manner as to make it easy to remove and replace them. A test mounting plate, test clips, selectable test loads, push-buttons, and indicator lights are used to test the SSR out of the circuit. The Low Power EM relay test socket is retained as in the previous design approach as is the use of LEDS. In the case of the SSR's the LED is used to indicate the excitation across the two input terminals.

7.3 STATIC LOGIC LDU

This design approach uses DC/DC converters to convert the high level signals from the External Input Devices to the low level signals utilized by Solid State Logic (Static Logic) Modules. The Solid State Logic Modules consist of Small Scale Integration (SSI) and Medium Scale Integration (MSI) logic chips to perform the input sensing, logical operations, and the necessary time intervals. It uses SSR's to drive all of the external output devices. Light Emitting Diodes (LEDS) are used to indicate status of the inputs to, and outputs from, the Logic/ Drive Unit (LDU). An external tester is used to test the components of this LDU.

This approach does not include any proprietary solid state logic modules such as Direct Static Logic by Culter-Hammer, Ladder Static Logic by Cutler-Hammer, Static Control by General Electric, Norpak by Square D, Cardlok by Allen-Bradley, Versaframe by Ebbert Engineering Company, LDC 40 by Automatic Timing and Controls Company,etc. All proprietary logic modules were eliminated from consideration because standard logic chips having the required logic functions are readily available from a multitude of manufacturers. Use of the standard logic chips facilitated reliability predictions by the use of Section 2.1 of MIL-HDBK-217B (Reliability Prediction of Electronic Equipment.)

7.4 NON-LSI PROGRAMMABLE CONTROLLER LDU

This design approach uses a modern commercial Programmable Controller (PC) to perfrom the sensing, logical operations, and drive functions. The PC is a computer-like device that contains input DC/DC converters to sense the inputs and reduce the relatively high signal levels to the lower logic levels used in the logical section of the controller. SSR's are used to convert the output logic levels to the power levels required by the output devices of the EIOD. A Read Only Memory (ROM) is interrogated by Central Processing Unit (CPU) and used to direct the sequential sampling of the logic inputs, perform the required logical operations, and sequential turn-on and turn-off of the output devices. The present controller, the PDP-14, is a first generation PC. The NON-LSI Programmable Controller is a modern PC that is typical of PC's offered by several manufacturers. The NON-LSI indicates that a microprocessor on a Large Scale Integration (LSI) chip is not utilized for the CPU, rather the CPU is built using SSI and MSI chips. Light emitting diodes are also used in this design approach to indicate the status of input and outputs of the controller. A NON-LSI Programmable Controller has been built by the Naval Weapons Support Center (NWSC) at Crane, Indiana. It was demonstrated on the USS KITTY HAWK (CV 63) in 1977 at the Puget Sound Naval Shipyard. Due to certain maintainability short comings of that equipment NWSC is presently developing a programmable controller that uses a 16 bit microprocessor as the CPU. The microprocessor is contained on a single chip referred to in this study (See 7.6) as a Very Large Scale Integration (VLSI) chip.

7.5 LSI PROGRAMMABLE CONTROLLER LDU

This design approach is the same as the NON-LSI approach with the exception that the Central Processing Unit (CPU) of the LDU is incorporated in a Large Scale Integration (LSI) chip. The LSI chip is called a microprocessor and is an 8 bit CPU. Typical examples of the chip are the Intel 8080, Motorola 6800, MOS Technology 6502, etc. Several commerical manufacturers of Programmable Controllers offer models that utilize a microprocessor. The Intel 8080 and the Motorola 6800 microprocessors have been qualified under the Navy Standard Electronic Module Program (MIL-M-28787).

7.5 VLSI PROGRAMMABLE CONTROLLER LDU

The design approach is identical to the LSI Programmable Controller with the exception that it utilizes a more advanced microprocessor. The microprocessor is a 16 bit CPU packaged on a single chip which is referred to in this study as a Very Large Scale Integration (VLSI) chip. Several 16 bit microprocessors are avaiable but are not known to be used in commercial programmable controllers. However, the Texas Instruments TMS 9900 microprocessor has been qualified under the Navy Standard Electronic Module program. A Programmable Controller utilizing the VLSI TMS 9900 microprocessor is being developed by the Naval Weapons Support Center (NWSC) at Crane, Indiana ; it is about 18 months from completion.

8.0 EVALUATION OF DESIGN APPROACHES

In Section 7.0, "Definition of the Candidate Automatic Controller Design Approaches," six design concepts were selected and defined for evaluation. As explained in that section, the External Input/Output Devices (EIOD) are specified in the basic requirements of Section 5.0 and are common to the six design approaches. The design approaches are primarily concerned with the mechanization of a Logic/Drive Unit (LDU) that combines with the EIOD to constitute an Automatic Controller.

The evaluation of the design approaches were performed with respect to the following seven criteria: Reliability, Maintainability, Equipment Supportability, Standardization, Human Interface, Failsafe Operation, and Life Cycle Cost. The evaluation was not concerned with the functional capability of the different design approaches; that capability has been sufficiently demonstrated by similar operational equipment.

The six design approaches were separately evaluated with respect to reliability since their constituent component type and count differed significantly. However, the reliability evaluation indicated that the two design approaches based on relays to perform the logical operations were virtually the same with respect to reliability, and that the NON-LSI and LSI commercial programmable controller design approaches were similarly the same with respect to reliability. Since the other evaluations could be satisfactorily performed assuming only one relay based design approach and only one commercial programmable controller based design approach, all evaluation ratings are given for only four design approaches for the reasons explained in the reliability evaluation.

8.1 RELIABILITY EVALUATION

The reliability of electromechanical components such as pushbuttons, limit switches, and electromagnetic relays is a function of the number of times they are actuated over the period of interest. In contrast, the reliability of solid state components is a function of the portion of the time they are energized over the period of interest. For the AC, some of the components need to be energized continuously and others need not be energized all the time, e.g., the solid state relays that drive the latching hydraulic solenoids. Paragraph 5.6.4.1 of the basic requirements section (Section 5.0) specify that the AC shall have a predicted probability of failure of less than 0.006 over a 24 hour period when the elevator is operated at the rate of 6 dispatches per day. Paragraph 5.6.4.2 states that the predicted probability of failure over 24 hours shall be less than 0.03 when the elevator is operated at the rate of 144 dispatches per day. The lower dispatch rate is representative of those times when the elevator is experiencing little or no use and corresponds to 2,190 dispatches per year. The higher dispatch rate is representative of those times when the demand on the elevator is great, e.g., "On-Load" or "Strike-Up" operations.

In addition to the usage rates defined in Paragraphs 5.6.4.1 and 5.6.4.2, an intermediate rate between those two rates was used to give an insight to how the reliability varied between the extremes. The three dispatch rates are:

Long Term (nominal usage)	6 dispatches/day (.25 dispatch/hour) (2,190 dispatches year)
Low Short Term (medium usage)	24 dispatches/day (1 dispatch/hour)
High Short Term (high usage)	144 dispatches/day (6 dispatches/hour)

Component failure rate data for the components used in the EIOD and the LDU were largely determined by using MIL-HDBK-217B (Notice 2). The component failure rate data for components at 50°C is illustrated in Table 8.1.1. The determination of the Mean-Time-Between-Failure (MTBF) for the EIOD and for each of the six design approaches from the component failure rate data is given in Appendices A and B; the results of that determination are given in Table 8.1.2. The table indicates the MTBF's as a function of the three usage rates and as a function of three levels of component quality. The three levels of component quality are: Commercial (COM), Military-Standard (MIL-STD), and High Reliability (HI-REL). It should be noted that commercial

COMPONENT	FAILURE RATE PER 1x10^6 CYCLES OR 1x10^6 HOURS		
	COMMERCIAL GRADE	MIL-STD (HI-GRADE COM)	HI REL
CYCLE SENSITIVE UNITS			
MOMENTARY PB SWITCH (DPST)	1.08	0.072	-
LIMIT SWITCH (SPST)	15.4	2.8245	-
LOW POWER EM RELAY (SPST)	0.2654	0.0456	-
LOW POWER EM RELAY (3PDT)	1.128	0.1939	-
HIGH POWER EM RELAY (SPST	0.4945	0.0567	-
TIME DELAY RELAY (DPDT)	0.7963	0.205	-
SOLENOID VALVE	8.3333	8.3333	-
ALARM BELL	2.5	2.5	-
TIME SENSITIVE UNITS			
INCANDESCENT LAMPS	1.0000	1.0000	-
LIGHT EMITTING DIODES (LEDS)	1.4200	0.2840	0.057
PROXIMITY SENSORS	4.903	2.6528	-
TIMER CHIP (SSI)	11.7	7.02	0.39
DC/DC CONVERTER	14.963	3.0	0.598
SSI LOGIC CHIP (10 GATES/CHIP)	6.1	3.66	0.203
MSI LOGIC CHIP (100 GATEW/CHIP)	19.685	11.811	0.656
ROM CHIP	7.222	4.333	0.241
8080 μPROCESSOR CHIP (1100 GATES/CHIP)	350.543	210.326	11.685
9900 μPROCESSOR CHIP (3100 GATES/CHIP)	408.293	244.976	13.61
SOLID STATE RELAY*	18.426 (0.921)	3.7 (0.185)	0.736 (0.0368)

*THE SSR MAY BE TREATED AS A CYCLE SENSITIVE UNIT BY ALLOWING EXCITATION TO IT FOR ONLY A LIMITED AMOUNT OF TIME PER DISPATCH. THE NUMBERS IN PARENTHESES CORRESPOND TO 3 MINUTES PER DISPATCH.

TABLE 8.1.1 — COMPONENT FAILURE RATE DATA

	ELEVATOR DISPATCH RATE								
	6 DISPATCHES/DAY (NOMINAL USAGE)			24 DISPATCHES/DAY (MEDIUM USAGE)			144 DISPATCHES/DAY (HEAVY USAGE)		
	COMPONENT QUALITY			COMPONENT QUALITY			COMPONENT QUALITY		
EQUIPMENT GROUP	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL
EIOD	3,661	6,516	-	1,976	3,705	-	486	956	-
EM RELAY LDU	15,017	80,128	164,826	6,848	38,683	51,446	1,482	8,696	9,210
HYBRID RELAY LDU	14,527	76,650	166,889	6,451	35,437	52,252	1,371	7,740	9,365
STATIC LOGIC LDU	625	2,218	15,651	617	2,198	15,462	569	1,647	14,226
NON LSI LDU	555	1,749	14,160*	549	1,736	13,993*	511	1,658	12,973*
LSI LDU	487	1,383	12,650*	482	1,375	12,516*	452	1,326	11,694*
VLSI LDU	461	1,257	12,062	457	1,251	11,940	430	1,210	11,189

* NOTE - COMMERCIAL PROGRAMMABLE CONTROLLERS DO NOT USE HI-REL QUALITY COMPONENTS, THE DATA IS INCLUDED ONLY FOR THEORETICAL INFORMATION

TABLE 8.1.2 — MTBF IN HOURS FOR THE EIOD AND FOR THE LDU DESIGN APPROACHES

Programmable Controllers do not use MIL-STD or HI-REL parts; however, they often use the commercial equivalent of MIL-STD components. The relation of the probability of no failure as a function of time and MTBF is given by the following equation:

$$P_{NF} = \epsilon^{-t/MTBF}$$

Accordingly Table 8.1.3 indicates the probability of no failure over a 24 hour period for the MTBF's of the equipment groups of Table 8.1.2. The overall MTBF of the Automatic Controller (AC) is a function of the individual LDU MTBF's and the EIOD MTBF. Table 8.1.4 indicates the AC MTBF's for the six LDU design approaches; and Table 8.1.5 indicates the probability of no failure of the AC over a 24 hour period.

Comparison of the information of Tables 8.1.2, 8.1.3, 8.1.4 and 8.1.5 with the reliability requirements of Section 5.0 indicates that, at the nominal usage rate, the two Relay based design approaches meet the reliability requirements with commercial quality components. The Static Logic, NON-LSI, LSI and VLSI design approaches need HI-REL quality components. At the heavy usage rate the two Relay based design approaches need MIL-STD quality components; the other design approaches can almost meet the heavy usage reliability requirement using MIL-STD quality components but need the HI-REL components to meet the specification. Since commercial NON-LSI and LSI Programmable Controllers are available that use the commercial equivalent MIL-STD components, this evaluation and the others that follow assume commercial NON-LSI and LSI Programmable Controllers. The other four design approaches could be/are being developed by Navy Activities, and it is reasonable to assume the use of the highest quality of components available.

Based on the information presented in the two preceding paragraphs the six design approaches were reduced to four and are designated in all the evaluations as follows:

- Relay
- SEM Static Logic
- Commercial PC
- SEM PC

The reliability evaluation is based on the MTBF of the highest quality of available components for the design approaches indicated in Table 8.1.2, 8.1.3, 8.1.4 and 8.1.5. It is seen that the Relay LDU has an advantage for the nominal and medium elevator usages, while the Static Logic design approach has an advantage for the heavy elevator usage. Taking into account the MTBF for the three usage rates the following relative ratings for the design approaches have been determined as follows:

DESIGN APPROACH	RELATIVE RATING (MAX=100)
RELAY	100
SEM STATIC LOGIC	100
COMMERCIAL PC	90
SEM PC	100

	ELEVATOR DISPATCH RATE								
	6 DISPATCHES/DAY (NOMINAL USAGE)			24 DISPATCHES/DAY (MEDIUM USAGE)			144 DISPATCHES/DAY (HEAVY USAGE)		
	COMPONENT QUALITY			COMPONENT QUALITY			COMPONENT QUALITY		
EQUIPMENT GROUP	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL
EIOD	.9935	.9963	-	.9879	.9935	-	.9518	.9752	-
EM RELAY LDU	.9984	.9997	.9999	.9966	.9993	.9995	.9839	.9972	.9974
HYBRID RELAY LDU	.9983	.9997	.9999	.9963	.9993	.9995	.9826	.9969	.9974
STATIC LOGIC LDU	.9623	.9892	.9985	.9618	.9891	.9984	.9587	.9855	.9983
NON LSI LDU	.9577	.9864	.9983*	.9572	.9863	.9983*	.9541	.9856	.9982*
LSI LDU	.9519	.9828	.9981*	.9514	.9827	.9981*	.9478	.9821	.9979*
VLSI LDU	.9493	.9811	.9980	.9488	.9810	.9980	.9457	.9804	.9978

* NOTE - COMMERCIAL PROGRAMMABLE CONTROLLERS DO NOT USE HI-REL QUALITY COMPONENTS, THE DATA IS INCLUDED ONLY FOR THEORETICAL INFORMATION

TABLE 8.1.3 — PROBABILITY OF NO FAILURE OVER 24 HOURS FOR THE EIOD AND FOR THE LDU DESIGN APPROACHES

AUTOMATIC CONTROLLER DESIGN/APPROACH	ELEVATOR DISPATCH RATE								
	6 DISPATCHES/DAY (NOMINAL USAGE)			24 DISPATCHES/DAY (MEDIUM USAGE)			144 DISPATCHES/DAY (HEAVY USAGE)		
	COMPONENT QUALITY			COMPONENT QUALITY			COMPONENT QUALITY		
	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL
EM RELAY LDU/EIOD	4,544	6,026	6,268	2,404	3,381	3,456	581	861	866
HYBRID RELAY LDU/EIOD	4,498	6,005	6,271	2,353	3,354	3,460	563	851	867
STATIC LOGIC LDU/EIOD	570	1,655	4,601*	528	1,380	2,989*	357	605	895*
NON LSI LDU/EIOD	511	1,379	4,462**	478	1,182	2,829**	333	606	890**
LSI LDU/EIOD	453	1,141	4,300**	427	1,003	2,859**	307	556	884**
VLSI LDU/EIOD	431	1,054	4,231	407	935	2,828	296	536	881

* NOTE 1 - HI-REL STATIC LOGIC NOT AVAILABLE FROM TRADITIONAL COMMERCIAL EQUIPMENT MANUFACTURERS

**NOTE 2 - COMMERCIAL PROGRAMMABLE CONTROLLERS DO NOT USE HI-REL QUALITY COMPONENTS, THE DATA IS INCLUDED ONLY FOR THEORETICAL INFORMATION

TABLE 8.1.4 – MTBF IN HOURS FOR AUTOMATIC CONTROLLER DESIGN APPROACHES

AUTOMATIC CONTROLLER DESIGN/APPROACH	ELEVATOR DISPATCH RATE								
	6 DISPATCHES/DAY (NOMINAL USAGE)			24 DISPATCHES/DAY (MEDIUM USAGE)			144 DISPATCHES/DAY (HEAVY USAGE)		
	COMPONENT QUALITY			COMPONENT QUALITY			COMPONENT QUALITY		
	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL	COM	MIL-STD	HI-REL
EM RELAY LDU/EIOD	.9947	.9960	.9964	.9900	.9929	.9931	.9595	.9725	.9727
HYBRID RELAY LDU/EIOD	.9947	.9960	.9964	.9900	.9929	.9931	.9582	.9722	.9727
STATIC LOGIC LDU/EIOD	.9588	.9856	.9948*	.9556	.9828	.9920*	.9350	.9611	.9735*
NON LSI LDU/EIOD	.9541	.9827	.9946**	.9510	.9799	.9918**	.9305	.9612	.9734**
LSI LDU/EIOD	.9484	.9792	.9944**	.9453	.9764	.9916**	.9248	.9578	.9732**
VLSI LDU/DIOD	.9458	.9775	.9943	.9427	.9747	.9915	.9220	.9562	.9731

* NOTE 1 - HI-REL STATIC LOGIC NOT AVAILABLE FROM TRADITIONAL COMMERCIAL EQUIPMENT MANUFACTURERS

**NOTE 2 - COMMERCIAL PROGRAMMABLE CONTROLLERS DO NOT USE HI-REL QUALITY COMPONENTS, THE DATA IS INCLUDED ONLY FOR THEORETICAL INFORMATION

TABLE 8.1.5 — PROBABILITY OF NO FAILURE OVER 24 HOURS FOR AUTOMATIC CONTROLLER DESIGN APPROACHES

8.2 MAINTAINABILITY

The maintainability over its life cycle of an equipment is a function of 1) the intrinsic maintainability of equipment as determined by its design features, 2) the availability of spare parts throughout its projected useful life, 3) its use of standard components, 4) the match between the equipment complexity and the skills of the assigned maintenance personnel, and 5) the severity of damage when it fails. Thus we see that the cradle-to-grave maintainability (Life Cycle Maintainability) is determined by the equipment and its total life environment. This section of the study evaluation deals with the intrinsic maintainability; the other factors involved in the Life Cycle Maintainability are discussed in the next four sections.

The basic measure of the intrinsic maintainability of an equipment is its Mean-Time-To-Repair (MTTR). MTTR is the mean sum of active time spent performing the following tasks:

- Verification of an apparent malfunction.
- Top level fault isolation to indicate the equipment group or package within which the malfunction has occurred.
- Additional fault isolation as required to trace the malfunction to a Line Replaceable Unit (LRU).
- Replacement or repair of the defective LRU.
- Checkout of system operation to verify the system is ready to be put back in service.

The mean time spent in non-active repair activities is combined with the MTTR to obtain the Mean-Down-Time (MDT) that the equipment is out of service. The non-active repair time is generally referred to as Administrative Delay Time (ADT). Typical examples of the constituents of ADT are:

- Inform the Officer-Of-The-Day (OOD) of the equipment problem and request permission to take the equipment out of service for corrective maintenance.
- Take the equipment out of service and inform all interested parties.

- Assign personnel as required to perform corrective maintenance.
- Request and obtain replacement parts or labor to repair defective parts.
- Keep the OOD informed of the repair status.
- Maintain the necessary logs/records.
- Inform the OOD when the equipment is ready to be put back in service.
- Put the equipment back in service and inform all interested parties.

The Mean-Down-Time (MDT) can be used with the Mean-Time-Between-Failure (MTBF) in an equation to give an indication of the Availability (A_o) of an equipment. The operational availability is simply the percentage of the total time that a system is available; the equation for A_o is:

$$A_o = \frac{\text{Uptime}}{\text{Total Time}} = \frac{\text{MTBF}}{\text{MTBF + MDT}}$$

An alternate form of this equation is:

$$A_o = \frac{1}{1 + \frac{\text{MTTR + ADT}}{\text{MTBF}}}$$

The alternate equation form is of interest because it clearly shows that if the ADT is significantly larger than MTTR then efforts to reduce MDT should concentrate on the ADT.

The determination of the MTTR of an equipment is normally determined by conducting special tests or by keeping records of the active repair times incurred during actual operation. Sometimes prediction of the MTTR is attempted based on the design of the equipment. The particular method of prediction is a function of the design status of the equipment: the more complete the design status, the more specific the method to predict the MTTR. When the designs are in the concept stage, i.e., they are design approaches rather than specific designs, the prediction method is of necessity more qualitative than quantitatime.

The maintainability evaluation used in this study did not have as its objective the prediction of a quantitative MTTR value. Instead, the objective was to estimate the relative suitability of the design approaches to accomplishing a low MTTR based on certain design features. The design features considered appropriate were: 1) the simplicity of the design, 2) the maturity of the design, i.e., has the maintenance approach been successfully demonstrated, 3) the use of built-in test and fault isolation aids, and 4) the ease with which a Line Replaceable Unit (LRU) can be removed and replaced.

The design approaches for the Logic/Drive Unit of the Automatic Controller were investigated for their potential with respect to the four design features discussed in the previous paragraph. The following "broad brush" ratings were assigned:

	SIMPLICITY (MAX=25)	MATURITY (MAX=25)	BUILT-IN (MAX=25)	LRU (MAX=25)	TOTAL (MAX=100)
RELAY	25	25	25	25	100
SEM STATIC LOGIC	25	25	15	25	90
COMMERCIAL PC	15	15	20	25	75
SEM PC	17.5	12.5	25	25	80

8.3 EQUIPMENT SUPPORTABILITY

Equipment supportability is concerned with the probability that required spare parts can be obtained within a reasonable time at reasonable cost. The period of interest is from the date the equipment is placed in service to the date that it is expected to remove the equipment from service. Insufficient equipment supportability can result in undesirable inconvenience, high maintenance cost, and even premature removal from service.

The most common reasons for insufficient equipment supportability are: 1) the equipment has become technically obsolete, 2) there are too few systems requiring support, and 3) the number of suppliers of the system and/or components has decreased. The above stated reasons are dependent on each other and can result in a chain reaction.

Technical obsolescence can be induced due to utilization of a better phenomena, e.g., transistors versus vacuum tubes, or by the utilization of better manufacturing processes, e.g., integrated transistor circuits versus discrete transistors. The number of systems can be insufficient to induce good support because not many systems were produced, or the systems were more quickly removed from service by other users. As more attractive "Second Generation" systems are developed and fewer "First Generation" systems require support, more suppliers determine the market as being uneconomical and they decrease/drop their support efforts. This results in fewer or no suppliers ready, willing, and able to support economically "outmoded" systems/equipment.

The period of interest for equipment supportability evaluation of the IWHS Automatic Controller is 20 years. Again the emphasis is on the Logic/Drive Unit (LDU) because the External Input/Output Devices are sufficiently supportable and are common to each LDU design approach.

Although electromechanical (EM) relays have been replaced by solid state switching/logic devices in many applications, the EM relay remains the preferred device in many applications. The EM relay is presently a supportable device because it is not technically obsolete, there are many systems using EM relays and there are many manufacturers of EM relays. There is no reason to believe that the EM relay will not be satisfactorily supported for the next 20 years and even much longer.

The Solid State Relay (SSR) is a much more recent device which is tending to replace the EM relay in some medium power switching applications. The SSR is a commonly used device now and will be even more common in the future. In 20 years the SSR is likely to be available in the same form that it is now.

The Standard Electronic Module (SEM) program module listing as of 1 April 1978 (Appendix F) lists 197 modules that have been qualified and specified, 22 modules that have been qualified and are in the process of being specified, and 83 modules that are under development.

Some of the older SEMS are not recommended for use in new designs; in general these older modules are available in later pin, compatible, modules that have a better performance characteristic, e.g., speed of response. The more common SEMS, e.g., "NAND GATES," "INVERTER GATES," etc., have a high probability of being supported for the next 20 years. The more specialized SEMS, e.g., "MICROPROCESSORS" have a somewhat lower probability of being supported over the same time period.

Commercial electronic equipment is in general characterized by a technical obsolescence period in the range of 5 to 10 years. The seemingly ever constant striving by manufacturers toward higher speed, larger scale of integration, lower manufacturing cost, and even planned technical obsolescence virtually guarantees that, from the supportability viewpoint, equipment that is 10 years old will not be economically attractive. There are exceptions, of course, but these are relatively rare.

Four sub-criteria were used to determine the equipment supportability over the 20 year period of interest. The four sub-criteria are: 1) the probability that the equipment will not become obsolete, 2) the number of systems using the equipment, 3) the number of manufacturers making the equipment, and 4) the number of manufacturers making the components used in the equipment. Of the four sub-criteria, the probability of non-obsolescence is considered the most important. Therefore it has a maximum value of 85, the other sub-criteria each have a maximum value of 5.

On the basis of an analysis of the significant components involved in each design approach the following ratings have been assigned:

	PROB. OF NON.-OBSO. (MAX=85)	NO. OF SYS. (MAX=5)	NO. OF SYS. MANU. (MAX=5)	NO. OF COMP. MANU. (MAX=5)	TOTAL (MAX=100)
RELAY	85	5	5	5	100
SEM STATIC LOGIC	81.6	2.8	2.8	2.8	90
COMMERCIAL PC	8.5	.5	.5	.5	10
SEM PC	73.1	2.3	2.3	2.3	80

8.4 STANDARDIZATION

For the purposes of this study, standardization is defined as the use of interchangeable Line Replaceable Units (LRU) within the Automatic Controller (AC) and with other systems onboard the aircraft carrier. Of special interest is the use of LRU's that are interchangeable between the AC and other equipment maintained by the Electricians Mate (EM). In general, a high degree of standardization is a desirable objective because it tends to make spare parts more available and increase the familiarity of the EM with the equipment. In equipments where an LRU is not required for each equipment mode, the interchangeable LRU's can be swapped during failure isolation activities without obtaining a completely spare LRU. In effect, the equipment supplies its own temporary spare LRU. Carrying this idea a bit further, if a completely spare LRU is not available, it is sometimes feasible to temporarily borrow an LRU from another equipment that is not being used. However, it is reasonable to assume that the more standard an LRU, the higher the probability that a completely spare LRU will be available. It must be pointed out that an over zealous effort to standardize can result in a decrease in system effectiveness due to the use of a standard part in an application where a non-standard part would be better from the standpoint of functional performance, reliability, etc.

Table 8.4.1 indicates the component types and quantities used in the six design approaches for the Logic/Drive Unit (LDU). Since the External Input/Output Devices are common to all the design approaches, they do not enter into the standardization evaluation. An analysis of the table indicates that the regular and hybrid relay design approaches both have a high degree of standardization within the LDU. If the solid state relays and/or the EM relays are properly chosen, a high degree of standardization with other systems could be achieved since relays are a very common part of other systems, particularly the other elevators onboard the aircraft carriers in question. Because the other elevators have relay controllers, the EM will be more familiar with a relay controller for the IWHS elevator. The SEM Static Logic and the

NO.	COMPONENT	RELAY REGULAR	RELAY HYBRID	STATIC LOGIC	PROGRAMMABLE CONTROLLER NON-LSI	PROGRAMMABLE CONTROLLER 8080	PROGRAMMABLE CONTROLLER 9900
1	LOW POWER EM RELAY (3PDT)	82	82	0	0	0	0
2	LOW POWER EM RELAY (SPST)	11	11	0	0	0	0
3	HIGH POWER EM RELAY (SPST)	18	0	1	1	1	1
4	SOLID STATE RELAY (SPST)	0	18	29	29	29	29
5	TIME DELAY EM RELAY (DPDT)	2	2	0	0	0	0
6	LIGHT EMITTING DIODE	113	113	113	113	113	113
7	DC/DC CONVERTER	0	0	82	82	82	82
8	SSI LOGIC CHIP (10 GATE)	0	0	49	25	25	25
9	MSI LOGIC CHIP (100 GATE)	0	0	0	10	5	5
10	SSI TIMER	0	0	2	10	10	10
11	LSI CHIP (8080 μPROCESSOR)	0	0	0	0	1	0
12	VLSI CHIP (9900 μPROCESSOR)	0	0	0	0	0	1
13	READ ONLY MEMORY (ROM-1024 BIT)	0	0	0	8	8	16
14	LOGIC POWER SUPPLY	0	0	1	1	1	1

TABLE 8.4.1 — COMPONENT TYPE AND QUANTITY UTILIZED IN ALTERNATE LOGIC/DRIVE UNIT OF ELEVATOR CONTROLLER

SEM PC design approaches are likely to have a high degree of standardization within the system due to the use of fairly common Standard Electronic Modules (SEM) such as "AND/NAND," "OR/NOR," "INVERTER," "FLIP/FLOP," "COUNTER," etc. As the Navy wide use of SEM's increases, the SEM based design approaches potentially can have a high degree of standardization with other onboard systems. However, the use of SEM's (or its equivalents) in other equipment maintained by the EM is not as prevalent as relays and is not likely to be over the next 20 years. The two Commercial PC design approaches can have some standardization within the system due to the relative large numbers of DC/DC converters and solid state relays. The logic chips in themselves could be fairly well standardized but the LRU boards upon which they are mounted are likely to be large in size, few in number, and highly integrated, i.e., the LRU's will not be standardized.

Consideration of the above observations leads to the following evaluation rating of the design approaches:

	WITHIN SYS. (MAX=33-1/3)	OTHER SYS. (MAX=33-1/3)	OTHER MTCE (MAX=33-1/3)	TOTAL (MAX=100)
RELAY	33-1/3	33-1/3	33-1/3	100
SEM STATIC LOGIC	30	30	20	80
COMMERCIAL PC	20	10	10	40
SEM PC	30	30	20	80

8.5 HUMAN INTERFACE

To be maintainable, a system must successfully interface with the Enlisted Rate assigned to perform maintenance on that system. A successful interface can be achieved by two basically different concepts. The traditional concept is to make the equipment "understandable" to the maintenance personnel so that they can "trouble shoot" it. What constitutes "understandable" is determined by the formal and on-the-job training they have received, information contained in their Rate Training Manual, the similarity of the equipment with other equipment maintained by them, etc. Another concept is based on the premise that the maintenance personnel need not understand the equipment and what it does; they need only be able to *follow simple instructions* that tell in "cookbook" fashion how to perform the required maintenance. "Trouble shooting" other than that covered by the "cookbook" procedures is not provided for. Under the "cookbook" approach the "trouble shooting" has been performed a priori by the design engineer. This concept is based on the assumption that a maintenance problem that does not require traditional "trouble shooting" by the EM is sufficiently improbable so that the EM need not "understand" the equipment.

In the case of the Electrician's Mate (EM), these two concepts as applied to the IWHS Elevator Controller interface with him in a completely different manner. For the one concept the EM is challenged to utilize the highest skills and knowledge he possesses, while for the other concept the EM is either confronted with a situation that utilizes his lowest skills and knowledge, or with a situation for which he is not properly trained. A fundamental question is, "How does the typical EM react to the two different concepts?". This is a very difficult question to answer and is not fully attempted in this study. The purpose of raising the question is to indicate that possibly the only way of answering the question is to perform a meaningful test.

Experience has shown that the EM reacts favorably to the traditional concept, as exemplified by Relay and Static Logic Controllers, that uses his highest skills and knowledge. It is also known that the EM reacts unfavorably to the PDP-14 Controller because it too often required skills and knowledge that he evidently does not have in sufficient quality and quantity. When this happens, the EM tends to lose confidence in the equipment and tends to attribute difficult system failures to the PDP-14 Controller. It does not necessarily follow that another programmable controller, other than the PDP-14, would evoke the same responses. What does follow is that until the EM is exposed to that other programmable controller the Human Interface is in some reasonable doubt.

In order to assess the interface between the EM and the design approaches the following evaluation factors are: 1) compatibility with formal and on-the-job training of the EM, 2) availability of applicable information in the EM Rate Training Manuals, etc., 3) similarity with other equipment maintained by the EM, 4) the relative number of EM's qualified to maintain similar equipment, and 5) the relative number of years the similar equipment has been maintained by the EM's.

The design approaches for the Logic/Drive Unit were investigated according to the above five factors and assigned the following ratings:

	TRNG. COMP. (MAX=20)	AVAIL. INFO. (MAX=20)	EQPT. SIM. (MAX=20)	NO. OF EM'S (MAX=20)	EQPT. YRS. (MAX=20)	TOTAL (MAX=100)
RELAY	20	20	20	20	20	100
SEM STATIC LOGIC	18	18	14	12	18	80
COMMERCIAL PC	8	12	6	6	8	40
SEM PC	8	12	6	6	8	40

8.6 FAILSAFE OPERATION

In the event that an equipment experiences a malfunction it is mandatory that it "prevent" injury to personnel and desirable that it "prevent" or "minimize" significant damage to the rest of the system. In other words the system should "Failsafe". The IWHS Elevator Control System incorporates several safety devices that tend to make the system Failsafe (FS), e.g., "overtravel switches," slack cable switches," "overspeed governor switch," etc. These safety devices are common to both the automatic and the manual operation of the elevator.

It is desirable that the Automatic Controller exhibit FS design features that pertain to internal AC operation and minimize reliance on the external safety devices. The basic requirements for the FS Operation are stated in Section 5.6.3 of the "Baseline Requirements Specification for the Automatic Controller of the IWHS Elevator Control System". Essentially the FS requirements are that no single failure within the AC shall result in an unscheduled or uncontrolled operation of the platform, and that the temporary loss of electrical power shall cause the AC to stop the platform/hatches and come to a safe condition. The AC and the platform/hatches are required to stay in that position even after the electrical power is restored.

The design features that contribute to satisfactory FS operation are as follows: 1) the ability to accommodate mixed input signal "true states," i.e., one "true state" is represented by a non-ground potential while another "true state" is represented by a different potential (such as ground), 2) the ability to prevent a malfunction from causing another malfunction or a chain of malfunctions, 3) the percentage of the Logic/Drive Unit (LDU) represented by a damaged Line Replaceable Unit, and 4) the amenability of the design to economically incorporate exhaustive self-checks during operation.

The regular relay and the hybrid relay design approaches can accommodate mixed input "true states" by the proper interchange of "normally closed" and "normally open" contacts. However, with the practice of using LEDS (Light Emitting Diodes) to indicate excitation to a relay coil, there are potential conflicts if it is desired to have an LED illuminated for a given state of the elevator system, e.g., to have a given set of LEDS all lighted to facilitate visual checkout. Relays don't tend to allow the malfunction of one relay to cause a malfunction in another relay. Relays are in individual packages and constitute a single Line Replaceable Unit (LRU) with the result that the LRU is a small percentage of the Logic/Drive Unit. Relay based designs are not noted for their self-test capability, but it can be done. The main difficulty is that self-test capability would take many more relays resulting in a decreased reliability and possibly result in an unacceptable reaction time.

The Static Logic design approach can also easily accommodate mixed input "true states"; but like the relay approach, the use of LEDS to actively indicate the actual state of the input during a particular elevator system condition is a problem. Malfunctions of static logic devices rarely results in a chain reaction so that isn't a problem. Static logic, as mechanized by Standard Electric Modules (SEM) tend to have relatively small LRU's. The Static Logic approach has not normally included self-test but, like the relay approach, it can be implemented by additional logic elements. Reaction time is not a problem with static logic because its speed of response of static logic is much better that relays.

With respect to FS operation the potential capabilities of the Commercial and the SEM Based Programmable Controller (PC) are sufficiently similar that they can be discussed together. The PC can, and normally does, utilize mixed input "true state" signals and the failure of an internal logic element rarely results in a chain reaction of logic elements. Both PC approaches can easily incorporate extensive self-test capability with addition of more Read-Only-Memory (ROM) and a few logic elements. The SEM PC utilizes many SEM LRU's which individually represent a very small percentage of the LDU. In contrast the Commercial PC uses a higher degree of physical integration that results in a minimum number of larger LRU's that represent a more significant portion of the LDU.

The above considerations lead to the following ratings for the four basic design approaches:

	MIXED STATES (MAX=25)	CHAIN REAC. (MAX=25)	% OF LDU (MAX=25)	SELF TEST (MAX=25)	TOTAL (MAX=100)
RELAY	22.5	25	25	7.5	80
SEM STATIC LOGIC	22.5	25	20	12.5	80
COMMERCIAL PC	25	25	15	25	90
SEM PC	25	25	25	25	100

8.7 LIFE CYCLE COST

The total cradle-to-grave cost, commonly referred to as the Life Cycle Cost (LCC), of ownership of an equipment can be conveniently separated into three distinct cost areas. The first cost area consists of the cost elements required to acquire the equipment. For this study the identified cost elements are: 1) the cost of developing the equipment hardware, 2) the cost of developing any required software, 3) the procurement cost of production equipment, 4) the cost of initial spare parts, and 5) the cost of developing information to be inserted in the IWHS Elevator Technical Manual. The second cost area consists of the cost elements required to put the equipment in place and bring it up to operational status. The identified cost elements for this are: 1) the cost of installing the equipment of the aircraft carriers, 2) the cost of developing a training course for the ships maintenance personnel, and 3) the cost of initial training sessions for the ships maintenance personnel. The third cost area consists of all the cost elements involved in operating, maintaining and supporting the equipment throughout its useful life. The applicable cost elements are: 1) the maintenance labor costs, 2) the cost of replacement of malfunctioned parts of the equipment, 3) the cost of periodic refresher training sessions for the ships maintenance personnel, and 4) the cost of managing and supporting the equipment throughout its operational life.

Estimates of the above listed 12 costs for each of the four design approaches is listed in Table 8.7.1. The listed costs should be considered as only relative "First Cut Estimates," suitable only as a figure of merit for relative LCC evaluation. A more exhaustive LCC analysis is required to generate firm costs for budgeting purposes.

The general cost model used to determine the total of a specific cost element is:

Element Cost (C_E) = Cost per unit (C_u) x number of units (N_u) x product of cost modifier factors (F_c)

The term "unit" is used interchangeably for one-time costs and for recurring costs, e.g., development units, production units, training units, etc. The applicable C_u's and N_u's are given in Table 8.7.2. The seven cost modifier factors used in this estimate were: 1) units in fleet (F_{CF}), 2) personnel learning (F_{CL}), 3) equipment age (F_{CA}), 4) equipment spare parts (F_{cs}), 5) equipment replacement parts (F_{CR}), 6) inflation percentage (F_{CI}), and 7) outyear discount (F_{CD}). Table

NO.	LIFE CYCLE COST ELEMENT	RELAY	SEM SL	COM PC	SEM PC
		COST			
	ACQUISITION GROUP				
1	EQUIPMENT DEVELOPMENT	15K	50K	-	200K
2	SOFTWARE DEVELOPMENT	-	-	50K	NOTE 2
3	EQUIPMENT PROCUREMENT	400K	600K	400K	1,000K
4	TECH. MANUAL INFO. DEVELOPMENT	20K	30K	40K	50K
5	INITIAL SPARES PROCUREMENT	20K	30K	20K	50K
	INSTALLATION GROUP				
6	TRAINING COURSE DEVELOPMENT	10K	20K	40K	50K
7	INSTALLATION AND CHECKOUT	200K	300K	400K	400K
8	INITIAL TRAINING	20K	40K	80K	80K
	OP, MTCE, AND SUPPORT GROUP				
9	MAINTENANCE LABOR	300K	300K	300K	300K
10	REPLACEMENT PARTS	100K	150K	100K	250K
11	REFRESHER TRAINING	40K	120K	240K	240K
12	MANAGEMENT AND SUPPORT	300K	400K	600K	600K
	TOTAL LCC	1,425K	2,040K	2,270K	3,210K

NOTES: 1. "K" INDICATES THOUSANDS OF DOLLARS, I.E., 15K MEANS $15,000.
2. THIS COST ELEMENT NOT CHARGED AGAINST ELEVATOR CONTROLLER TASK (PER NWSC).

TABLE 8.7.1 ESTIMATED LIFE CYCLE COSTS FOR THE AUTOMATIC CONTROLLER DESIGN APPROACHES

LCC #	LIFE CYCLE ELEMENT	REFERENCE COST PER UNIT RELAY	SEM SL	COM PC	SEM PC	NO. OF UNITS
1	EQUIPMENT DEVELOPMENT	15K	50K	-	200K	1
2	SOFTWARE DEVELOPMENT (NOTE 2)	-	-	50K	-	1
3	EQUIPMENT PROCUREMENT	20K	30K	20K	50K	20
4	TECH. MANUAL INFO. DEVELOPMENT	20K	30K	40K	50K	1
5	INITIAL SPARE PROCUREMENT	20K	30K	20K	70K	20
6	TRAINING COURSE DEVELOPMENT	10K	20K	40K	40K	1
7	INSTALLATION AND CHECKOUT	10K	15K	20K	20K	20
8	INITIAL TRAINING	2K	4K	8K	8K	10
9	MAINTENANCE LABOR	1.5K	1.5K	1.5K	1.5K	400
10	REPLACEMENT PARTS	20K	30K	20K	50K	400
11	REFRESHER TRAINING	2K	6K	12K	12K	40
12	MANAGEMENT AND SUPPORT	15K	20K	30K	30K	20

NOTES:
1. "K" INDICATES THOUSANDS OF DOLLARS, I.E., 15K MEANS $15,000.
2. THE SEM PC SOFTWARE DEVELOPMENT COST HAS ALREADY BEEN PAID (PER NWSC).
3. 10 UNITS DERIVED FROM 10 SHIPS.
4. 400 UNITS DERIVED FROM 20 EQUIPMENTS X 20 YEARS.
5. 40 UNITS DERIVED FROM 10 SHIPS X FOUR REFRESHER TRAINING SESSIONS PER SHIP

TABLE 8.7.2 REFERENCE PER UNIT COST AND NUMBER OF UNITS FOR USE IN THE GENERAL COST MODEL

8.7.3 indicates which cost modifier factors could apply to each of the cost elements of Table 8.7.2. Investigation of the seven cost modifier factors lead to the conclusion that, for the purposes of this study, only three factors needed to be utilized. Those three factors and the values used are:

• Units in fleet	.5
• Equipment spare parts	.05
• Equipment replacement parts	.0125

The other four factors were seen to indicate a trend to offset each other to the extent that they did not need to be considered in a "First Cut Estimate".

The ratings for the four design approaches are given below. The relative ratings were derived by dividing the minimum total LCC figures, in this case the Relay Design Approach total, by the other LCC figures and multiplying the quotient by 100.

DESIGN APPROACH	RELATIVE RATING
RELAY	100
SEM STATIC LOGIC	70
COMMERCIAL PC	63
SEM PC	44

LCC #	LIFE CYCLE COST ELEMENT	COST MODIFIER FACTORS						
		FLEET	LEARN	AGE	SPARES	REPLACE	INFLATION	DISCOUNT
1	EQUIPMENT DEVELOPMENT							
2	SOFTWARE DEVELOPMENT							
3	EQUIPMENT PROCUREMENT						X	X
4	TECH. MANUAL INFO. DEVELOPMENT							
5	INITIAL SPARES PROCUREMENT				X		X	X
6	TRAINING COURSE DEVELOPMENT							
7	INSTALLATION AND CHECKOUT		X				X	X
8	INITIAL TRAINING		X				X	X
9	MAINTENANCE LABOR	X	X	X			X	X
10	REPLACEMENT PARTS	X		X		X	X	X
11	REFRESHER TRAINING	X	X				X	X
12	MANAGEMENT AND SUPPORT		X	X			X	X

TABLE 8.7.3 THE APPLICATION OF COST MODIFIER FACTORS FOR DETERMINING LIFE CYCLE COSTS

8.8 OVERALL EVALUATION

The evaluation of the design approaches for the replacement IWHS Elevator Automatic Controller has been performed in the preceding sub-sections with respect to Reliability, Maintainability, Equipment Supportability, Standardization, Human Interface, Failsafe Operation, and Life Cycle Cost. A total of thirty-four readily identifiable sub-criteria were used in deriving the seven evaluation ratings. The task of this overall evaluation is to reduce the individual ratings to a single rating for a given design approach which is then used to indicate the "Best" design approach for a new Automatic Controller.

The results of the seven evaluations of each basic design approach is indicated in Table 8.8.1. An overall rating could be based on the assumption that the seven evaluation criteria are equal in importance. If that assumption is correct, then the overall evaluation rating for each design approach is obtained by summing the individual ratings for a given approach. The approach with the highest overall sum would be the "best" approach and the others ranked "second best," etc., according to their overall sums. The result of such an overall evaluation is:

DESIGN APPROACH	OVERALL EVALUATION	"BEST" RATING
RELAY	680	1
SEM STATIC LOGIC	590	2
SEM PC	534	3
COMMERCIAL PC	503	4

It could reasonably be argued that the seven evaluation criteria are not of equal importance, but then the problem is to determine their relative importance. One approach to the assignment of relative importance is to assume that the Reliability evaluation is equal in importance to the Life Cycle Cost evaluation, and that taken together they are equal in importance relative to the remaining five criteria. A further assumption is that the remaining five criteria are of equal relative importance. The relative importance ratings can be reduced to a weighting factor which is used as a multiplying factor of the individual ratings. An appropriate set of weighting factors could be

DESIGN APPROACH	RELIAB.	MAINT.	EQPT. SUPT.	STD.	HUMAN INTER.	FAIL SAFE	LCC
RELAY	100	100	100	100	100	80	100
SEM STATIC LOGIC	100	90	90	80	80	80	70
COMMERCIAL PC	90	70	10	40	40	90	63
SEM PC	100	80	80	80	40	100	44

TABLE 8.8.1 INDIVIDUAL EVALUATION RATINGS FOR THE AUTOMATIC CONTROLLER DESIGN APPROACHES

0.25 for Reliability and Life Cycle Cost, and 0.1 for the other five criteria. The results of applying the above weighting factors and summing to obtain the overall rating is:

DESIGN APPROACH	OVERALL EVALUATION	"BEST" RATING
RELAY	98.0	1
SEM STATIC LOGIC	84.5	2
SEM PC	74.0	3
COMMERCIAL PC	63.2	4

A comparison of the "Best" Rating obtained from the equal importance method and the weighted importance method results in the same relative ranking. The only assignment of weighting factors that could drastically change the relative rankings would have to be one which strongly emphasized Failsafe Operation and strongly de-emphasized the other criteria, especially Life Cycle Cost. Since both methods indicate the same relative ranking, that ranking is considered sufficiently indicative of the desirability of the design approaches.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

In the overall evaluation performed in Section 8.0 it was determined that the relative rating of the four basic design approaches are as follows:

Relative Rating	Design Approach
Best	Relay
2nd Best	SEM Static Logic
3rd Best	SEM PC
4th Best	Commercial PC

To the casual observer the above results are rather unexpected; one would not expect a sophisticated Automatic Controller (AC) composed of electromechanical relays to be able to compete with a controller composed of solid state components with respect to reliability and life cycle maintainability. However a careful review of this study reveals the following appropriate reasons why the relay controller is best for the IWHS elevators.

1. The dispatch rates of the elevator are sufficiently low that the Relay Logic/Drive Unit (LDU) has a very adequate reliability.
2. The reliability of the External Input/Output Devices (EIOD) is so much less than any of the LDU design approaches that the overall reliability of the AC is affected more by the EIOD than by the LDU.
3. Relays are very common devices, they have been around a long time, they are easily understood, within their application they are subject to very little technical or planned obsolescence, they are available from alternate sources, and relays will be available in their present form for the foreseeable future.
4. With the exception of one Static Logic controller on CV 64, all the weapons elevators on Aircraft Carriers CV 59 through CV 64 are Relay controllers; thus Relay controllers will be very familiar to the Electrician's Mate (EM) on those ships.
5. The training and everyday experience of an EM is conducive to "trouble shooting" logic devices through which he can easily trace the signal and observe the step-by-step operation of the controller.

6. Relays can interface directly with the high contr signal levels presented by the external input devices i.e. i erface DC/DC Converters are not required.

7. Relays are relatively low in cost.

8. Efficient techniques exist for designing with rel s, e.g., relay ladder diagrams.

It should be noted that this study was limited to the ircraft Carriers (CV 59 through CV 64) that have the IWHS elevator It was also limited by an acceptance of the Electrician's Mate (E with his present training and normal daily work experience, as the listed Rate performing the electrical maintenance on the elevators. T final results might have been different if a larger population of ships ad been included, if the Data Systems technician (DS) had been con dered as the potential Enlisted Rate performing the electrical mainten ce, or if a large group of EM's were to be specially trained and ass ned primarily to work on elevators. Another important factor tha could affect the outcome is the possible future selection/development o a Navy Standard Elevator Controller to be utilized on a variety o ships.

It is the final conclusion of this study that a total ystems approach to the IWHS elevator controller problem IWHS corr tly identified the Relay design approach as the "best" solution.

9.2 RECOMMENDATIONS

Based on the information obtained and developed durin the course of this study, the following actions are recommended:

1. Develop, fabricate, install, and evaluate the PSNS elay Controller on the USS CONSTELLATION (CV 64) during it upcoming yard period.

2. Develop a preliminary design of a SEM Static Logi Controller and submit it to a design review to determine whether t should be fabricated, installed and evaluated against other con ollers.

3. Install and evaluate, when it becomes available, e new SEM PC on an IWHS Elevator.

4. Eliminate any further consideration of a Commerci PC or any elevator control equipment based on proprietary desig for which

second sources would not be available for the next 20 years.

5. Immediately initiate a program to select better and/or more reliable External Input/Output Devices.

6. Initiate a study to determine the best approach to improving the maintainability of the PDP-14 controllers until they are replaced by the Relay Controller.

APPENDIX

TABLE OF CONTENTS

APPENDIX A - CALCULATION OF THE MEAN-TIME-BETWEEN-FAILURES (MTBF) FOR THE EXTERNAL INPUT/OUTPUT DEVICES (EIOD)

Notes:
1. For an explanation of the dispatch rates refer to Appendix B.
2. Although there 60 pushbuttons included in the EIOD, a maximum of 2 are used per dispatch.

A-1 Nominal Usage (6 Dispatches/Day)

Component Type	Quan.	Quality: Com.	Quality: MIL-STD
Pushbutton Switch	2*	0.540	0.036
Limit Switch	12	46.800	8.474
Proximity Switch	36	176.498	95.676
Indicator Lamp	19	19.000	19.000
Hydraulic Solenoid Valve	14	29.667	29.667
Alarm Bell	1	0.625	0.625
λ(Failures/1×10^6 hours)		273.130	153.478
MTBF (hours)		3,661	6,516

*See Note 2

A-2 Medium Usage (24 Dispatches/Day)

Com. λ = (176.498+19.000)+(24/6) [273.130-(176.498+19.000)]

= 506.026

Com. MTBF = 1,976 hours

MIL-STD λ = (95.676+19.000)+(24/6) [153.478-(95.676+19.000)]

= 269.884

MIL-STD MTBF = 3,705 hours

A-3 Heavy Usage (144 Dispatches/Day)

Com. λ = (176.498+19.000)+(144/6) [273.130-(176.498+19.000)]

= 2,058.666

Com. MTBF = 486 hours

MIL-STD λ = (95.676+19.000)+(144/6) [153.478-(95.676+19.000)]

= 1,045.924

MIL-STD MTBF = 956 hours

APPENDIX B CALCULATION OF THE MEAN-TIME-BETWEEN FAILURE (MTBF) FOR THE LOGIC/DRIVE UNIT (LDU DESIGN APPROACHES)

Notes:

1. Nominal usage corresponds to 2190 elevator dispatches per year which translates to an average of 6 dispatches per day and 0.25 dispatches per hour.
2. Medium usage corresponds to 1 dispatch per hour which translates to 24 dispatches per day and 8760 dispatches per year.
3. Heavy usage corresponds to 6 dispatches per hour which translates to 144 dispatches per day.
4. The component count for the calculations is given in Table B-1.
5. The component failure rate data used in the calculations is given in Table B-2.
6. The MTBF is equal to $1x10^6/\lambda$.
7. The calculation is based on the assumption that every component must work during a dispatch i.e. a serial reliability model is utilized.
8. It is estimated that an average of only 25% of the 113 Light Emitting Diodes (LEDS) will be in the "On-State"; therefore 28 LEDS is used in the calculation instead of 113.
9. The component quality indicator in the calculation indicate the quality of highest quality components used in the calculation. In the nominal usage tables a parentheses encloses the failure rate for those components which are not equal to the highest quality utilited in the configuration.

NO.	COMPONENT	RELAY REGULAR	RELAY HYBRID	STATIC LOGIC	PROGRAMMABLE CONTROLLER NON-LSI	PROGRAMMABLE CONTROLLER 8080	PROGRAMMABLE CONTROLLER 9900
1	LOW POWER EM RELAY (3PDT)	82	82	0	0	0	0
2	LOW POWER EM RELAY (SPST)	11	11	0	0	0	0
3	HIGH POWER EM RELAY (SPST)	18	0	1	1	1	1
4	SOLID STATE RELAY (SPST)	0	18	29	29	29	29
5	TIME DELAY EM RELAY (DPDT)	2	2	0	0	0	0
6	LIGHT EMITTING DIODE	113	113	113	113	113	113
7	DC/DC CONVERTER	0	0	82	82	82	82
8	SSI LOGIC CHIP (10 GATE)	0	0	49	25	25	25
9	MSI LOGIC CHIP (100 GATE)	0	0	0	10	5	5
10	SSI TIMER	0	0	2	10	10	10
11	LSI CHIP (8080 μPROCESSOR)	0	0	0	0	1	0
12	VLSI CHIP (9900 μPROCESSOR)	0	0	0	0	0	1
13	READ ONLY MEMORY (ROM-1024 BIT)	0	0	0	8	8	16
14	LOGIC POWER SUPPLY	0	0	1	1	1	1

TABLE B–1 – COMPONENT TYPE AND QUANTITY UTILIZED IN ALTERNATE LOGIC/DRIVE UNIT OF ELEVATOR CONTROLLER

	FAILURE RATE PER $1x10^6$ CYCLES OR $1x10^6$ HOURS		
COMPONENT	COMMERCIAL GRADE	MIL-STD (HI-GRADE COM)	HI-REL
<u>CYCLE SENSITIVE UNITS</u>			
MOMENTARY PB SWITCH (DPST)	1.08	0.072	-
LIMIT SWITCH (SPST)	15.4	2.8245	-
LOW POWER EM RELAY (SPST)	0.2654	0.0456	-
LOW POWER EM RELAY (3PDT)	1.128	0.1939	-
HIGH POWER EM RELAY (SPST)	0.4945	0.0567	-
TIME DELAY RELAY (DPDT)	0.7963	0.205	-
SOLENOID VALVE	8.3333	8.3333	-
ALARM BELL	2.5	2.5	-
<u>TIME SENSITIVE UNITS</u>			
INCANDESCENT LAMPS	1.0000	1.0000	-
LIGHT EMITTING DIODES (LEDS)	1.4200	0.2840	0.057
PROXIMITY SENSORS	4.903	2.6528	-
TIMER CHIP (SSI)	11.7	7.02	0.39
DC/DC CONVERTER	14.963	3.0	0.598
SSI LOGIC CHIP (10 GATES/CHIP)	6.1	3.66	0.203
MSI LOGIC CHIP (100 GATES/CHIP)	19.685	11.811	0.656
ROM CHIP	7.222	4.333	0.241
8080 μ PROCESSOR CHIP (1100 GATES/CHIP)	350.543	210.326	11.685
9900 μ PROCESSOR CHIP (3100 GATES/CHIP)	408.293	244.976	13.61
SOLID STATE RELAY*	18.426 (0.921)	3.7 (0.185)	0.736 (0.0368)

*THE SSR MAY BE TREATED AS A CYCLE SENSITIVE UNIT BY ALLOWING EXCITATION TO IT FOR ONLY A LIMITED AMOUNT OF TIME PER DISPATCH. THE NUMBERS IN PARENTHESES CORRESPOND TO 3 MINUTES PER DISPATCH.

TABLE B—2 — COMPONENT FAILURE RATE DATA

B-1 REGULAR EM RELAY LDU

B-1a NOMINAL USAGE

Component Type	Quan	Quality: Com	MIL-STD	HI-REL
Logic Relay (3 PDT Low Power)	82	23.125	3.974	(3.974)
Time Delay Relay	2	0.398	0.103	(0.103)
Low Power EM Relay (SPST)	11	0.730	0.125	(0.125)
High Power EM Relay	18	2.225	0.255	(0.255)
Light Emitting Diode	28	40.115	8.023	1.610
λ (Failures/1x10^6 hours)		66.593	12.480	6.067
MTBF (hours)		15,017	80,128	164,826

B-1b Medium Usage

Com Qual: λ = (24/6)(66.593-40.115) + 40.115 = 146.027
MTBF = 6,848 hours

MIL-STD Qual: λ = (24/6)(12.480-8.023) + 8.023 = 25.851
MTBF = 38,683 hours

HI-REL Qual: λ = (24/6)(6.067-1.610) + 1.610 = 19,438
MTBF = 51,446 hours

B-1c Heavy Usage

Com Qual: λ = (144/6)(66.953-40.115) + 40.115 = 684.227
MTBF = 1,462 hours

MIL-STD Qual: λ = (144/6)(12.480-8.023) + 8.023 = 114.991
MTBF = 8,696 hours

HI-REL Qual: λ = (144/6)(6.067-1.610) + 1.610 = 108.578
MTBF = 9,210 hours

B-2 HYBRID EM RELAY LDU

B-2a NOMINAL USAGE

Component Type	Quan	Quality: Com	MIL-STD	HI-REL
Logic Relay (PDT Low Power)	82	23.125	3.974	(3.974)
Time Delay Relay	2	0.398	0.103	(0.103)
Low Power EM Relay (SPST)	11	0.730	0.125	(0.125)
Solid State Relay	18	4.145	0.833	0.166
Light Emitting Diode	28	40.115	8.023	1.610
High Power EM Relay	1	0.124	0.014	(0.014)
λ (Failure/1x10^6 hours)		68.837	13.072	5.992

MTBF (hours)	14,527	76,650	166,889

B-2b MEDIUM USAGE

Com Qual $\lambda = (24/6)(68.837-40.115) + 40.115 = 155.003$

MTBF = 6,451 hours

MIL-STD Qual $\lambda = (24/6)(13.072-8.023) + 8.023 = 28.219$

MTBF = 35,437 hours

B-2c HEAVY USAGE

Com Qual $\lambda = (144/6)(68.837-40.115) + 40.115 = 729.443$

MTBF = 1,371 hours

MIL-STD Qual $\lambda = (144/6)(13.072-8.023) + 8.023 = 129.199$

MTBF = 7,740 hours

HI-REL Qual $\lambda = (144/6)(5.992-1.610) + 1.610 = 106.778$

MTBF = 9,365 hours

B-3 STATIC LOGIC LDU

B-3a NOMINAL USAGE

		Quality		
Component Type	Quan	Com	MIL-STD	HI-REL
DC/DC Converter	82	1226.940	245.903	49.036
SSI Logic Chip	49	298.876	179.325	9.962
Timer Chip	2	23.529	14.079	0.784
Solid State Relay	29	6.677	1.341	0.267
Light Emitting Diode	28	40.115	8.023	1.610
High Power EM Relay	1	0.124	0.014	(0.014)
Logic Power Supply	1	3.690	2.220	(2.220)
λ (Failure/1x10^6 hours)		1599.951	450.905	63.893
MTBF (hours)		625	2,218	15,651

B-3b MEDIUM USAGE

Com Qual $\lambda = 1599.951 + (\frac{24}{6} - 1)(6.677 + 0.124) = 1620.354$

MTBF = 617 hours

MIL-STD Qual $\lambda = 450.905 + (\frac{24}{6} - 1)(1.341 + 0.014) = 454.97$

MTBF = 2,198 hours

HI-REL Qual $\lambda = 63.833 + (\frac{24}{6} - 1)(0.267 + 0.014) = 64.676$

MTBF = 15,462 hours

B-3c HEAVY USAGE

Com Qual $\lambda = 1599.951 + (\frac{144}{6} - 1)(6.677 + 0.124) = 1756.374$

MTBF = 569 hours

MIL-STD Qual $\lambda = 450.95\ (\frac{144}{6} - 1)(6.677 + 0.124) = 607.328$

MTBF = 1,647 hours

HI-REL Qual $\lambda = 63{,}833 + (\frac{144}{6} - 1)(0.267 + 0.014) = 70{,}296$

MTBF = 14,226 hours

B-4 NON-LSI PROGRAMMABLE CONTROLLER LDU

B-4a NOMINAL USAGE

Component Type	Qua	Quality Com	MIL-STD	HI-REL
DC/DC Converter	82	1226.940	245.803	49.036
SSI Logic Chip	25	152.488	91.493	5.083
MSI Logic Chip	10	196.845	118.107	6.562
ROM Chips	8	57.776	34.664	1.928
Timer Chips	10	117.000	70.200	3.900
Solid State Relay	29	6.677	1.341	0.267
Light Emitting Diode	28	40.115	8.023	1.610
High Power EM Relay	1	0.124	0.014	(0.014)
Logic Power Supply	1	3.690	2.220	(2.220)
λ (Failure/$1\text{x}10^6$ hours)		1802.047	571.865	70.620
MTBF (hours)		555	1,749	14,160

B-4b MEDIUM USAGES

Com Qual $\lambda = 1802.047 + (\frac{24}{6} - 1)(6.677 + 0.24) = 1822.450$

MTBF = 549 hours

MIL-STD Qual $\lambda = 571.865 + (\frac{24}{6} - 1)(1{,}341 + 0.014) = 575.930$

MTBF = 1,736 hours

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HI-REL Qual $\lambda = 70.620 + (\frac{24}{6} - 1)(0.267 + 0.014) = 71.463$

MTBF = 13,993 hours

B-4c HEAVY USAGE

Com Qual $\lambda = 1802.047 + (\frac{144}{6} - 1)(6.677 + 0.124) = 1958.470$

MTBF = 511 hours

MIL-STD Qual $\lambda = 571.865 + (\frac{144}{6} - 1)(1.341 + 0.014) = 603.030$

MTBF = 1,658 hours

HI-REL Qual $\lambda = 70.620 + (\frac{144}{6} - 1)(0.267 + 0.014) = 77.083$

MTBF = 12,973 hours

B-5 LSI PROGRAMMABLE CONTROLLER LDU

B-5a NOMINAL USAGE

		Quality		
Component Type	Quan	Com	MIL-STD	HI-REL
DC/DC Converter	82	1226.940	245.803	49.036
SSI Logic Chip	25	152.488	91.493	5.083
MSI Logic Chip	5	98.423	59.054	3.281
LSI Chip (8080 uProc)	1	350.543	210.326	11.685
ROM Chip	8	57.776	34.664	1.928
Timer Chip	10	117.000	70.200	3.900
Solid State Relay	29	6.677	1.341	0.297
Light Emitting Diode	28	40.115	8.023	1.610
High Power EM Relay	1	0.124	0.014	(0.014)
Logic Power Supply	1	3.690	2.220	(2.220)
λ (Failure/1×10^6 hours)		2053.776	723.138	79.054
MTBF (hours)		487	1,383	12,650

B-5b MEDIUM USAGE

Com Qual $\lambda = 2053.776 + (\frac{24}{6} - 1)(6.677 + 0.124) = 2074.179$

MTBF = 482 hours

MIL-STD Qual $\lambda = 723.138 + (\frac{24}{6} - 1)(1.341 + 0.014) = 727.203$

MTBF = 1,375 hours

HI-REL Qual $\lambda = 79.054 + (\frac{24}{6} - 1)(0.267 + 0.014) = 79.897$

MTBF = 12,516 hours

B-5c *HEAVY USAGE*

Com Qual $\lambda = 2053.776 + (\frac{144}{6} - 1)(6.677 + 0.124) = 2210.199$

MTBF = 452 hours

MIL-STD Qual $\lambda = 723.138 + (\frac{144}{6} - 1)(1.341 + 0.014) = 754.303$

MTBF = 1,326 hours

HI-REL Qual $\lambda = 79.054 + (\frac{144}{6} - 1)(0.267 + 0.014) = 85.517$

MTBF = 11,694 hours

B-6 VLSI PROGRAMMABLE CONTROLLER LDU

B-6a NOMINAL USAGE

		Quality		
Component Type	Quan	Com	MIL-STD	HI-REL
DC/DC Converter	82	1226.940	245.803	49.036
SSI Chip	25	152.488	91.493	5.083
MSI Chip	5	98.423	59.054	3.281
LSI Chip (9900 uProc)	1	408.293	244.976	13.610
ROM Chip	16	115.552	69.328	3.856
Timer Chip	10	117.000	70.200	3.900
Solid State Relay	29	6.677	1.341	0.297
Light Emitting Diode	28	40.115	8.023	1.610
High Power EM Relay	1	0.124	0.014	(0.014)
Logic Power Supply	1	3.690	2.220	(2.220)
λ (Failure/$1x10^6$ hours)		2169.302	795.452	82.907
MTBF (hours)		461	1,257	12,062

B-6b MEDIUM USAGE

Com Qual

$$\lambda = 2169.302 + (\frac{24}{6} - 1)(6.677 + 0.124) = 2{,}189.705$$

MTBF = 457 hours

MIL-STD Qual

$$\lambda = 795.452 + (\frac{24}{6} - 1)(1.341 + 0.014) = 799.517$$

MTBF = 1,251 hours

HI-REL Qual

$$\lambda = 82.907 + (\frac{24}{6} - 1)(0.267 + 0.014) = 83.750$$

MTBF = 11,940 hours

B-6c HEAVY USAGE

Com Qual

$$\lambda = 2169.302 + (\frac{144}{6} - 1)(6.677 + 0.124) = 2{,}325.725$$

MTBF = 430 hours

MIL-STD Qual

$$\lambda = 795.452 + (\frac{144}{6} - 1)(1.341 + 0.014) = 826.617$$

MTBF = 1,210 hours

HI-REL Qual

$$\lambda = 82.907 + (\frac{144}{6} - 1)(0.267 + 0.014) = 89.370$$

MTBF = 11,189 hours

APPENDIX C SUMMARY OF THE EM 3 & 2 RATE TRAINING MANUAL NAVEDTRA 10546-D

This Rate Training Manual provides information related to the tasks assigned to the EM 3 & 2 who operate and maintain a variety of electrical/electromechanical/electronic equipment as indicated below:

A. Power Generation and Distribution (AC and DC)

- Generators
- Controllers
- Switching
- Cabling

B. Lighting

- Lighting Fixtures
- Incandescent Lamps
- Fluorescent Lamps
- Cabling
- Circuit Breakers
- Navigation and Signal Lights
- Searchlights

C. Ship Degaussing (Manual and Automatic)

- Degaussing Coils
- Motor-Generator
- Rheostat Control

D. Electrical Propolsion

- Generators
- Motors
- Control Consoles

E. Central Operations Systems

- Generators
- Propulsion
- Boilers — Engine Room Console
- Auxiliaries
- Data Logger
- Throttle Control

F. Auxiliaries

- Storage Batteries/Battery Charger
- Internal Combustion Engine Electrical Equipment
- Electromechanical Steering Gear
- Winches
- Elevators
- UNREP Equipment
- Electric Fork Lift
- Electric Gallery Equipment
- Electric Laundry Equipment

G. Sensing Switches

- Pushbutton
- Limit
- Pressure
- Temperature
- Float
- Proximity

H. Electronic Components

- Resistors
- Capacitors
- Transformers
- Electron Tubes
- Semiconductor Devices

I. Relays

- Logic
- Power Switching
- Current Direction Sensing
- Power Direction Sensing
- Phase Failure Sensing

J. Sound Motion Picture Equipment

The Rate Training Manual also introduces the EM 3 & 2 to the symbols and elementary operations of logical devices such as:

- And/Nand Gate
- Or/Nor Gate

- Flip/Flops
- Single Shot Multivibrator
- Schmitt Trigger
- Memory
- Pulsers
- Steppers
- Amplifiers
- Logic Diagrams
- Relay Logic
- Semiconductor Logic

The manual also describes the following listed test equipment the EM 3 & 2 is expected to operate and usually maintain.

1. Tachometers (mechanical and stroboscopic)
2. Multimeters (electronic and non-electronic)
3. Wheatstone bridge
4. Cathode ray oscilloscope
5. Audio signal generator
6. Digital voltmeter

APPENDIX D - OCCUPATIONAL STANDARDS FOR THE ELECTRICIAN'S MATE (EM)

The following information has been taken in toto from NAVPERS 18068D, Manual of Enlisted Manpower and Personnel Classifications and Occupational Standards.

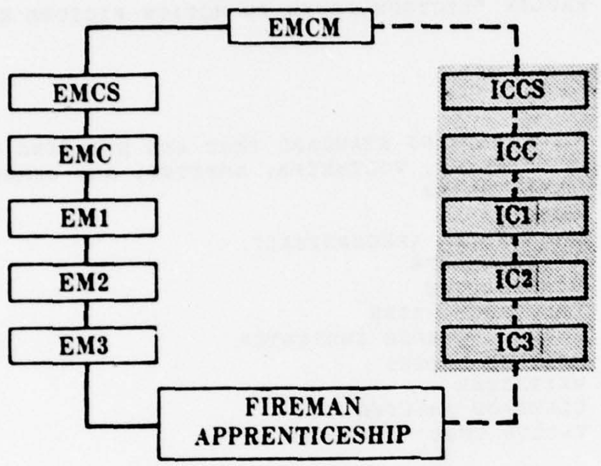
ELECTRICIAN'S MATE

(EM)

Electrician's Mates (EM) stand watch on generators, switchboards, control equipment, and electrical equipment; operate and perform organizational and intermediate maintenance on power and lighting circuits, electrical fixtures, film projectors, motors, generators, voltage and frequency regulators, controllers, distribution switchboards, and other electrical equipment; test for short circuits, ground or other casualties; and rebuild electrical equipment, including solid state circuitry elements, in an electrical shop.

GENERAL INFORMATION

CAREER PATTERN



Normal path of advancement to Warrant Officer and Limited Duty Officer categories is to Engineering Technician (713X/723X) and LDO Engineering/Repair (613X/623X), *or to Nuclear Power Technician* (715X/725X) and LDO Nuclear Power (615X/625X).

SPECIAL PHYSICAL REQUIREMENTS

Normal color perception.

CITIZENSHIP/SECURITY REQUIREMENTS

EMCM - must be eligible for access to classified information.

SAFETY

The observance of proper safety precautions in all areas is an integral part of each billet and the responsibility of every Navy man & woman; therefore, it is a universal requirement for all ratings.

ELECTRICIAN'S MATE THIRD CLASS (EM3)

14 ELECTRONICS MAINTENANCE

14668 REPLACE FAULTY ELECTRON TUBES IN MOTION-PICTURE EQUIPMENT

18 TEST EQUIPMENT

18446 OPERATE THE FOLLOWING STANDARD TEST AND METERING EQUIPMENT:
- A. MULTIMETER, VOLTMETER, AMMETER, AND OHMMETER
- B. TUBE TESTER
- C. MEGGER
- D. TACHOMETER (MECHANICAL)
- E. OSCILLOSCOPE
- F. STROBOSCOPE
- G. FREQUENCY METER
- H. PHASE-SEQUENCE INDICATOR
- I. VOLTAGE TESTER
- J. WATTMETER
- K. CLAMP-ON AMMETER
- L. VACUUM TUBE VOLTMETER

24 ELECTRICAL MAINTENANCE

24030 USE AMERICAN STANDARD WIRE GAGE, PREPARE WIRE FOR INSTALLATION, AND MAKE STANDARD SPLICES

24432 IDENTIFY LUBRICANTS, CLEANING MATERIALS, AND SOLVENTS USED IN MAINTENANCE OF ELECTRICAL EQUIPMENT

24433 REPLACE BLOWN FUSES

24434 DETECT AND LOCATE GROUNDS, OPEN CIRCUITS, AND SHORT CIRCUITS IN LIGHTING AND POWER CIRCUITS

24435 SOLDER ELECTRICAL CONNECTIONS AND SPLICES

24436 IDENTIFY THE FOLLOWING:
- A. CABLE MARKING
- B. EQUIPMENT MARKING
- C. PANEL MARKING
- D. SWITCH MARKING
- E. PHASE AND POLARITY MARKING

24437 IDENTIFY TYPES OF INSULATING MATERIALS AND VARNISHES

24438 EXAMINE MOTORS AND GENERATORS UNDER "LOAD" AND "NO-LOAD" CONDITIONS FOR CLEANLINESS, VIBRATION, UNUSUAL OR EXCESSIVE NOISE, HEATING, LUBRICANT LEAKAGE, AND CONDITION OF BRUSHES, COMMUTATORS, COLLECTOR RINGS, BEARINGS, AND BOLTS

24439 CLEAN AND LUBRICATE ELECTRIC MOTORS AND MOTOR-GENERATOR SETS

24440 OPERATE THE FOLLOWING:
- A. A SINGLE A.C. OR D.C. GENERATOR
- B. AN A.C. OR D.C. GENERATOR OPERATING IN PARALLEL

24 ELECTRICAL MAINTENANCE - CONTINUED

24441 MEASURE INSULATION RESISTANCE OF ALTERNATORS, GENERATORS, AND EXCITERS

24442 DETECT AND LOCATE GROUNDS, OPEN CIRCUITS, AND SHORT CIRCUITS IN A.C. AND D.C. MOTORS AND CONTROLLERS

24443 REPLACE GENEPATOR AND MOTOR BEARINGS

24445 REPLACE PORTABLE STORAGE AND DRY CELL BATTERIES

24446 REPLACE WORN GASKETS AND SEALS OF WATERTIGHT ELECTRICAL FIXTURES

24447 REPAIR PORTABLE ELECTRIC TOOLS, PORTABLE LIGHTS, AND FANS

24448 PREPARE, ACTIVATE, AND PLACE IN SERVICE NEW STORAGE BATTERIES

24449 LOG HYDROMETER READINGS ON STORAGE BATTERIES

24450 DETERMINE BATTERY CONDITION

24451 TROUBLESHOOT AND REPAIR SMALL BOAT ELECTRICAL SYSTEMS

24452 OPERATE AUTOMATIC BUS TRANSFER (ABT) SWITCHES

24453 TEST, INSPECT, ADJUST, CLEAN, LUBRICATE, AND REPAIR SIGNAL LIGHTS, SEARCHLIGHTS, RUNNING LIGHTS, ANCHOR LIGHTS AND ROTARY BEACONS

24454 OPERATE DEGAUSSING EQUIPMENT

24455 PROVIDE EMERGENCY POWER TO MAIN DISTRIBUTION BOARD FROM EMERGENCY SWITCHBOARD THROUGH FEEDBACK SWITCH

24466 MAINTAIN ELECTRIC RANGE, OVEN AND DEEP FAT FRYER INCLUDING CALIBRATING THERMOSTATS

24486 INTERPRET COLOR CODING OF CAPACITORS, RESISTORS, MULTICONDUCTOR CABLES, CHASSIS WIRING, AND TRANSFORMER WIRING

24493 TEST AND REPAIR OR REPLACE THE FOLLOWING:

A. PORTABLE CABLES
B. SELF-CONTAINED RELAYS (PLUG-IN)
C. LAMPS, FUSES, AND TUBES
D. MULTICONDUCTOR CONNECTORS AND RECEPTACLES
E. SOLENOIDS
F. INDUCTORS
G. CAPACITORS
H. RECTIFIERS
I. RELAYS
J. SWITCHES

24494 COMPUTE THE FOLLOWING:

A. RESISTANCE, INDUCTANCE, AND CAPACITANCE IN A.C. CIRCUITS
B. CURRENT, VOLTAGE, POWER, PHASE ANGLE, IMPEDANCE, AND RESONANT FREQUENCY IN A.C. SERIES AND PARALLEL CIRCUITS
C. CURRENT, VOLTAGE, POWER, AND RESISTANCE IN D.C. SERIES AND PARALLEL CIRCUITS

ELECTRICIAN'S MATE THIRD CLASS (EM3)

24 ELECTRICAL MAINTENANCE - CONTINUED

24511 INSPECT AND CORRECT DEFICIENCIES IN:
- A. BRUSH PIGTAILS
- B. BRUSH ALIGNMENT AND DISTANCE
- C. BRUSH HOLDERS
- D. BRUSH PRESSURE

24544 PREPARE EMERGENCY DIESEL GENERATORS FOR AUTOMATIC OPERATION

28 TECHNICAL DRAWINGS

28391 READ, INTERPRET, AND WORK FROM SCHEMATIC DIAGRAMS AND BLUEPRINTS OF BASIC ELECTRICAL, ELECTRONIC AND LOGIC CIRCUITS

42 GENERAL WATCHSTANDING

42341 STAND ELECTRICAL WATCH AT THE FOLLOWING STATIONS:
- A. STEERING ENGINEROOM
- B. ANCHOR WINDLASS
- C. HOIST EQUIPMENT AND/OR ELEVATOR
- D. DEGAUSSING SWITCHBOARD
- E. EMERGENCY SWITCHBOARD

42349 STAND WATCH ON A.C. OR D.C. SHIP'S SERVICE GENERATOR AND DISTRIBUTION SWITCHBOARD

42350 MAINTAIN REQUIRED RECORDS AT WATCH STATION

46 PUBLICATIONS

46113 USE AND MAINTAIN TECHNICAL AND MAINTENANCE MANUALS

50 MAINTENANCE PLANNING AND QUALITY ASSURANCE

50303 USE MAINTENANCE REQUIREMENT CARDS (MRC)

50928 PREPARE A MAINTENANCE DATA FORM FOR:
- A. COMPLETED MAINTENANCE ACTIONS (MAF)
- B. DEFERRED MAINTENANCE ACTIONS
- C. WORK REQUESTS

54 LOGISTICS SUPPORT

54633 PACKAGE, PROCESS, AND DOCUMENT REPAIRABLES FOR TURN-IN

54634 PREPARE MOTION-PICTURE FILM FOR TRANSFER AND STOWAGE

54800 IDENTIFY CATEGORIES OF MATERIAL CONTAINED IN EACH VOLUME OF COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL)

ELECTRICIAN'S MATE THIRD CLASS (EM3)

94 MECHANICAL MAINTENANCE

94579 PERFORM PREVENTIVE MAINTENANCE ON MOTION-PICTURE PROJECTOR

95 AUDIO-VISUAL TRAINING AID EQUIPMENT

95315 OPERATE MOTION-PICTURE PROJECTORS FOR SINGLE AND DUAL OPERATION

95316 INSPECT, REWIND, SPLICE, AND PREPARE FILM FOR PROJECTION

98 ENVIRONMENTAL POLLUTION CONTROL

98242 PERFORM TASKS ASSOCIATED WITH ENVIRONMENTAL AND POLLUTION CONTROL PROGRAMS

ELECTRICIAN'S MATE SECOND CLASS (EM2)

14 ELECTRONICS MAINTENANCE

14670 TEST AND REPAIR OR REPLACE THE FOLLOWING:
A. INSTALLED MULTICONDUCTOR CABLES
B. POTENTIOMETERS, TRANSFORMERS, RESISTORS, AND CAPACITORS
C. SEMI-CONDUCTOR CIRCUITRY
D. AUTOMATIC VOLTAGE REGULATORS (A.C. AND D.C.)
E. CHASSIS WIRING
F. MECHANICAL CONTROLLERS
G. MODULES, MODULE CARDS, ASSEMBLIES, SUB-ASSEMBLIES AND COMPONENTS IN ELECTRONIC EQUIPMENT
H. LOGIC CIRCUITS
I. TUNED CIRCUITS
J. OSCILLATORS
K. MULTIVIBRATORS AND PULSE SHAPING EQUIPMENT

14671 IDENTIFY CIRCUIT LOADING EFFECTS OF TEST EQUIPMENT

14672 PERFORM ELECTRONIC SERVICING OF FILM PROJECTOR

18 TEST EQUIPMENT

18449 OPERATE AND USE SIGNAL GENERATOR

18450 OPERATE INSTRUMENT TRANSFORMER

24 ELECTRICAL MAINTENANCE

24456 DETECT AND LOCATE GROUNDS, OPEN CIRCUITS, AND SHORT CIRCUITS IN DEGAUSSING SYSTEMS

24457 MAINTAIN CIRCUIT BREAKERS

24458 PERFORM CORRECTIVE MAINTENANCE ON MOTION-PICTURE PROJECTION EQUIPMENT AT SHIPBOARD LEVEL

24459 TEST AND UNDERCUT ARMATURE COMMUTATORS

24460 CONDUCT BENCH TESTS ON MOTOR AND GENERATOR WINDINGS

24461 MAINTAIN AND REPAIR STATIC INVERTERS

24462 OPERATE AND MAINTAIN A.C. AND D.C. SHIP PROPULSION EQUIPMENT

24463 INSPECT AND CORRECT DEFICIENCIES IN COLLECTOR RINGS

24464 PERFORM BENCH-TEST OF CONTROLLERS AND INSERT NEW CONTACT POINTS; REPAIR BAKELITE PANELS

24465 MAINTAIN ELECTRICAL COMPONENTS OF INSTALLED WASHERS, DRYERS, AND EXTRACTORS

ELECTRICIAN'S MATE SECOND CLASS (EM2)

24 ELECTRICAL MAINTENANCE - CONTINUED

24467 INSTALL NEW POWER AND LIGHTING CIRCUITS

24468 CONNECT SHORE POWER TO MAIN DISTRIBUTION BOARD

24469 TEST, REMOVE, AND INSTALL INSTRUMENT TRANSFORMERS AND METERS ON POWER LIGHTING SWITCHBOARDS AND CONTROL PANELS

24470 LOCATE ALARM AND INDICATING ACO SWITCHBOARDS FOR SHIPS CONTROL, INDICATING AND PROPULSION SYSTEMS FOR NORMAL, EMERGENCY AND CASUALTY CONDITIONS

24471 IDENTIFY SHIP CONTROL AND ALARM CIRCUITS AND CABLES BY CIRCUIT DESIGNATION

24521 INSPECT AND MAINTAIN:

A. BATTERY CHARGERS
B. HELD STARTING UNITS
C. CATHODE PROTECTIVE UNITS
D. AIR-CONDITIONING CONTROL CIRCUITS
E. DEHYDRATOR AIR DRIERS
F. AIR COMPRESSOR CONTROL CIRCUITS
G. ELECTROSTATIC VENT FOG PRECIPITATOR
H. NO-BREAK POWER SUPPLIES
I. HOIST/WINCH SYSTEMS
J. TRANSFER-AT-SEA EQUIPMENT CONTROLS

28 TECHNICAL DRAWINGS

28393 INTERPRET DRAWINGS AND DEGAUSSING CHART

50 MAINTENANCE PLANNING AND QUALITY ASSURANCE

50632 COMPLETE PLANNED MAINTENANCE SUB-SYSTEM (PMS) FEEDBACK REPORTS

54 LOGISTICS SUPPORT

54801 INVENTORY INSTALLED EQUIPMENT AND VERIFY SPARE PART SUPPORT IN COSAL

54802 ORDER REPAIR PARTS AND SPECIAL TOOLS REQUIRED FOR INSTALLED EQUIPMENT MAINTENANCE USING COSAL

ELECTRICIAN'S MATE FIRST CLASS (EM1)

18 TEST EQUIPMENT

18442	DETERMINE APPROPRIATE TEST EQUIPMENT FOR TESTS AND MEASUREMENTS

24 ELECTRICAL MAINTENANCE

24472	ISOLATE GROUNDS, OPEN CIRCUITS, AND SHORT CIRCUITS IN SHIP'S SERVICE AND EMERGENCY GENERATORS AND ASSOCIATED SWITCH GEAR
24473	INSPECT AND TEST-OPERATE AUTOMATIC STARTING EQUIPMENT OF EMERGENCY GENERATORS
24474	CONDUCT BENCH TESTS ON ELECTRIC GOVERNORS
24475	CHECK LOGIC OR SOLID STATE ELECTRO-HYDRAULIC CONTROLLERS
24476	TEST, INSPECT, AND DIRECT REPAIRS OF AUTOMATIC DEGAUSSING EQUIPMENT
24477	INSPECT SHIP'S SERVICE AND EMERGENCY SWITCHBOARD EQUIPMENT WHEN POWER IS SECURED
24478	ESTIMATE EXTENT OF CASUALTY TO EQUIPMENT UNDER EM COGNIZANCE
24479	IDENTIFY AND CLASSIFY CASUALTIES OF MOTION-PICTURE PROJECTION EQUIPMENT AS REPAIRABLE AT SHIPBOARD OR TENDER LEVEL
24480	REMOVE, TEST, AND REPLACE DEFECTIVE COMPONENTS IN AUTOMATIC-DEGAUSSING CONTROL PANELS
24491	DETERMINE TYPE AND VALUE OF ACCEPTABLE SUBSTITUTE COMPONENTS

50 MAINTENANCE PLANNING AND QUALITY ASSURANCE

50934	CHECK ELECTRICAL OPERATING LOGS AND MAINTENANCE RECORDS TO DETERMINE IF EQUIPMENT IS OPERATING PROPERLY
50986	REVIEW COMPLETED MAINTENANCE DATA COLLECTION SUB-SYSTEM (MDCS) FORMS
50987	PREPARE WEEKLY SCHEDULES OF PREVENTIVE MAINTENANCE

54 LOGISTICS SUPPORT

54827	POST CHANGES AND ADDITIONS TO COSAL

APPENDIX E - TASK INVENTORY OF ELECTRICIAN'S MATES ON AIRCRAFT CARRIERS CV59, CV62, CV63 AND CV64

The Navy Occupational Task Analysis Program (NOTAP) is a Department of the Navy occupational development and analysis center which reports to PERS-23. NOTAP gathers and processes data concerning what tasks Navy personnel are performing. They recently completed a task inventory of the Electrician's Mate (EM). This task inventory included data from four of the six carriers that have the IWHS weapons elevators. The NOTAP data is included in this report to present specific information regarding what percentage of the EM's work on weapons elevators, and what percent of their time is spent working on the elevators. This information is indicated in several tasks but especially Tasks M1 through M5. The complete aircraft carrier task inventory is included in this appendix to give an insight into the total EM duties.

JOB DESCRIPTIONS OF
EM - ELECTRICTION MATE
WEAPONS ELEVATOR MAITENANCE

DUTY JOB DESCRIPTION	CASES	TASKS	DUTIES	MEMBERS
	2563	543	26	263

COUNT OF DUTIES OR TASKS LISTED.......................................
CUMULATIVE SUM OF AVERAGE PERCENT TIME SPENT BY ALL MEMBERS..........
AVERAGE PERCENT TIME SPENT BY ALL MEMBERS.................
AVERAGE PERCENT TIME SPENT BY MEMBERS PERFORMING....
PERCENT OF MEMBERS PERFORMING.................

ORDERED BY DUTY IDENTIFIERS.

D-TSK	DUTY TITLE	%	%	%	%	N
****						
A	MANAGEMENT	57.03	6.63	3.78	3.78	
B	SUPERVISION	55.13	5.59	3.08	6.86	
C	ADMINISTRATION	74.14	5.41	4.01	10.87	
D	TRAINING	44.48	5.02	2.23	13.10	
E	SUPPLY/FISCAL	63.12	5.96	3.78	16.88	5
F	PLANNED MAINTENANCE SYSTEM	53.99	8.59	4.64	21.52	
G	POWER GENERATION (GENERAL)	35.36	5.75	2.03	23.55	
H	POWER GENERATION (SPECIFIC)	35.36	7.04	2.49	26.04	
I	GENERAL ELECTRICAL MAINTENANCE	78.32	7.83	6.13	32.17	
J	POWER DISTRIBUTION	88.21	15.83	13.96	46.14	10
K	ELECTRONIC CONTROLLED EQUIPMENT (STATIC/SOLID STATE)	15.59	4.58	0.71	46.85	
L	AUDIO VISUAL EQUIPMENT	9.50	10.99	1.04	47.89	
M	HEAVY POWER EQUIPMENT	41.06	13.57	5.57	53.46	
N	LIGHT POWER EQUIPMENT	66.16	8.21	5.43	58.90	
P	AVIATION SYSTEMS EQUIPMENT	23.19	21.84	5.06	63.96	15
R	SHOP REPAIR OPERATIONS	54.37	6.84	3.72	67.68	
S	CONTROLLERS AND MOTORS	61.98	13.03	8.06	75.74	
T	SPECIAL SYSTEMS (INTERIOR COMMUNICATIONS RELATED FUNCTIONS)	15.59	4.33	0.67	76.41	
U	AUTOMATED PROPULSION SYSTEM	12.16	5.39	0.65	77.06	
V	ALARMS	2.66	2.56	0.07	77.13	20
W	LIGHTING	47.91	13.98	6.70	83.83	
X	ELECTRICALLY DRIVEN VEHICLES	0.76	6.44	0.05	83.88	
Y	HOTEL SERVICES EQUIPMENT	20.15	16.62	3.35	87.22	
Z	GENERAL MILITARY DUTIES	93.54	13.48	12.60	99.83	

JOB DESCRIPTIONS OF
EM - ELECTRICTION MATE
WEAPONS ELEVATOR MAITENANCE

TASK JOB DESCRIPTION	CASES	TASKS	DUTIES	MEMBERS
	2563	543	26	263

COUNT OF DUTIES OR TASKS LISTED..
CUMULATIVE SUM OF AVERAGE PERCENT TIME SPENT BY ALL MEMBERS............
AVERAGE PERCENT TIME SPENT BY ALL MEMBERS...................
AVERAGE PERCENT TIME SPENT BY MEMBERS PERFORMING....
PERCENT OF MEMBERS PERFORMING..... ....

ORDERED BY TASK IDENTIFIERS.

D-TSK ####	TASK TITLE	%	%	%	%	N
A 1	REVIEW ENLISTED PERFORMANCE EVALUATIONS (DEPARTMENT/ DIVISION LEVEL)	19.39	1.26	3.24	0.24	
A 2	MAKE PERSONNEL ASSIGNMENTS	39.92	1.91	0.76	1.00	
A 3	ASSIGN WORK PRIORITIES	33.84	2.09	3.71	1.71	
A 4	WRITE BILLET/JOB DESCRIPTIONS	13.69	1.33	0.18	1.89	
A 5	SCREEN MESSAGES, BULLETINS, CORRESPONDENCE, AND OTHER DIRECTIVES FOR APPROPRIATE ACTION	12.92	1.75	3.22	2.11	
A 6	REVIEW MANPOWER REQUIREMENTS	11.78	1.33	3.16	2.27	
A 7	COORDINATE WITH MILITARY ACTIVITIES FOR REQUIRED MAINTENANCE	17.11	1.90	0.32	2.59	
A 8	INITIATE ACTION TO OBTAIN REQUIRED PERSONNEL FOR OWN AREA OF RESPONSIBILITY	22.81	1.77	0.40	2.99	
A 9	MONITOR TRAINING PROGRAM	16.35	1.32	3.21	3.23	
A 1J	REPRESENT COMMAND AT CONFERENCES AND MEETINGS	6.46	0.82	0.05	3.26	
A 11	EVALUATE OPERATIONAL COMMITMENTS IN ORDER TO SCHEDULE WORK LOAD	14.45	1.48	3.21	3.47	
A 12	PERFORM AS A MEMBER OF AN OPERATIONAL READINESS INSPECTION (ORI) TEAM	4.56	1.20	0.05	3.52	
A 13	PREPARE CASUALTY REPORTS (CASREPS)	9.88	0.93	0.09	3.61	
A 14	PREPARE SITUATION REPORTS (SITREPS)	7.60	0.93	3.37	3.68	
A 15	PREPARE CASUALTY CORRECTION REPORTS (CASCOR)	6.46	1.09	0.07	3.74	
B 1	WRITE ENLISTED PERFORMANCE EVALUATIONS ON SUBORDINATES	25.36	1.75	3.44	4.18	
B 2	MAKE WORK ASSIGNMENTS	40.68	2.06	0.84	5.02	
B 3	PREPARE WATCH BILL	21.29	1.96	0.42	5.44	
B 4	ENSURE WORK ASSIGNED TC SUBORDINATES IS COMPLETED	45.62	2.15	0.98	6.42	
B 5	COORDINATE WORK WITHIN DIVISION	20.91	1.66	0.34	6.76	
B 6	SERVE AS A MEMBER CF CCMMAND BOARDS/COMMITTEES (SUCH AS WELFARE AND RECREATION COMMITTEE, HUMAN RELATIONS COUNCIL)	3.80	1.49	0.06	6.82	
C 1	DRAFT NAVAL MESSAGES	2.28	1.49	0.03	6.85	
C 2	DRAFT NAVAL LETTERS	2.28	1.76	0.04	6.89	

D-TSK	TASK TITLE	%	%	%	%	N
****						
C 3	DRAFT BUSINESS LETTERS	3.42	1.78	0.06	6.95	
C 4	DRAFT SPEEDLETTERS	1.90	1.20	0.02	6.97	25
C 5	MAINTAIN TICKLER FILE	3.42	1.45	0.05	7.02	
C 6	UPDATE PUBLICATIONS/INSTRUCTIONS (PEN AND INK AND PAGE CHANGES)	10.64	1.34	0.14	7.16	
C 7	MAINTAIN CORRESPONDENCE/MESSAGE FILES	7.98	1.87	0.15	7.30	
C 8	TYPE CORRESPONDENCE/FORMS	3.42	2.09	0.07	7.37	
C 9	TYPE NAVAL MESSAGES	1.14	1.53	0.02	7.39	30
C 10	MAINTAIN BULLETIN BOARDS	9.88	1.54	0.15	7.54	
C 11	ROUTE CORRESPONDENCE/PUBLICATIONS/INSTRUCTIONS,ETC.	6.08	1.61	0.10	7.64	
C 12	MAINTAIN DIVISION OFFICER'S NOTEBOOK	4.18	1.46	0.06	7.70	
C 13	MAINTAIN STATUS BOARDS	17.49	1.56	0.27	7.97	
C 14	DISTRIBUTE SAFETY MATERIAL (SUCH AS PUBLICATIONS AND POSTERS)	9.88	1.34	0.13	8.10	35
C 15	DRAFT INSTRUCTIONS/NOTICES	3.42	1.42	0.05	8.15	
C 16	REVIEW (CHOP) OUTGOING CORRESPONDENCE/MESSAGES	2.66	1.60	0.04	8.19	
C 17	FILL OUT WORK REQUESTS/WORK ORDERS	39.16	1.78	0.70	8.88	
C 18	MAINTAIN LOGS (ANY TYPE OF OFFICIAL LOG)	61.98	2.50	1.55	10.43	
C 19	MAINTAIN LEAVE SCHEDULES	12.16	1.29	0.16	10.59	40
C 20	UPDATE RECALL BILL	8.36	1.02	0.08	10.67	
C 21	UPDATE WATCH, QUARTER, AND STATION BILL	12.16	1.04	0.12	10.80	
D 1	PREPARE INDIVIDUAL TRAINING RECORDS	10.26	1.08	0.11	10.90	
D 2	UPDATE INDIVIDUAL TRAINING RECORDS	11.02	1.25	0.14	11.04	
D 3	SCHEDULE TRAINING LECTURES	14.83	1.23	0.18	11.22	45
D 4	REVIEW LESSON GUIDES (INSTRUCTOR GUIDES) FOR ACCURACY AND COMPLETENESS	8.36	0.92	0.08	11.30	
D 5	ADMINISTER TESTS/EXAMINATIONS	6.08	1.03	0.06	11.36	
D 6	GRADE TESTS/EXAMINATIONS	5.70	0.93	0.05	11.41	
D 7	WRITE LESSON GUIDES (INSTRUCTOR GUIDES)	4.94	0.86	0.04	11.45	
D 8	PREPARE TRAINING REPORTS	10.26	1.41	0.14	11.59	50
D 9	WRITE TRAINING OUTLINES	6.46	0.92	0.06	11.65	
D 10	PREPARE TESTS/EXAMINATIONS	5.32	0.80	0.04	11.69	
D 11	SIGN OFF PRACTICAL FACTORS	34.98	1.56	0.54	12.23	
D 12	WRITE COURSES OF STUDY (CURRICULUMS)	2.66	1.07	0.03	12.26	
D 13	UPDATE TRAINING MATERIAL (SUCH AS INSTRUCTOR GUIDES OR PLANS)	3.34	0.82	0.02	12.28	55
D 14	CONDUCT CLASSROOM TRAINING (MILITARY/PROFESSIONAL)	12.92	1.41	0.18	12.46	
D 15	PREPARE TRAINING LECTURES	12.16	1.10	0.13	12.60	
D 16	CONSTRUCT TRAINING AIDS	4.56	0.72	0.03	12.63	
D 17	MAINTAIN/UPDATE PERSONNEL QUALIFICATION STANDARDS (PQS) CHART/RECORD	20.91	1.76	0.36	12.99	
E 1	ORDER PARTS, TOOLS, OR SUPPLIES	38.43	2.36	0.91	13.91	60
E 2	CONDUCT INVENTORY OF CONTROLLED EQUIPAGE (PLANT ACCOUNT PROPERTY)	9.50	1.67	0.16	14.05	
E 3	CONDUCT INVENTORY OF PARTS, TOOLS, OR SUPPLIES	28.14	1.99	0.56	14.61	
E 4	PICK UP PARTS, TOOLS, OR SUPPLIES	44.48	2.28	1.02	15.63	

D-TSK ####	TASK TITLE	%	%	%	%	N
E 5	TURN IN PARTS, TOOLS, OR SUPPLIES	25.09	2.26	0.57	16.20	
E 6	DRAFT SURVEYS ON LOST OR DAMAGED EQUIPMENT	8.74	1.09	0.09	16.29	65
E 7	MAKE SERVMART, SEAMART, OR SUBMART RUNS	19.77	1.76	0.35	16.64	
E 8	MAINTAIN DIVISION OPERATIONAL TARGET (OPTAR) ACCOUNTING RECORDS	3.80	1.66	0.06	16.70	
E 9	ENTER CHANGES TO SHIP EQUIPMENT CONFIGURATON ACCOUNTING SYSTEM (SECAS)	2.28	1.00	0.02	16.72	
E 10	VALIDATE COORDINATED SHIPBOARD/SHORE BASE ALLOWANCE LIST (COSAL)	5.70	0.65	0.04	16.75	
F 1	MAINT/IN/UPDATE PLANNED MAINTENANCE (PMS) CYCLE SCHEDULE	19.01	1.88	0.36	17.11	70
F 2	PREPARE/UPDATE PMS QUARTERLY SCHEDULE	22.05	1.88	0.42	17.52	
F 3	PREPARE/UPDATE PMS WEEKLY SCHEDULE	27.76	1.90	0.53	18.05	
F 4	MAINTAIN/UPDATE PMS SYSTEM WITH QUARTERLY FORCE REVISIONS (QFR)	15.21	1.73	0.26	18.31	
F 5	PREPARE DEFERRED ACTION, MAINTENANCE ACTION, AND WORK REQUEST FORMS (OPNAV 4790/2K, 2L)	28.90	1.68	0.48	18.80	
F 6	PREPARE FEEDBACK FORMS (OPNAV 4790/7B)	17.11	1.21	0.20	19.00	75
F 7	PREPARE EQUIPMENT GUIDE LISTS (EGL)	24.33	1.33	0.32	19.32	
F 8	PREPARE/UPDATE MANHOURS ACCOUNTING (MHA) FORMS	11.40	1.43	0.16	19.48	
F 9	CONDUCT SPOT CHECKS ON PMS ACTIONS	30.42	2.09	0.64	20.12	
F 10	MAINTAIN MAINTENANCE REQUIREMENT CARD (MRC) DECK	20.15	1.44	0.29	20.41	
F 11	SCREEN/REVIEW COMPLETED MAINTENANCE DATA COLLECTION SYSTEMS (MDCS) FORMS	10.64	1.37	0.14	20.55	80
F 12	REVIEW/UPDATE CURRENT SHIP'S MAINTENANCE PROJECTS (CSMP)	16.35	1.52	0.25	20.80	
F 13	MAINTAIN JOB SEQUENCE NUMBER (JSN) LOG	23.95	1.37	0.33	21.13	
F 14	REPORT PMS ACTIONS USING LOCAL FORMS	18.25	1.33	0.24	21.37	
G 1	CLEAN/LUBRICATE COMPONENTS OF GENERATORS/ALTERNATORS	25.85	1.54	0.40	21.76	
G 2	TEST/INSPECT COMPONENTS OF GENERATORS/ALTERNATORS	27.38	1.67	0.46	22.22	85
G 3	TROUBLESHOOT GENERATORS/ALTERNATORS	23.57	1.39	0.33	22.55	
G 4	ADJUST/ALIGN COMPONENTS OF GENERATORS/ALTERNATORS	21.67	1.35	0.29	22.84	
G 5	REMOVE/REPLACE COMPONENTS OF GENERATORS/ALTERNATORS	22.81	1.32	0.30	23.14	
G 6	CLEAN/LUBRICATE COMPONENTS OF HIGH VOLTAGE DIRECT CURRENT (HVDC) POWER SUPPLY SYSTEMS	6.46	0.98	0.06	23.20	
G 7	TEST/INSPECT COMPONENTS OF HVDC POWER SUPPLY SYSTEMS	6.84	0.84	0.06	23.26	90
G 8	TROUBLESHOOT HVDC POWER SUPPLY SYSTEMS	6.46	0.86	0.05	23.31	
G 9	ADJUST/ALIGN COMPONENTS OF HVDC POWER SUPPLY SYSTEMS	6.08	0.75	0.04	23.35	
G 10	REMOVE/REPLACE COMPONENTS OF HVDC POWER SUPPLY SYSTEMS	4.94	0.64	0.03	23.38	
H 1	CLEAN/LUBRICATE COMPONENTS OF 400HZ MOTOR/GENERATOR SETS (VOLTAGE AND FREQUENCY REGULATED)	17.49	0.96	0.16	23.54	
H 2	TEST/INSPECT COMPONENTS OF 400HZ M/G SETS (VOLTAGE AND FREQUENCY REGULATED)	17.49	1.13	0.21	23.74	95
H 3	ADJUST COMPONENTS OF 400HZ M/G SETS (VOLTAGE AND FREQUENCY REGULATED)	17.49	0.95	0.16	23.90	
H 4	REMOVE/REPLACE COMPONENTS OF 400HZ M/G SETS (VOLTAGE AND FREQUENCY REGULATED)	15.59	0.81	0.12	24.03	

D-TSK ####	TASK TITLE	%	%	%	%	N
H 5	CLEAN/LUBRICATE COMPONENTS OF 400HZ M/G SETS (VOLTAGE REGULATED)	13.69	0.82	0.11	24.14	
H 6	TEST/INSPECT COMPONENTS OF 400HZ M/G SETS (VOLTAGE REGULATED)	14.83	0.92	0.14	24.28	
H 7	TROUBLESHOOT 400HZ M/G SETS (VOLTAGE REGULATED)	12.16	0.81	0.11	24.37	100
H 8	ADJUST COMPONENTS OF 400HZ M/G SETS (VOLTAGE REGULATED)	12.92	0.86	0.11	24.48	
H 9	REMOVE/REPLACE COMPONENTS OF 400HZ M/G SETS (VOLTAGE REGULATED)	12.16	0.75	0.09	24.57	
H 10	CLEAN/LUBRICATE COMPONENTS OF DEGAUSSING SYSTEMS	8.74	0.85	0.07	24.64	
H 11	TEST/INSPECT COMPONENTS OF DEGAUSSING SYSTEMS	7.88	0.80	0.08	24.72	
H 12	TROUBLESHOOT DEGAUSSING SYSTEMS	8.36	0.68	0.06	24.77	105
H 13	ADJUST/ALIGN COMPONENTS OF DEGAUSSING SYSTEMS	7.60	0.59	0.04	24.82	
H 14	REMOVE/REPLACE COMPONENTS OF DEGAUSSING SYSTEMS	6.84	0.62	0.04	24.86	
H 15	CLEAN/LUBRICATE COMPONENTS OF SHORE STATION POWER GENERATION SYSTEM	6.08	0.89	0.05	24.91	
H 16	TEST/INSPECT COMPONENTS OF SHORE STATION POWER GENERATION SYSTEMS	7.22	1.37	0.13	25.03	
H 17	TROUBLESHOOT SHORE STATION POWER GENERATION SYSTEMS	5.70	0.87	0.05	25.05	110
H 18	ADJUST/ALIGN COMPONENTS OF SHORE STATION POWER GENERATION SYSTEMS	5.70	0.95	0.05	25.10	
H 19	REMOVE/REPLACE COMPONENTS OF SHORE STATION POWER GENERATION SYSTEMS	4.94	1.06	0.05	25.16	
H 20	CLEAN COMPONENTS OF THE AUTOMATIC EMERGENCY GENERATOR CONTROL SYSTEM	15.97	1.21	0.19	25.35	
H 21	TEST/INSPECT COMPONENTS OF THE AUTOMATIC EMERGENCY GENERATOR CONTROL SYSTEM	15.59	1.11	0.17	25.52	
H 22	ADJUST/ALIGN COMPONENTS OF THE AUTOMATIC EMERGENCY GENERATOR CONTROL SYSTEM	12.92	0.94	0.12	25.64	115
H 23	REMOVE/REPLACE COMPONENTS OF THE AUTOMATIC EMERGENCY GENERATOR CONTROL SYSTEM	12.92	0.91	0.12	25.76	
H 24	CLEAN COMPONENTS OF SHORE BASED EMERGENCY POWER SYSTEMS	2.66	0.60	0.02	25.77	
H 25	TEST/INSPECT COMPONENTS OF SHORE BASED EMERGENCY POWER SYSTEMS	2.66	1.05	0.03	25.80	
H 26	ADJUST/ALIGN COMPONENTS OF SHORE BASED EMERGENCY POWER SYSTEMS	2.28	0.43	0.0	25.80	
H 27	REMOVE/REPLACE COMPONENTS OF SHORE BASED EMERGENCY POWER SYSTEMS	2.28	0.50	0.01	25.81	120
I 1	INSTALL GROUND/BONDING STRAPS ON EQUIPMENT	39.16	1.44	0.56	26.37	
I 2	TEST/INSPECT PERSONAL SAFETY EQUIPMENT	49.81	1.91	0.95	27.32	
I 3	REMOVE/REPLACE RUBBER MATTING	42.20	1.38	0.58	27.90	
I 4	MAKE CABLE RUNS (NEW INSTALLATION)	59.31	1.82	1.08	28.98	
I 5	REMOVE/REPLACE SECTIONS OF CABLE RUNS	55.51	2.00	1.11	30.10	125
I 6	RIG/UNRIG DECORATIVE OR SECURITY LIGHTS	22.05	2.36	0.52	30.62	
I 7	CLEAN/LUBRICATE COMPONENTS OF SMALL CRAFT ELECTRICAL SYSTEMS	10.26	1.95	0.20	30.82	
I 8	TEST/INSPECT SMALL CRAFT ELECTRICAL SYSTEMS	9.50	2.05	0.19	31.01	

D-TSK	TASK TITLE	%	%	%	%	N
I 9	TROUBLESHOOT SMALL CRAFT ELECTRICAL SYSTEMS	9.88	2.17	0.21	31.22	
I 10	ADJUST SMALL CRAFT ELECTRICAL SYSTEMS	8.74	2.28	0.20	31.42	130
I 11	REMOVE/REPLACE COMPONENTS OF SMALL CRAFT ELECTRICAL SYSTEMS	8.36	2.22	0.18	31.60	
I 12	CLEAN/LUBRICATE COMPONENTS OF AMPLIDYNES	10.26	0.90	0.09	31.69	
I 13	TEST/INSPECT COMPONENTS OF AMPLIDYNES	11.02	0.88	0.10	31.79	
I 14	REMOVE/REPLACE COMPONENTS OF AMPLIDYNES	7.98	0.91	0.07	31.86	
I 15	PROVIDE TECHNICAL ASSISTANCE TO OTHER COMMANDS	7.22	0.77	0.05	31.91	135
J 1	CLEAN/LUBRICATE COMPONENTS OF AUTOMATIC CIRCUIT BREAKERS	37.26	1.57	0.58	32.50	
J 2	TEST/INSPECT COMPONENTS OF AUTOMATIC CIRCUIT BREAKERS	35.36	1.44	0.51	33.00	
J 3	TROUBLESHOOT AUTOMATIC CIRCUIT BREAKERS	31.94	1.30	0.41	33.42	
J 4	REMOVE/REPLACE COMPONENTS OF AUTOMATIC CIRCUIT BREAKERS	31.56	1.44	0.45	33.87	
J 5	ADJUST/ALIGN COMPONENTS OF AUTOMATIC CIRCUIT BREAKERS	30.04	1.35	0.40	34.27	140
J 6	CLEAN COMPONENTS OF AUTOMATIC BUS SYNCHRONIZING MONITOR SYSTEM	7.22	1.13	0.08	34.35	
J 7	TEST/INSPECT COMPONENTS OF AUTOMATIC BUS SYNCHRONIZING MONITOR SYSTEM	6.84	0.89	0.06	34.41	
J 8	TROUBLESHOOT AUTOMATIC BUS SYNCHRONIZING MONITOR SYSTEMS	6.08	0.58	0.03	34.44	
J 9	ADJUST/ALIGN COMPONENTS OF AUTOMATIC BUS SYNCHRONIZING MONITOR SYSTEM	5.70	0.57	0.03	34.48	
J 10	REMOVE/REPLACE COMPONENTS OF AUTOMATIC BUS SYNCHRONIZING MONITOR SYSTEM	5.70	0.58	0.03	34.51	145
J 11	CLEAN/LUBRICATE COMPONENTS OF AUTOMATIC BUS TRANSFER (ABT)	42.58	1.74	0.74	35.25	
J 12	TEST/INSPECT COMPONENTS OF ABT'S	62.74	1.75	1.10	36.35	
J 13	TROUBLESHOOT ABT'S	55.13	1.58	0.87	37.22	
J 14	ADJUST/ALIGN COMPONENTS OF ABT'S	49.05	1.45	0.71	37.93	
J 15	REMOVE/REPLACE COMPONENTS OF THE ABT'S	49.43	1.49	0.74	38.67	150
J 16	TEST/INSPECT MANUAL BUS TRANSFER (MBT)	35.36	1.07	0.38	39.04	
J 17	ADJUST/ALIGN MBT	28.14	0.98	0.27	39.32	
J 18	REMOVE/REPLACE COMPONENTS OF MBT	27.38	0.94	0.26	39.57	
J 19	CLEAN/LUBRICATE COMPONENTS OF ELECTRICAL DISTRIBUTION SWITCHBOARDS	25.85	1.45	0.37	39.94	
J 20	TEST/INSPECT COMPONENTS OF ELECTRICAL DISTRIBUTION SWITCHBOARDS	23.57	1.36	0.32	40.26	155
J 21	TROUBLESHOOT ELECTRICAL DISTRIBUTION SWITCHBOARDS	20.91	1.08	0.22	40.49	
J 22	ADJUST/ALIGN COMPONENTS OF ELECTRICAL DISTRIBUTION SWITCHBOARDS	20.16	1.20	0.24	40.73	
J 23	REMOVE/REPLACE COMPONENTS OF ELECTRICAL DISTRIBUTION SWITCHBOARDS	19.77	1.10	0.22	40.94	
J 24	CLEAN/LUBRICATE COMPONENTS OF 400HZ ELECTRICAL DISTRIBUTION SYSTEMS	16.73	1.08	0.18	41.12	
J 25	TEST/INSPECT 400HZ ELECTRICAL DISTRIBUTION SYSTEMS	17.11	0.95	0.16	41.28	160
J 26	TROUBLESHOOT 400HZ ELECTRICAL DISTRIBUTION SYSTEMS	14.45	0.82	0.12	41.40	
J 27	ADJUST COMPONENTS OF 400HZ ELECTRICAL DISTRIBUTION SYSTEMS	14.45	0.96	0.14	41.54	
J 28	REMOVE/REPLACE COMPONENTS OF 400HZ ELECTRICAL DISTRIBUTION SYSTEMS	14.45	0.96	0.14	41.67	

D-TSK ####	TASK TITLE	%	%	%	%	N
J 29	PREPARE SHORE POWER CABLES AND CONNECTION BOXES FO[illegible]	46.77	1.70	0.80	42.47	
J 30	PHASE SEQUENCE TEST SHORE POWER	38.02	1.41	0.59	43.00	165
J 31	RIG/UNRIG SHORE POWER	65.02	2.01	1.31	44.31	
J 32	CLEAN COMPONENTS OF CASUALTY POWER SYSTEM	33.04	1.24	0.37	44.68	
J 33	TEST/INSPECT COMPONENTS OF CASUALTY POWER SYSTEM	26.61	1.06	0.28	44.96	
J 34	REMOVE/REPLACE COMPONENTS OF CASUALTY POWER SYSTEM	23.95	1.02	0.24	45.21	
J 35	CLEAN COMPONENTS OF LOW VOLTAGE DIRECT CURRENT VARIABLE POWER SUPPLIES	7.98	1.63	0.13	45.33	170
J 36	TEST/INSPECT COMPONENTS OF LOW VOLTAGE DIRECT CURRENT VARIABLE POWER SUPPLIES	8.74	1.42	0.12	45.46	
J 37	TROUBLESHOOT LOW VOLTAGE DIRECT CURRENT VARIABLE POWER SUPPLIES	9.12	1.49	0.13	45.59	
J 38	ADJUST/ALIGN COMPONENTS OF LOW VOLTAGE DIRECT CURRENT VARIABLE POWER SUPPLIES	7.22	1.51	0.11	45.70	
J 39	REMOVE/REPLACE COMPONENTS OF LOW VOLTAGE DIRECT CURRENT VARIABLE POWER SUPPLIES	6.46	1.50	0.10	45.80	
K 1	CLEAN COMPONENTS OF LOAD/VOLTAGE MONITOR SYSTEMS	14.83	1.15	0.17	45.96	175
K 2	TEST/INSPECT COMPONENTS OF LOAD/VOLTAGE MONITOR SYSTEMS	12.92	1.09	0.14	46.10	
K 3	TROUBLESHOOT LOAD/VOLTAGE MONITOR SYSTEMS	12.54	1.06	0.13	46.24	
K 4	ADJUST/ALIGN COMPONENTS OF LOAD/VOLTAGE MONITOR SYSTEMS	12.16	1.00	0.12	46.36	
K 5	REMOVE/REPLACE COMPONENTS OF LOAD/VOLTAGE MONITOR SYSTEMS	11.40	0.95	0.11	46.46	
K 6	CLEAN/LUBRICATE COMPONENTS OF 400HZ GYROCOMPASS POWER SUPPLY SYSTEMS (STATIC)	2.66	0.65	0.02	46.48	180
K 7	TEST/INSPECT COMPONENTS OF 400HZ GYROCOMPASS POWER SUPPLY SYSTEMS (STATIC)	1.14	0.36	0.0	46.48	
K 8	TROUBLESHOOT 400HZ GYROCOMPASS POWER SUPPLY SYSTEM (STATIC)	1.14	1.12	0.01	46.49	
K 9	ADJUST/ALIGN COMPONENTS OF 400HZ GYROCOMPASS POWER SUPPLY SYSTEMS (STATIC)	0.76	0.26	0.0	46.49	
K 10	REMOVE/REPLACE COMPONENTS OF 400HZ GYROCOMPASS POWER SUPPLY SYSTEMS (STATIC)	1.14	0.40	0.0	46.49	
L 1	TEST/INSPECT COMPONENTS OF AUDIO SYSTEMS (SUCH AS PUBLIC ADDRESS, MOVIE)	3.04	1.78	0.05	46.54	185
L 2	TROUBLESHOOT AUDIO SYSTEMS (SUCH AS PUBLIC ADDRESS, MOVIE)	3.42	1.29	0.04	46.59	
L 3	REMOVE/REPLACE COMPONENTS OF AUDIO SYSTEMS (SUCH AS PUBLIC ADDRESS, MOVIE)	3.04	1.49	0.04	46.63	
L 4	SET-UP/BREAK-DOWN AUDIO SYSTEMS (SUCH AS PUBLIC ADDRESS, MOVIE)	4.18	2.05	0.08	46.71	
L 5	CLEAN/LUBRICATE COMPONENTS OF PROJECTORS (SUCH AS 16MM, SLIDE, OVERHEAD)	4.56	1.75	0.08	46.79	
L 6	TEST/INSPECT COMPONENTS OF PROJECTORS (SUCH AS 16MM, SLIDE, OVERHEAD)	4.18	1.88	0.08	46.87	190
L 7	TROUBLESHOOT PROJECTORS (SUCH AS 16MM, SLIDE, OVERHEAD)	5.70	1.40	0.08	46.95	
L 8	ADJUST/ALIGN COMPONENTS OF PROJECTORS (SUCH AS 16MM, SLIDE OVERHEAD)	4.56	1.47	0.06	47.01	
L 9	REMOVE/REPLACE COMPONENTS OF PROJECTORS (SUCH AS 16MM, SLIDE, OVERHEAD)	5.32	1.53	0.08	47.09	

D-TSK ####	TASK TITLE	%	%	%	%	N
L 10	PREPARE/UPDATE MOTION PICTURE INSPECTION RECORD (NAVPERS 3043)	2.66	1.39	0.04	47.13	
L 11	PREPARE U. S. NAVY MOTION PICTURE EXHIBITION TRANSFER & INVENTORY RECORD (NAVPERS 1710/12)	3.42	1.58	0.35	47.18	195
L 12	PREPARE NOTIFICATION OF MOTION PICTURE TRANSFER (NAVPERS 3042)	3.42	1.44	0.05	47.23	
L 13	PREPARE MOTION PICTURE DAMAGE, LOSS AND DESTRUCTION REPORT (NAVPERS 3041)	3.42	0.93	0.03	47.25	
L 14	CHECK-IN/OUT FILMS	5.32	1.65	0.09	47.34	
L 15	CLEAN/INSPECT FILMS	4.94	1.77	0.08	47.43	
L 16	SPLICE FILMS	5.70	1.38	0.08	47.50	200
M 1	CLEAN/LUBRICATE COMPONENTS OF WEAPONS ELEVATORS	12.54	1.48	0.18	47.69	
M 2	TEST/INSPECT COMPONENTS OF WEAPONS ELEVATORS	12.16	1.34	0.16	47.85	
M 3	TROUBLESHOOT WEAPONS ELEVATORS	12.16	1.29	0.16	48.00	
M 4	ADJUST/ALIGN COMPONENTS OF WEAPONS ELEVATORS	12.16	1.13	0.14	48.14	
M 5	REMOVE/REPLACE COMPONENTS OF WEAPONS ELEVATORS	11.02	1.18	0.13	48.27	205
M 6	CLEAN/LUBRICATE COMPONENTS OF PERSONNEL ELEVATORS	4.18	0.62	0.03	48.30	
M 7	TEST/INSPECT COMPONENTS OF PERSONNEL ELEVATORS	4.18	0.80	0.03	48.33	
M 8	TROUBLESHOOT PERSONNEL ELEVATORS	4.56	0.81	0.04	48.37	
M 9	ADJUST/ALIGN COMPONENTS OF PERSONNEL ELEVATORS	4.94	0.83	0.04	48.41	
M 10	REMOVE/REPLACE COMPONENTS OF PERSONNEL ELEVATORS	4.56	0.85	0.04	48.44	210
M 11	CLEAN/LUBRICATE COMPONENTS OF CRANES	10.64	0.88	0.09	48.53	
M 12	TEST/INSPECT COMPONENTS OF CRANES	10.64	0.95	0.10	48.63	
M 13	TROUBLESHOOT CRANES	11.02	0.94	0.10	48.74	
M 14	ADJUST COMPONENTS OF CRANES	9.50	0.89	0.08	48.82	
M 15	REMOVE/REPLACE COMPONENTS OF CRANES	5.88	0.91	0.09	48.91	215
M 16	CLEAN/LUBRICATE COMPONENTS OF CONVEYORS	7.98	0.99	0.08	48.99	
M 17	TEST/INSPECT COMPONENTS OF CONVEYORS	7.60	0.93	0.07	49.05	
M 18	TROUBLESHOOT CONVEYORS	8.36	0.90	0.07	49.13	
M 19	ADJUST/ALIGN COMPONENTS OF CONVEYORS	7.98	0.91	0.07	49.20	
M 20	REMOVE/REPLACE COMPONENTS OF CONVEYORS	8.74	1.05	0.09	49.29	220
M 21	CLEAN/LUBRICATE COMPONENTS OF AIR CONDITIONING CONTROL SYSTEMS	19.01	1.23	0.23	49.52	
M 22	TEST/INSPECT COMPONENTS OF AIR CONDITIONING CONTROL SYSTEMS	19.01	1.09	0.20	49.72	
M 23	TROUBLESHOOT AIR CONDITIONING CONTROL SYSTEMS	21.29	1.17	0.25	49.97	
M 24	ADJUST/ALIGN COMPONENTS OF AIR CONDITIONING CONTROL SYSTEMS	17.87	1.06	0.19	50.16	
M 25	REMOVE/REPLACE COMPONENTS OF AIR CONDITIONING CONTROL SYSTEMS	20.15	1.12	0.22	50.38	225
M 26	CLEAN/LUBRICATE COMPONENTS OF REFRIGERATION CONTROL SYSTEMS	11.40	0.78	0.09	50.47	
M 27	TEST/INSPECT COMPONENTS OF REFRIGERATION CONTROL SYSTEMS	13.30	0.88	0.12	50.59	
M 28	TROUBLESHOOT REFRIGERATION CONTROL SYSTEMS	14.07	0.99	0.14	50.72	
M 29	ADJUST/ALIGN COMPONENTS OF REFRIGERATION CONTROL SYSTEMS	10.64	0.82	0.08	50.81	
M 30	REMOVE/REPLACE COMPONENTS OF REFRIGERATION CONTROL SYSTEMS	10.26	0.84	0.08	50.89	230
M 31	CLEAN/LUBRICATE COMPONENTS OF WINCHES	17.49	1.14	0.20	51.09	
M 32	TEST/INSPECT COMPONENTS OF WINCHES	18.63	1.18	0.22	51.31	
M 33	TROUBLESHOOT WINCHES	17.87	1.06	0.19	51.49	

D-TSK	TASK TITLE	%	%	%	%	N
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M 34	ADJUST/ALIGN COMPONENTS OF WINCHES	14.83	0.97	0.14	51.63	
M 35	REMOVE/REPLACE COMPONENTS OF WINCHES	16.73	1.02	0.17	51.80	235
M 36	CLEAN/LUBRICATE COMPONENTS OF CAPSTANS/ANCHOR WINDLASS	14.07	1.01	0.14	51.94	
M 37	TEST/INSPECT COMPONENTS OF CAPSTANS/ANCHOR WINDLASS	13.30	1.02	0.14	52.08	
M 38	TROUBLESHOOT CAPSTANS/ANCHOR WINDLASS	14.83	1.07	0.16	52.23	
M 39	ADJUST/ALIGN COMPONENTS OF CAPSTANS/ANCHOR WINDLASS	13.30	1.00	0.13	52.37	
M 40	REMOVE/REPLACE COMPONENTS OF CAPSTANS/ANCHOR WINDLASS	13.30	1.02	0.13	52.50	240
M 41	CLEAN/LUBRICATE COMPONENTS OF ELECTRO-HYDRAULIC CARGO HATCH COVER SYSTEMS	2.28	0.72	0.02	52.51	
M 42	TEST/INSPECT COMPONENTS OF ELECTRO-HYDRAULIC CARGO HATCH COVER SYSTEMS	3.04	0.91	0.02	52.54	
M 43	TROUBLESHOOT ELECTRO-HYDRAULIC CARGO HATCH COVER SYSTEMS	3.04	0.83	0.02	52.56	
M 44	ADJUST/ALIGN COMPONENTS OF ELECTRO-HYDRAULIC CARGO HATCH COVER SYSTEMS	2.66	0.88	0.02	52.58	
M 45	REMOVE/REPLACE COMPONENTS OF ELECTRO-HYDRAULIC CARGO HATCH COVER SYSTEMS	2.66	0.89	0.02	52.60	245
M 46	CLEAN/LUBRICATE COMPONENTS OF DIVISIONAL HANGAR DOORS	9.50	1.00	0.09	52.69	
M 47	TEST/INSPECT COMPONENTS OF DIVISIONAL HANGAR DOORS	10.64	1.03	0.11	52.80	
M 48	ADJUST/ALIGN COMPONENTS OF DIVISIONAL HANGAR DOORS	10.26	0.83	0.08	52.89	
M 49	REMOVE/REPLACE COMPONENTS OF DIVISIONAL HANGAR DOORS	10.26	0.82	0.08	52.97	
N 1	CLEAN/LUBRICATE COMPONENTS OF SHOP POWER EQUIPMENT (SUCH AS SAWS, GRINDERS, BUFFERS, RECEPTACLES)	33.08	1.59	0.52	53.49	250
N 2	TEST/INSPECT SHOP POWER EQUIPMENT	37.26	1.69	0.63	54.12	
N 3	ADJUST SHOP POWER EQUIPMENT	28.52	1.42	0.40	54.53	
N 4	REMOVE/REPLACE COMPONENTS OF SHOP POWER EQUIPMENT	28.14	1.35	0.38	54.90	
N 5	TEST/INSPECT PORTABLE ELECTRICAL DEVICES (SUCH AS DRILLS, GRINDERS, COFFEE POTS)	48.29	2.19	1.06	55.96	
N 6	REMOVE/REPLACE COMPONENTS OF PORTABLE ELECTRICAL DEVICES	37.64	1.86	0.70	56.66	255
N 7	CLEAN/LUBRICATE COMPONENTS OF DEHYDRATORS	9.12	1.11	0.10	56.76	
N 8	TEST/INSPECT COMPONENTS OF DEHYDRATORS	6.84	0.76	0.05	56.81	
N 9	ADJUST/ALIGN COMPONENTS OF DEHYDRATORS	6.84	0.76	0.05	56.85	
N 10	REMOVE/REPLACE COMPONENTS OF DEHYDRATORS	7.22	0.71	0.05	56.90	
N 11	TEST/INSPECT IMMERSION HEATERS	8.36	0.79	0.06	56.97	260
N 12	REMOVE/REPLACE IMMERSION HEATERS	6.74	0.88	0.38	57.34	
N 13	CLEAN/LUBRICATE COMPONENTS OF SHIP'S HEATING EQUIPMENT	2.66	0.65	0.02	57.06	
N 14	TEST/INSPECT COMPONENTS OF SHIP'S HEATING EQUIPMENT	3.04	0.65	0.02	57.07	
N 15	ADJUST COMPONENTS OF SHIP'S HEATING EQUIPMENT	3.80	0.63	0.02	57.10	
N 16	REMOVE/REPLACE COMPONENTS OF SHIP'S HEATING EQUIPMENT	3.42	0.60	0.02	57.12	265
N 17	TEST/INSPECT ELECTRICALLY HEATED WINDOWS	7.98	0.95	0.07	57.19	
N 18	REMOVE/REPLACE ELECTRICALLY HEATED WINDOWS	5.32	0.86	0.04	57.23	
N 19	CLEAN/LUBRICATE COMPONENTS OF ESCALATORS	6.46	0.69	0.04	57.28	
N 20	TEST/INSPECT COMPONENTS OF ESCALATORS	9.12	0.93	0.08	57.36	
N 21	ADJUST/ALIGN COMPONENTS OF ESCALATORS	8.74	0.77	0.06	57.43	270
N 22	REMOVE/REPLACE COMPONENTS OF ESCALATORS	6.84	0.70	0.04	57.47	
N 23	CLEAN/LUBRICATE COMPONENTS OF VENDING MACHINES	1.14	0.44	0.0	57.47	
N 24	TEST/INSPECT VENDING MACHINES	1.90	0.76	0.01	57.48	

D-TSK	TASK TITLE	%	%	%	%	N
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N 25	ADJUST VENDING MACHINES	1.14	0.69	0.0	57.48	
N 26	REMOVE/REPLACE COMPONENTS OF VENDING MACHINES	1.14	0.62	0.0	57.48	275
N 27	CLEAN/LUBRICATE COMPONENTS OF WELDING EQUIPMENT	8.74	0.96	0.08	57.56	
N 28	TEST/INSPECT WELDING EQUIPMENT	14.83	1.00	0.14	57.71	
N 29	ADJUST WELDING EQUIPMENT	11.40	0.96	0.11	57.81	
N 30	REMOVE/REPLACE COMPONENTS OF WELDING EQUIPMENT	13.30	0.96	0.12	57.94	
N 31	TEST/INSPECT SHIP'S WINDSHIELD WIPERS	8.74	1.59	0.14	58.07	280
N 32	ADJUST/ALIGN SHIP'S WINDSHIELD WIPERS	7.98	1.56	0.12	58.20	
N 33	REMOVE/REPLACE SHIP'S WINDSHIELD WIPERS	7.60	1.34	0.10	58.30	
N 34	TEST/INSPECT SHIP'S WHISTLE	0.76	0.57	0.0	58.30	
N 35	REMOVE/REPLACE COMPONENTS OF SHIP'S WHISTLE	1.14	0.53	0.0	58.30	
P 1	CLEAN/LUBRICATE COMPONENTS OF 60HZ FLIGHT DECK AVIATION POWER SYSTEMS (100 AMPERE (AMP) OUTLET)	9.12	1.08	0.10	58.39	285
P 2	TEST/INSPECT 60HZ FLIGHT DECK AVIATION POWER SYSTEMS (100 AMP OUTLET)	10.26	1.06	0.11	58.50	
P 3	TROUBLESHOOT 60HZ FLIGHT DECK AVIATION POWER SYSTEMS (100 AMP OUTLETS)	10.26	0.98	0.10	58.60	
P 4	ADJUST 60HZ FLIGHT DECK AVIATION POWER SYSTEM (100 AMP OUTLETS)	8.74	0.97	0.08	58.69	
P 5	REMOVE/REPLACE COMPONENTS OF 60HZ FLIGHT DECK AVIATION POWER SYSTEMS (100 AMP OUTLETS)	9.12	1.04	0.09	58.78	
P 6	CLEAN/LUBRICATE COMPONENTS OF 400HZ AIRCRAFT START AND SERVICING SYSTEMS	11.02	1.49	0.16	58.94	290
P 7	TEST/INSPECT 400HZ AIRCRAFT AND SERVICING SYSTEMS	12.16	1.47	0.18	59.12	
P 8	TROUBLESHOOT 400HZ AIRCRAFT START AND SERVICING SYSTEMS	11.02	1.36	0.15	59.27	
P 9	ADJUST 400HZ AIRCRAFT START AND SERVICING SYSTEMS	10.64	1.37	0.14	59.41	
P 10	REMOVE/REPLACE COMPONENTS OF 400HZ AIRCRAFT START AND SERVICING SYSTEMS	11.78	1.31	0.15	59.56	
P 11	CLEAN/LUBRICATE COMPONENTS OF AUTOMATIC STANCHIONS	7.98	1.09	0.08	59.65	295
P 12	TEST/INSPECT COMPONENTS OF AUTOMATIC STANCHIONS	8.74	1.01	0.09	59.73	
P 13	ADJUST/ALIGN COMPONENTS OF AUTOMATIC STANCHIONS	8.36	1.04	0.08	59.82	
P 14	REMOVE/REPLACE COMPONENTS OF AUTOMATIC STANCHIONS	8.74	0.93	0.08	59.90	
P 15	CLEAN/LUBRICATE COMPONENTS OF AVIATION FUEL SYSTEMS (FLIGHT & HANGAR DECK)	12.16	1.31	0.16	60.05	
P 16	TEST/INSPECT COMPONENTS OF THE AVIATION FUEL SYSTEMS (FLIGHT & HANGAR)	11.40	1.25	0.14	60.19	300
P 17	ADJUST/ALIGN COMPONENTS OF THE AVIATION FUEL SYSTEMS (FLIGHT & HANGAR DECK)	10.26	1.03	0.10	60.30	
P 18	REMOVE/REPLACE COMPONENTS OF THE AVIATION FUEL SYSTEMS (FLIGHT & HANGAR DECK)	11.02	1.34	0.14	60.44	
P 19	CLEAN/LUBRICATE COMPONENTS OF THE AVIATION FUEL SYSTEMS (PUMP ROOM)	9.12	1.13	0.10	60.54	
P 20	TEST/INSPECT COMPONENTS OF THE AVIATION FUEL SYSTEMS (PUMP ROOM)	10.26	1.06	0.11	60.65	
P 21	TROUBLESHOOT AVIATION FUEL SYSTEMS (PUMP ROOM)	11.78	1.05	0.12	60.77	305

D-TSK	TASK TITLE	%	%	%	%	N
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P 22	ADJUST/ ALIGN COMPONENTS OF THE AVIATION FUEL SYSTEMS (PUMP ROOM)	9.50	0.89	0.08	60.85	
P 23	REMOVE/REPLACE COMPONENTS OF THE AVIATION FUEL SYSTEMS (PUMP ROOM)	9.12	0.97	0.09	60.94	
P 24	CLEAN/LUBRICATE COMPONENTS OF ARRESTING GEAR SYSTEMS	4.94	1.60	0.08	61.02	
P 25	TEST/INSPECT COMPONENTS OF ARRESTING GEAR SYSTEMS	4.94	1.84	0.09	61.11	
P 26	TROUBLESHOOT ARRESTING GEAR SYSTEMS	5.32	1.67	0.09	61.19	310
P 27	ADJUST/ALIGN COMPONENTS OF ARRESTING GEAR SYSTEMS	5.32	1.49	0.08	61.27	
P 28	REMOVE/REPLACE COMPONENTS OF ARRESTING GEAR SYSTEMS	5.32	1.78	0.09	61.36	
P 29	CLEAN/LUBRICATE COMPONENTS OF AIRCRAFT/HELO STARTING & SERVICING POWER SYSTEMS (28 VOLTS DIRECT CURRENT (28VDC))	9.12	1.33	0.12	61.48	
P 30	TEST/INSPECT COMPONENTS OF AIRCRAFT/HELO STARTING & SERVICING POWER SYSTEMS (28 VDC)	9.12	1.24	0.11	61.59	
P 31	TROUBLESHOOT AIRCRAFT/HELO STARTING AND SERVICING SYSTEMS (28 VDC)	8.36	1.04	0.08	61.68	315
P 32	ADJUST/ALIGN COMPONENTS OF AIRCRAFT/HELO STARTING & SERVICING POWER SYSTEMS (28VDC)	7.98	0.97	0.08	61.75	
P 33	REMOVE/REPLACE COMPONENTS OF AIRCRAFT/HELO STARTING & SERVICING POWER SYSTEMS (28VDC)	8.74	3.91	3.38	61.83	
P 34	CLEAN/LUBRICATE COMPONENTS OF CATAPULT LAUNCH SYSTEMS	5.32	1.92	0.10	61.93	
P 35	TEST/INSPECT COMPONENTS OF CATAPULT LAUNCH SYSTEMS	5.32	1.92	0.10	62.03	
P 36	TROUBLESHOOT CATAPULT LAUNCH SYSTEMS	6.08	1.75	0.10	62.13	320
P 37	ADJUST/ALIGN COMPONENTS OF CATAPULT LAUNCH SYSTEMS	4.94	1.52	0.07	62.21	
P 38	REMOVE/REPLACE COMPONENTS OF CATAPULT LAUNCH SYSTEMS	5.32	1.76	0.09	62.30	
P 39	CLEAN/LUBRICATE COMPONENTS OF ELEVATOR LOCKS	4.94	0.77	0.04	62.33	
P 40	TEST/INSPECT COMPONENTS OF ELEVATOR LOCKS	5.32	0.82	0.04	62.37	
P 41	ADJUST/ALIGN COMPONENTS OF ELEVATOR LOCKS	5.32	0.83	0.04	62.41	325
P 42	REMOVE/REPLACE COMPONENTS OF ELEVATOR LOCKS	5.32	0.84	0.04	62.46	
P 43	CLEAN/LUBRICATE COMPONENTS OF ELEVATOR SIDE DOORS	7.60	1.21	0.09	62.55	
P 44	TEST/INSPECT COMPONENTS OF ELEVATOR SIDE DOORS	8.36	1.32	0.11	62.66	
P 45	ADJUST/ALIGN COMPONENTS OF ELEVATOR SIDE DOORS	8.36	1.01	0.08	62.74	
P 46	REMOVE/REPLACE COMPONENTS OF ELEVATOR SIDE DOORS	7.22	0.86	0.06	62.80	330
P 47	CLEAN/LUBRICATE COMPONENTS OF AIRCRAFT ELEVATOR CONTROL SYSTEMS	8.74	1.14	0.10	62.90	
P 48	TEST/INSPECT COMPONENTS OF AIRCRAFT ELEVATOR CONTROL SYSTEMS	8.74	0.92	0.08	62.98	
P 49	TROUBLESHOOT AIRCRAFT ELEVATOR CONTROL SYSTEMS	9.50	1.16	0.11	63.09	
P 50	ADJUST/ALIGN COMPONENTS OF AIRCRAFT ELEVATOR CONTROL SYSTEMS	9.12	0.99	0.09	63.17	
P 51	REMOVE/REPLACE COMPONENTS OF AIRCRAFT ELEVATOR CONTROL SYSTEMS	8.74	0.90	0.08	63.25	335
R 1	CLEAN COMPONENTS OF AUTOMATIC BATTERY CHARGERS	6.46	1.92	0.12	63.37	
R 2	TEST/INSPECT AUTOMATIC BATTERY CHARGERS	6.84	1.95	0.13	63.51	
R 3	TROUBLESHOOT AUTOMATIC BATTERY CHARGERS	6.46	1.90	0.12	63.63	
R 4	CALIBRATE AUTOMATIC BATTERY CHARGERS	4.18	1.86	0.08	63.70	
R 5	REMOVE/REPLACE COMPONENTS OF AUTOMATIC BATTERY CHARGERS	7.98	2.15	0.17	63.87	340

D-TSK ####	TASK TITLE	%	%	%	%	N
R 6	CHARGE LEAD-ACID BATTERIES	7.98	3.29	0.26	64.13	
R 7	CLEAN/INSPECT LEAD-ACID BATTERTS	8.36	3.29	0.27	64.41	
R 8	TEST/TEST-DISCHARGE LEAD-ACID BATTERIES	7.22	2.92	0.21	64.61	
R 9	REWIND STATORS	15.59	1.68	0.26	64.87	
R 10	REWIND ARMATURES	9.50	1.02	0.10	64.97	345
R 11	REWIND COILS (SUCH AS SOLENOIDS)	12.54	1.25	0.16	65.13	
R 12	RESEAL SUBMERSIBLE ELECTRIC MOTORS	11.40	0.81	0.09	65.22	
R 13	COMPILE REWIND DATA FOR STATORS/SOLENOID COILS/ARMATURES	12.92	1.72	0.22	65.44	
R 14	RECONDITION CONTROLLER.	43.72	1.64	0.72	66.15	
R 15	RECONDITION MOTORS	33.46	1.46	0.49	66.64	350
R 16	REBUILD/OVERHALL STARTERS, GENERATORS, ALTERNATORS	16.35	1.10	0.18	66.82	
R 17	TURN DOWN/UNDERCUT COMMUTATORS OR ARMATURES	12.54	0.98	0.12	66.94	
S 1	CLEAN/LUBRICATE COMPONENTS OF MOTORS	42.96	1.46	0.63	67.57	
S 2	TEST/INSPECT COMPONENTS OF MOTORS	46.00	1.51	0.69	68.26	
S 3	TROUBLESHOOT MOTORS	49.05	1.66	0.82	69.07	355
S 4	ADJUST/ALIGN COMPONENTS OF MOTORS	42.20	1.43	0.60	69.68	
S 5	REMOVE/REPLACE COMPONENTS OF MOTORS	44.86	1.63	0.73	70.41	
S 6	CLEAN/LUBRICATE COMPONENTS OF CONTROLLERS	52.09	1.64	0.85	71.26	
S 7	TEST/INSPECT COMPONENTS OF CONTROLLERS	54.75	1.70	0.93	72.19	
S 8	TROUBLESHOOT CONTROLLERS	57.41	1.91	1.09	73.28	360
S 9	ADJUST/ALIGN COMPONENTS OF CONTROLLERS	49.81	1.58	0.79	74.07	
S 10	REMOVE/REPLACE COMPONENTS OF CONTROLLERS	52.47	1.74	0.91	74.98	
T 1	CLEAN COMPONENTS OF AUXILIARY BOILER CONTROL SYSTEMS	2.66	0.96	0.02	75.01	
T 2	TEST/INSPECT COMPONENTS OF AUXILIARY BOILER CONTROL SYSTEM	1.52	0.59	0.0	75.01	
T 3	TROUBLESHOOT AUXILIARY BOILER CONTROL SYSTEMS	1.52	0.66	0.01	75.01	365
T 4	ADJUST/ALIGN COMPONENTS OF AUXILIARY BOILER CONTROL SYSTEMS	1.52	0.66	0.01	75.02	
T 5	REMOVE/REPLACE COMPONENTS OF AUXILIARY BOILER CONTROL SYSTEMS	1.52	0.66	0.01	75.03	
T 6	CLEAN/LUBRICATE COMPONENTS OF AQUEOUS FILM FORMING FLUID (AFFF) FIRE FIGHTING SYSTEMS	4.94	0.81	0.04	75.07	
T 7	TEST/INSPECT COMPONENTS OF AFFF FIRE FIGHTING SYSTEMS	6.84	0.98	0.06	75.13	
T 8	TROUBLESHOOT AFFF FIRE FIGHTING SYSTEMS	6.46	0.80	0.05	75.18	370
T 9	ADJUST/ALIGN COMPONENTS OF AFFF FIRE FIGHTING SYSTEMS	6.08	0.74	0.04	75.23	
T 10	REMOVE/REPLACE COMPONENTS OF AFFF FIRE FIGHTING SYSTEMS .	5.32	0.76	0.04	75.27	
T 11	CLEAN/LUBRICATE COMPONENTS OF SHIP'S SERVICE DIAL TELEPHONE SYSTEMS	0.38	0.17	0.0	75.27	
T 12	TEST/INSPECT SHIP'S SERVICE DIAL TELEPHONE SYSTEMS	0.38	0.17	0.0	75.27	
T 13	TROUBLESHOOT SHIP'S SERVICE DIAL TELEPHONE SYSTEMS	0.38	0.17	0.0	75.27	375
T 14	ADJUST SHIP'S SERVICE DIAL TELEPHONE SYSTEMS	0.38	0.17	0.0	75.27	
T 15	REMOVE/REPLACE COMPONENTS OF SHIP'S SERVICE DIAL TELEPHONE SYSTEMS	0.76	0.53	0.0	75.27	
T 16	CLEAN COMPONENTS OF SOUND POWERED PHONE SYSTEMS	0.76	0.94	0.0	75.27	
T 17	TEST/INSPECT COMPONENTS OF SOUND POWERED PHONE SYSTEMS	1.52	1.46	0.02	75.29	
T 18	TROUBLESHOOT SOUND POWERED PHONE SYSTEMS	1.14	1.34	0.01	75.30	380
T 19	ADJUST/ALIGN COMPONENTS OF SOUND POWERED PHONE SYSTEMS	0.38	0.17	0.0	75.30	
T 20	REMOVE/REPLACE COMPONENTS OF SOUND POWERED PHONE SYSTEMS	0.38	0.17	0.0	75.30	

D-TSK ####	TASK TITLE	%	%	%	%	N
T 21	CLEAN/LUBRICATE COMPONENTS OF SHIP'S CONTROL EQUIPMENT (SUCH AS STEERING ENGINE ORDER TELEGRAPH)	1.14	0.37	0.0	75.30	
T 22	TEST/INSPECT COMPONENTS OF SHIP'S CONTROL EQUIPMENT (SUCH AS STEERING CONTROL, ENGINE-ORDER TELEGRAPH)	2.66	0.74	0.02	75.31	
T 23	TROUBLESHOOT SHIP'S CONTROL EQUIPMENT (SUCH AS STEERING CONTROL, ENGINE-ORDER TELEGRAPH)	3.04	0.75	0.02	75.33	385
T 24	ADJUST/ALIGN COMPONENTS OF SHIP'S CONTROL EQUIPMENT (SUCH AS STEERING CONTROL, ENGINE-ORDER TELEGRAPH)	2.66	0.67	0.02	75.35	
T 25	REMOVE/REPLACE COMPONENTS OF SHIP'S CONTROL EQUIPMENT (SUCH AS STEERING CONTROL, ENGINE-ORDER TELEGRAPH)	2.28	0.75	0.02	75.37	
T 26	CLEAN/LUBRICATE COMPONENTS OF ENGINE CONTROL CONSOLES	1.14	1.07	0.01	75.38	
T 27	TEST/INSPECT COMPONENTS OF ENGINE CONTROL CONSOLES	1.52	0.74	0.01	75.39	
T 28	TROUBLESHOOT ENGINE CONTROL CONSOLES	0.76	0.46	0.0	75.39	390
T 29	ADJUST/ALIGN COMPONENTS OF ENGINE CONTROL CONSOLES	0.76	0.52	0.0	75.39	
T 30	REMOVE/REPLACE COMPONENTS OF ENGINE CONTROL CONSOLES	0.76	0.52	0.0	75.39	
T 31	CLEAN COMPONENTS OF CONFLAGRATION (CONFLAG) STATION CONTROL SYSTEMS	3.80	0.95	0.04	75.42	
T 32	TEST/INSPECT COMPONENTS OF CONFLAG STATION CONTROL SYSTEMS	3.80	3.89	0.03	75.45	
T 33	TROUBLESHOOT CONFLAG STATION CONTROL SYSTEMS	4.18	1.42	0.06	75.51	395
T 34	REMOVE/REPLACE COMPONENTS OF CONFLAG STATION CONTROL SYSTEM	3.80	1.13	0.04	75.55	
T 35	CLEAN/LUBRICATE COMPONENTS OF GYROCOMPASSES	0.76	0.20	0.0	75.55	
T 36	TEST/INSPECT COMPONENTS OF GYROCOMPASSES	1.14	0.43	0.0	75.55	
T 37	TROUBLESHOOT GYROCOMPASSES	0.76	0.20	0.0	75.55	
T 38	ADJUST/ALIGN COMPONENTS OF GYROCOMPASSES	0.76	0.20	0.0	75.55	430
T 39	REMOVE/REPLACE COMPONENTS OF GYROCOMPASSES	1.14	0.43	0.0	75.55	
T 40	CLEAN/LUBRICATE COMPONENTS OF GYROCOMPASS REPEATER SYSTEMS	0.76	0.14	0.0	75.55	
T 41	TEST/INSPECT COMPONENTS OF GYROCOMPASS REPEATER SYSTEMS	0.76	0.14	0.0	75.55	
T 42	TROUBLESHOOT GYROCOMPASS REPEATER SYSTEMS	0.76	0.14	0.0	75.55	
T 43	ADJUST/ALIGN COMPONENTS OF GYROCOMPASS REPEATER SYSTEMS	0.76	0.20	0.0	75.55	405
T 44	REMOVE/REPLACE COMPONENTS OF GYROCOMPASS REPEATER SYSTEMS	0.76	0.20	0.0	75.55	
T 48	ADJUST/ALIGN COMPONENTS OF GAS TURBINE ELECTRICAL SYSTEMS	0.38	0.66	0.0	75.55	
U 1	CLEAN AUTOMATED PROPULSION SYSTEM (APS) BELL LOGGER	0.38	2.94	0.01	75.56	
U 2	TEST/INSPECT COMPONENTS OF APS BELL LOGGER	0.38	0.69	0.0	75.56	
U 5	CLEAN COMPONENTS OF APS THROTTLE SYSTEM	0.38	0.66	0.0	75.56	410
U 7	ADJUST/ALIGN COMPONENTS OF APS THROTTLE SYSTEM	0.38	0.44	0.0	75.56	
U 10	TEST/INSPECT COMPONENTS OF APS BEARING TEMPERATURE MONITOR SYSTEMS	0.38	1.30	0.0	75.56	
U 13	CLEAN COMPONENTS OF APS BOILER BURNER MANAGEMENT SYSTEMS	0.38	2.94	0.01	75.57	
U 21	CLEAN COMPONENTS OF APS LOCAL/REMOVE MOTOR AND VALVE CONTROL SYSTEMS	4.18	0.90	0.04	75.60	
U 22	TEST/INSPECT COMPONENTS OF APS LOCAL/REMOTE MOTOR AND VALVE CONTROL SYSTEMS	4.56	1.12	0.05	75.65	415
U 23	ADJUST/ALIGN COMPONENTS OF APS LOCAL/REMOTE MOTOR AND VALVE CONTROL SYSTEMS	4.18	0.87	0.04	75.69	
U 24	REMOVE/REPLACE COMPONENTS OF APS LOCAL/REMOTE MOTOR AND VALVE CONTROL SYSTEMS	4.18	0.84	0.03	75.72	

D-TSK	TASK TITLE	%	%	%	%	N
U 25	CLEAN COMPONENTS OF APS NO-BREAK POWER SUPPLY SYSTEMS	0.76	0.92	0.0	75.72	
U 26	TEST/INSPECT COMPONENTS OF APS NO-BREAK POWER SUPPLY SYSTEM	0.38	0.93	0.0	75.72	
U 27	ADJUST/ALIGN COMPONENTS OF APS NO-BREAK POWER SUPPLY SYSTEM	0.38	0.93	0.0	75.72	420
U 28	REMOVE/REPLACE COMPONENTS OF APS NO-BREAK POWER SUPPLY SYS	0.38	0.93	0.0	75.72	
U 32	REMOVE/REPLACE COMPONENTS OF APS SALINITY MONITOR SYSTEMS	0.38	6.24	0.02	75.74	
U 33	CLEAN COMPONENTS OF APS SHIP SERVICE (SS) DIESEL GENERATOR STATIC EXCITER SYSTEMS	6.46	1.33	0.06	75.83	
U 34	TEST/INSPECT COMPONENTS OF APS (SS) DIESEL GENERATOR STATIC EXCITER SYSTEMS	6.08	1.14	0.07	75.87	
U 35	ADJUST/ALIGN COMPONENTS OF APS (SS) DIESEL GENERATOR STATIC EXCITER SYSTEMS	5.70	1.12	0.06	75.93	425
U 36	REMOVE/REPLACE COMPONENTS OF APS (SS) DIESEL GENERATOR STATIC EXCITER SYSTEMS	6.46	1.09	0.07	76.00	
U 37	CLEAN COMPONENTS OF APS(SS)DIESEL GENERATOR WOODWARD GOVERNOR SYSTEMS (UG-8)	3.04	1.07	0.03	76.03	
U 38	TEST/INPSECT COMPONENTS OF APS SS DIESEL GENERATOR WOODWARD GOVERNOR SYSTEMS (UG-8)	3.42	1.01	0.03	76.06	
U 39	ADJUST/ALIGN COMPONENTS OF APS SS DIESEL GENERATOR WOODWARD GOVERNOR SYSTEMS (UG-8)	3.42	1.36	0.34	76.13	
U 40	REMOVE/REPLACE COMPONENTS OF APS SS DIESEL GENERATOR WOODWARD GOVERNOR SYSTEMS (UG-8)	3.42	1.01	0.03	76.13	430
U 41	CLEAN COMPONENTS OF APS SUPERVISORY ALARM SYSTEMS	0.38	1.96	0.0	76.13	
U 43	TROUBLESHOOT AUTOMATED PROPULSION SYSTEMS	0.38	0.80	0.0	76.13	
V 1	CALIBRATE COMPONENTS OF ALARM SYSTEMS	1.52	0.67	0.01	76.14	
V 2	CLEAN COMPONENTS OF GENERAL ALARMS	1.52	0.51	0.0	76.14	
V 3	TEST/INSPECT COMPONENTS OF GENERAL ALARMS	1.14	0.24	0.0	76.14	435
V 4	TROUBLESHOOT GENERAL ALARMS	1.52	0.73	0.01	76.15	
V 5	REMOVE/REPLACE COMPONENTS OF GENERAL ALARMS	1.14	0.24	0.0	76.15	
V 6	CLEAN COMPONENTS OF SUPERVISORY ALARM PANELS	1.14	0.58	0.0	76.15	
V 7	TEST/INSPECT COMPONENTS OF SUPERVISORY ALARM PANELS	1.14	0.58	0.0	76.15	
V 8	TROUBLESHOOT SUPERVISORY ALARM PANELS	1.14	0.75	0.0	76.15	440
V 9	REMOVE/REPLACE COMPONENTS OF SUPERVISORY ALARM PANELS	0.76	0.14	0.0	76.15	
V 10	CLEAN COMPONENTS OF SALINITY INDICATING SYSTEMS	0.76	0.14	0.0	76.15	
V 11	TEST/INSPECT SALINITY INDICATING SYSTEMS	0.76	0.14	0.0	76.15	
V 12	TROUBLESHOOT SALINITY INDICATING SYSTMES	0.76	0.20	0.0	76.15	
V 13	REMOVE/REPLACE COMPONENTS OF SALINITY INDICATING SYSTEMS	0.76	0.20	0.0	76.15	445
V 14	CALIBRATE COMPONENTS OF SALINITY INDICATING SYSTEMS	1.14	0.49	0.0	76.15	
W 1	TEST/INSPECT SEARCHLIGHTS	4.94	1.62	0.08	76.23	
W 2	REMOVE/REPLACE COMPONENTS OF SEARCHLIGHTS	6.46	1.45	0.09	76.32	
W 3	CLEAN COMPONENTS OF LIGHTING SYSTEMS	34.98	2.86	1.00	77.32	
W 4	TEST/INSPECT COMPONENTS OF LIGHTING SYSTEMS	36.88	2.88	1.06	78.38	450
W 5	TROUBLESHOOT LIGHTING SYSTEMS	40.68	3.12	1.27	79.65	
W 6	ADJUST COMPONENTS OF LIGHTING SYSTEMS	34.98	2.95	1.03	80.67	
W 7	REMOVE/REPLACE COMPONENTS OF LIGHTING SYSTEMS (SUCH AS BALLASTS, SOCKETS)	36.88	2.62	1.04	81.71	

D-TSK	TASK TITLE	%	%	%	%	N
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W 8	REMOVE/REPLACE CONSUMABLE COMPONENTS OF LIGHTING SYSTEMS (SUCH AS FUSES, LIGHTS, STARTERS)	37.64	2.98	1.12	82.83	
X 1	CLEAN/LUBRICATE COMPONENTS OF ELECTRIC FORK LIFTS	0.38	2.46	0.0	82.83	455
X 2	TEST/INSPECT COMPONENTS OF ELECTRIC FORK LIFTS	0.38	1.47	0.0	82.83	
X 3	ADJUST/ALIGN COMPONENTS OF ELECTRIC FORK LIFTS	0.76	1.16	0.0	82.83	
X 4	REMOVE/REPLACE COMPONENTS OF ELECTRIC FORK LIFTS	0.76	1.16	0.0	82.83	
X 5	CLEAN/LUBRICATE COMPONENTS OF ELECTRIC PALLET TRUCKS	0.38	0.85	0.0	82.83	
X 6	TEST/INSPECT COMPONENTS OF ELECTRIC PALLET TRUCKS	0.38	0.85	0.0	82.83	460
X 7	TROUBLESHOOT ELECTRICA DRIVEN VEHICLES (SUCH AS PALLET TRUCKS, FORKLIFT)	0.38	0.85	0.0	82.83	
X 8	ADJUST/ALIGN COMPONENTS OF ELECTRIC PALLET TRUCKS	0.38	0.85	0.0	82.83	
X 9	REMOVE/REPLACE COMPONENTS OF ELECTRIC PALLET TRUCKS	0.38	0.85	0.0	82.83	
Y 1	CLEAN/LUBRICATE COMPONENTS OF GALLEY EQUIPMENT	14.83	1.30	0.19	83.02	
Y 2	TEST/INSPECT COMPONENTS OF GALLEY EQUIPMENT	16.73	1.37	0.23	83.25	465
Y 3	TROUBLESHOOT GALLEY EQUIPMENT	17.11	1.61	0.27	83.52	
Y 4	ADJUST/ALIGN COMPONENTS OF GALLEY EQUIPMENT	16.73	1.45	0.24	83.76	
Y 5	REMOVE/REPLACE COMPONENTS OF GALLEY EQUIPMENT	17.11	1.68	0.28	84.05	
Y 6	CLEAN/LUBRICATE COMPONENTS OF SCULLERY EQUIPMENT	14.83	1.39	0.20	84.25	
Y 7	TEST/INSPECT COMPONENTS OF SCULLERY EQUIPMENT	15.59	1.45	0.22	84.47	470
Y 8	TROUBLESHOOT SCULLERY EQUIPMENT	15.97	1.52	0.24	84.71	
Y 9	ADJUST/ALIGN COMPONENTS OF SCULLERY EQUIPMENT	15.21	1.34	0.20	84.92	
Y 10	REMOVE/REPLACE COMPONENTS OF SCULLERY EQUIPMENT	15.97	1.52	0.24	85.16	
Y 11	CLEAN/LUBRICATE COMPONENTS OF LAUNDRY AND DRY CLEANING EQUIPMENT	14.07	1.44	0.20	85.36	
Y 12	TEST/INSPECT COMPONENTS OF LAUNDRY AND DRY CLEANING EQUIPMENT	14.45	1.51	0.22	85.57	475
Y 13	TROUBLESHOOT LAUNDRY AND DRY CLEANING EQUIPMENT	14.45	1.49	0.21	85.79	
Y 14	ADJUST/ALIGN COMPONENTS OF LAUNDRY AND DRY CLEANING EQUIPMENT	13.30	1.24	0.16	85.95	
Y 15	REMOVE/REPLACE COMPONENTS OF LAUNDRY AND DRY CLEANING EQUIPMENT	14.07	1.38	0.19	86.14	
Z 1	HOLD FIELD DAYS/SWEEPDOWNS	84.41	3.25	2.74	88.89	
Z 2	PAINT WORKING/LIVING SPACES	36.88	1.57	0.58	89.46	480
Z 3	PARTICIPATE IN WORKING PARTIES	40.30	2.27	0.91	90.37	
Z 4	STAND INSPECTIONS	87.07	3.90	3.40	93.77	
Z 5	ATTEND GENERAL DRILLS	68.82	2.56	1.76	95.54	
Z 6	COUNSEL PERSONNEL ON PERSONAL/MILITARY MATTERS	26.61	1.76	0.47	96.01	
Z 7	MAINTAIN ASSIGNED SPACE DAMAGE CONTROL SYSTEMS	17.87	1.48	0.26	96.27	485
Z 8	CONDUCT INSPECTIONS (SUCH AS ZONE, PERSONNEL, OR SAFETY)	21.67	1.94	0.42	96.69	
Z 9	ATTEND MEETINGS, SEMINARS, OR CONFERENCES	33.84	2.28	0.77	97.46	
Z 10	CONDUCT MEETINGS, SEMINARS, OR CONFERENCES	9.12	1.14	0.10	97.57	
Z 11	PARTICIPATE IN CASUALTY CONTROL DRILLS	50.95	2.29	1.16	98.73	

APPENDIX F THE NAVY STANDARD ELECTRONIC MODULE PROGRAM

The Navy Standard Electronic Module (SEM) program is directed toward the standardization of modular building blocks for all Navy solid state electronic systems. The program was initiated as a result of a study, in the early 1960's, performed at the Naval Avionics Facility, Indianapolis (NAFI) to determine what could be done to standardize electronic equipment. The SEM Program was formerly called "The Standard Hardware Program (SHP)." The objective of SHP, and now SEM, was to develop a family of functional electronic "plug-in" modules to serve as common building blocks from which systems engineers could construct a variety of complex electronic systems. The general specifications that establishes the quality assurance and procurement requirements for SEM building blocks is MIL-M-28787A "Standard Electronic Module Program, General Specification for." Detail requirements for a particular module is contained in the form of "slash-sheets" which are a part of the specification.

The basic SEM module is approximately 2.5 inches by 2.0 inches by 0.3 inches; larger size modules are available in multiples of the the basic module. In general, the electronics of the SEM modules are achieved by utilizing the Microcircuits of MIL-M-38510D which are described in Appendix G. As of 1 April, 1978 there were 197 SEM's that had been qualified and specified, 22 that had been qualified but still in the process of being specified, and 83 that were given designations but were still under development. The SEM status information is contained in a listing that is reproduced on the following pages.

1 APRIL 1978

STANDARD ELECTRONIC MODULES PROGRAM

MODULE LISTING

Formerly NAVELEX 0101-053B

	SLASH SHEET NO. M28787/	KEY* CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
	1	GDJ	Latch	1A	Four 4-bit latches, TTL (QBA[3])	B*	AP
	2	GDE	Flip-Flop, J-K	1A	Six J-K flip-flops, HSTTL	(2)	AP
5	3	GDA	Gate, NAND	1A	Twelve 2-input strobable, NAND gates, HSTTL	(1)	AP
	4	GDK	Gate, OR, Exclusive	1A	Multiple exclusive OR/NOR gates, TTL (QDB[3])	(1)	AP
	5	BDL	Multiplexer	1A	Three 8-input digital multiplexers, TTL (KHC[3])	A	AP
	6	FDA	Counter, Binary, Synchronous	1A	Three 4-bit synchronous binary counters, TTL	A	AP
	7	GDN	Decoder, Binary	1A	One of sixteen binary decoder, TTL (QBE[3])	A	AP
	8	GDC	Gate, NAND	1A	Six 4-input and two 3-input power NAND gates, HSTTL	A*	AP
	9	LDP	Gate, NAND	1A	Four 8-input NAND gates, TTL	(3)	AP
5	10	GDB	Gate, NAND	1A	Six 4-input and two 3-input NAND gates, HSTTL	(1)	AP
	11	KDL	Adder, Digital	1A	Two 4-bit and one 2-bit adders, TTL	A*	AP
	12	KDJ	Arithmetic Logic Unit	1A	Two 4-bit arithmetic logic units, TTL	(2)	AP
	13	FPQ	Network, Resistor, Independent	1C	Two 2.37Ω and two 332Ω, 4W, resistors (PPQ[1])		AP
	14	JBD	Terminator, Resistor-Capacitor	1A	Single ended terminator (ADD[2])		AP
5	15	PMN	Fuse	1B	Eight fuses (FMN[2])		AP
	16	JDK	Receiver, Interface	1A	Eighteen logic level receivers, TTL (AHB[3])	(1)	AP
	17	LDJ	Gate, AND-OR-INVERT	1A	Six AND-OR-INVERT gates, TTL (CBJ[3])	(1)	AP
	18	LDQ	Gate, NAND	1A	Twelve 2-input NAND gates, TTL (CHG[3])	(3)	AP
	19	LDN	Gate, NAND	1A	Six 4-input and two 3-input NAND gates, TTL (CHE[3])	(1)	AP
	20	LDC	Inverter	1A	Eighteen inverter gates, TTL (CBL[3])	(3)	AP
5	21	WDU	Gate, NAND	1A	Four 8-input NAND gates, HSTTL	A*	AP
	22	ABE	Diode, Programmable	1A	Twenty independent high speed diodes (ADE[1])	A	AP
	23	SBT	Receiver, Interface	1A	Receiver, SEM interface, 28V to 5V (SDT[1]) (SQT[3])		AP
	24	GPR	Rectifier, Low Current	1A	Twelve 1.75-amp rectifiers (QPR[1])		AP
	25	HPJ	Rectifier, High Current	1C	Three 8-amp diodes (RPJ[1])		AP
	26	GPN	Fuse	1B	One 20-amp fuse (QPN[1])		AP
	27	GDM	Counter, Up and Down, Binary	1A	Four 4-bit synchronous binary up/down counters, TTL	(1)	AP
5	28	PDM	Shift Register	1A	Two 32-bit shift registers, TTL		AP
5	29	FDH	Inverter	1A	Eighteen inverter gates, HSTTL	(1)	AP
	30	BBA	Counter, Up-Down, Binary	1A	Three binary up/down counters, TTL	A(1)	AP
	31	JDD	Counter, Up-Down, BCD, Presettable	1A	Three BCD, presettable up/down counters, TTL	A	AP
	32	KBR	Flip-Flop, D-Type	1A	Six D-type flip-flops, LPTTL	A	AP
	33	JDJ	Shift Register	1A	Four 4-bit serial/parallel shift registers, TTL	A	AP
	34	JBN	Multivibrator, Monostable	1A	Two monostable multivibrators (JDN[1])	A(1)	AP
	35	EPL	Resistor, Power	1C	3.84Ω power resistor, 12 watt (NPL[1])		AP
	36	YKT	Fuse	1B	One 3-amp slow blow fuse (YMT[1])		AP
	37	YKW	Fuse	1B	Eight fuses, 1 ea, 4/10, 3/4, 2, 5 amp; 2 ea, 1/4 and 1 amp (YMW[1])		AP
	38	NPM	Relay, DPDT	1B	Four undervoltage DPDT relays (EPM[1])	A(2)	AP
	39	KBC	Adder	1A	Two 4-bit and one 2-bit adder, LSTTL	A	AP
	40	KBL	Multiplexer, Digital	1A	Three 8-input digital multiplexers, LPTTL	A	AP
	41	EBL	Flip-Flop, J-K	1A	Six J-K flip-flops, TTL	(2)	AP
	42	JBK	Comparator, Magnitude	1A	One 4-bit and one 8-bit expandable magnitude comparators, LPTTL	A(1)	AP

	SLASH SHEET NO. M28787/	KEY* CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
	43	GPP	Power Supply, Reg., Programmable	2N	5V regulated power supply (QPP[1])		AP
	44	GBL	Latch	1A	Four 4-bit latches, LPTTL	A*	AP
	45	ZBZ	Counter, Binary Coded Decimal	1A	Three 4-bit synchronous BCD counters, LPTTL	A	AP
	46	ZBY	Counter, Binary	1A	Three 4-bit synchronous binary counters, LPTTL (ZQY[3])	A*	AP
	47	BBB	Buffer, Three State	1A	Six three state buffers, TTL	A	AP
	48	MDP	Driver, Translate	1A	Four 2-input negative interface line drivers		AP
	49	KDF	Diode Pairs	1A	Twelve separate diode pairs, series connected (BDF[1])		AP
	50	-	Cancelled				
	51	MDQ	Receiver, Translate	1A	Four negative interface line receivers, TTL	(1)	AP
s	52	AEN	Amplifier, Audio	1B	Audio amp. with pin programmable gain (AAN[1])		AP
	53	KDN	Receiver, Differential Line	1A	Ten differential line receivers, TTL (BHE[3])	(2)	AP
	54	QDH	Receiver, Interface	1A	Four interface receivers, slow NTDS	A(2)	AP
	55	KDM	Driver, Differential Line	1A	Eight 2-input and two 1-input differential line drivers, TTL (BHD[3])	(1)	AP
s	56	JAD	Amplifier, D.C.	1B	D.C. amplifier can be pin programmed for different gains (AAM[1])		AP
	57	TTY	Switch, Analog	1A	Eight low R_{on} analog switches (TSY[1])	(1)	AP
	58	ADK	Counter, Binary Coded Decimal	1A	Three 4-bit synchronous BCD counters, TTL	A	AP
	59	KDP	Shift Register	1A	Ten 8-bit shift registers, TTL		AP
	60	KDQ	Multiplexer, Digital	1A	Ten 2-input digital multiplexers, TTL	(1)	AP
	61	KDR	Flip-Flop, D-Type	1A	Six D-type flip-flops, TTL		AP
	62	CFA	Comparator, Analog	1A	Six analog comparators	B*	AP
s	63	QPG	Detector, Voltage, Threshold	1B	Overvoltage/undervoltage detector (QPQ[1])	(1)	AP
	64	LHJ	Gate, AND-OR-INVERT	1A	Six AND-OR-INVERT gates, STTL		AP
	65	AHA	Decoder	1A	Three 1-of-8 decoders, STTL		AP
	66	BHL	Multiplexer	1A	Three 8-input data selector/multiplexers, LSTTL	(1)	AP
	67	JHD	Multiplexer	1A	Three dual 4-line to 1-line data selector/multiplexers, LSTTL	A	AP
	68	LHH	Gate, NAND	1A	Four 4-input and four 3-input NAND gates, STTL		AP
	69	KHR	Flip-Flop, D-Type	1A	Six D-type flip-flops, STTL		AP
	70	FHA	Counter, Binary	1A	Three 4-bit synchronous binary counters, STTL	(1)	AP
	71	CHF	Shift Register	1A	16-bit bidirectional shift register, LSTTL	A	AP
	72	KHQ	Multiplexer	1A	Two 4-way and one 2-way multiplexers, LSTTL	A	AP
	73	JHK	Receiver, Interface	1A	Eighteen TTL bus transceivers, STTL	(1)	AP
	74	-	Memory, Read Only	1A	Two 512 x 8-bit ROMS/3-state outputs, TTL		AP
	75	LHP	Gate, NAND	1A	Four 8-input NAND gates, STTL		AP
	76	MHL	Encoder, Priority	1A	Two 8-input priority encoders, TTL (DHC[3])		AP
	77	MHK	Encoder, Parity	1A	Four 9-input parity encoders, STTL		AP
	78	AHD	Multiplexer	1A	Six 4:1 multiplexers, STTL		AP
	79	ROH	Arithmetic Logic Unit	1A	One 4-bit ALU and one look-ahead carry generator, STTL		AP
	80	BYF	Memory, Random Access	1A	1024 RAM with buffered 3-state outputs, NMOS		DC
	81	KHL	Multiplexer	1A	Three 8:1 multiplexers, STTL		AP
	82	RBG	Inverter	1A	Eighteen inverter gates, STTL		AP
	83	RBF	Gate, NAND	1A	Twelve 2-input NAND gates, STTL		AP
	84	CBF	Shift Register	1A	16-bit bidirectional shift register, STTL		DC
	85	BDN	Multiplexer, Digital	1A	Ten 2-input digital multiplexers, LPTTL		AP
	86	ERN	Relay, Power	1F	Single 3PDT break-before-make 20-amp relay		AP
	87	ARM	Regulator, Positive	1B	+5V or +15V regulator		AP
	88	SEX	Multiplexer, Analog	1A	Three 1 of 8 channel analog switches, CMOS		AP
	89	JBP	Driver, Lamp/Relay	1A	Four lamp/relay drivers, Class II (ABF[2])		UD
	90	QDB	Gate, Exclusive-OR/NOR	1A	Multiple exclusive OR/NOR gates, TTL, Class II (GDK[2])		UD
s	91	LJR	Test Point	1A	Test point module, Class II (CMH[2])		UD

	SLASH SHEET NO. M28787/	KEY* CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
	92	KHC	Multiplexer	1A	Three 8-input digital multiplexers, TTL, Class II (BDL[2])		UD
	93	QBA	Latch	1A	Four 4-bit latches, TTL, Class II (GDJ[2])		UD
	94	QBE	Decoder	1A	1 of 16 decoder, TTL, Class II (GDN[2])		UD
	95	RRP	Relay	1B	Five DPDT 2.0A relays, Class II (HRF[2])		UD
	96	AHB	Receiver, Interface	1A	Eighteen logic level receivers, TTL, Class II (JDK[2])		UD
	97	BHD	Driver, Differential Line	1A	Eight 2- and two 1-input diff. line drivers, TTL, Class II (KDM[2])		UD
	98	CBL	Inverter	1A	Eighteen inverter gates, TTL, Class II (LDC[2])		UD
	99	CHE	Gate, NAND	1A	Six 4- and two 3-input NAND gates, TTL, Class II (LDN[2])		UD
	100	CHG	Gate, NAND	1A	Twelve 2-input NAND gates, TTL, Class II (LDQ[2])		UD
	101	CBJ	Gate, AND-OR-INVERT	1A	Six AND-OR-INVERT gates, TTL, Class II (LDJ[2])		UD
	102	FBC	Shift Register	1A	Four 4-bit serial/parallel shift registers, TTL, Class II (PDL[2])		UD
	103	BHE	Receiver, Differential Line	1A	Ten differential line receivers, TTL, Class II (KDN[2])		UD
	104	DHC	Encoder, Priority	1A	Two 8-input priority encoders, TTL, Class II (MHL[2])		UD
	105	ZQY	Counter, Binary	1A	Three 4-bit synchronous binary counters, LPTTL, Class II (ZBY[2])		UD
	106	NHC	Flip-Flop, J-K	1A	Six J-K flip-flops, TTL, Class II		UD
s	107	GPJ	Driver, Audio Output	1D	Two audio power amplifiers (QPJ[1])		AP
s	108	PNF	Detector, Voltage Levels	1A	0, ±1, ±2, ±3 volt level detectors (FNF[1])	(1)	AP
	109	MDL	Driver, Interface	1A	Six line drivers, 500 feet of type 2SWA or 3SWA cable	(1)	AP
	110	MDM	Receiver, Interface	1A	Six transformer coupled line receivers	(2)	AP
	111	MDN	Terminator, Interface	1A	Sixteen 75Ω terminating resistors (Use with MDL/MDM)		AP
	112	PDL	Shift Register, Serial and parallel	1A	Four 4-bit serial/parallel shift registers, TTL (FBC[3])	A(1)	AP
	113	FAG	Switch, Analog	1A	Two 4PDT analog switches	(1)	AP
s	114	BDA	Gate, NAND	1A	Twelve 2-input NAND gates, DTL	(1)	AP
s	115	BDB	Gate, NAND	1A	Nine 3-input NAND gates, DTL	(1)	AP
s	116	BDC	Gate, NAND	1A	Four 8-input NAND gates, DTL	(1)	AP
s	117	BDD	Multivibrator, Monostable	1A	Two 0.1 to 1.5μs one-shots, DTL		AP
s	118	BDE	Multivibrator, Monostable	1A	Two 10 to 150μs one-shots, DTL		AP
s	119	BDH	Gate, NAND, Power	1A	Eight power NAND gates, DTL	(1)	AP
s	120	CDB	Gate, NAND, Power	1A	Four high current-high voltage decoder drivers, DTL	(2)	AP
s	121	CDD	Multivibrator, Monostable	1A	Two 1.0 to 15us one-shots, DTL		AP
s	122	CDE	Multivibrator, Monostable	1A	Two 100 to 1500μs one-shots, DTL		AP
s	123	ADH	Flip-Flop, J-K	1A	Five J-K flip-flops, DTL	(1)	AP
s	124	CMH	Test Point	1A	Test point module (LJR[3]), similar to CZH	(4)	AP
s	125	FLA	Extender, Test Point and Resistor	1A	Test points w/10KΩ isolation, similar to FZJ	(3)	AP
	126	FLB	Load, Resistor, Standard	1A	Twenty load resistors, values range from 10 ohms to 402K ohms		AP
s	127	FLE	Capacitor	1A	Two 1uF, two 0.0039μF, and ten 0.1uF capacitors	C	AP
	128	CTR	Transformer	1E	two 1:1 transformers	A	AP
	129	EMF	Isolation Module	1A	Twenty direct through connections, isolation		AP
	130	QPL	Network, Miscellaneous	1B	Three 240uF and three 180uF, 60V, polarized capacitors		AP
	131	RPM	Transformer, Output	1J	Power transformer, 10W; 400, 800, and 10 kHz		AP
s	132	MVJ	Oscillator, Square Wave	1C	9600 Hz square wave generator, DTL		AP
	133	NRN	Relay, 4PDT	1F	Single 4PDT break-before-make 10 amp relay	A	AP
	134	QPK	Network, Miscellaneous	1B	Three 600μF and three 800μF, 15V, polarized capacitors		AP
	135	QPM	Inductor, 1.5 Ampere	1D	Five 0.5mH, 1.5 amp inductors	A*	AP
	136	RPN	Transformer	1U	115V, 400 Hz, 3-phase transformer		AP

	SLASH SHEET NO. M28787/	KEY-CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
	137	VPX	Inductor	1E	110µH, 20 amp inductor		AP
	138	VTY	Transformer, Calibration	1F	Calibration transformer, primary, 5 taps; secondary, 16 taps		AP
	139	RTR	Transformer, Signal	1E	Two transformers, each primary and secondary has 6 taps	A	AP
	140	AGD	Multiplexer	1A	Six 4-line to 1-line data selector/ multiplexers, TTL		AP
	141	GYB	Memory, Random Access	1A	256 x 4-bit RAM with 3-state outputs, TTL	A	AP
	142	JDB	Comparator, Magnitude	1A	4-bit and 8-bit expandable magnitude comparator, TTL	(1)	AP
	143	GBB	Flip-Flop, J-K Bar	1A	Eight J-$\bar{K}$ flip-flops, TTL	(1)*	AP
	144	KMA	Quadrant Selector/Successive Approximator	1C	S/D converter quadrant selector/successive approximator		UD
	145	KMB	Processor, Input, S/D	1B	S/D converter, input processor		UD
	146	KMC	Processor, Reference, S/D	1B	S/D converter, reference processor		UD
	147	NVA	Oscillator	1A	3.8333, 7.6666, and 11.5000 MHz oscillator		AP
s	148	RDR	Inverter	1A	Eighteen inverter gates, DTL		AP
s	149	SDY	Flip-Flop, J-K	1A	Eight J-K flip-flops, DTL		AP
	150	-	Not assigned				
s	151	ZDZ	Gate, NAND, Expandable	1A	Six 4-input expand NAND gates, DTL		AP
	152	ABF	Driver, Lamp or Relay	1A	Four lamp/relay drivers (JBP[3])		AP
	153	NRF	Relay	1B	Five DPDT 2.0A relays, coil voltage 25 VDC (HRP[1]) (RRP[3])	B*	AP
	154	DBA	Logic, Converter, Analog/Digital	1A	A/D converter logic, TTL		AP
	155	DBC	Converter, Digital/Analog	1C	12-bit D/A converter, TTL	(1)	AP
	156	DBE	Gate, Inverter	1A	Eighteen inverter gates, LPTTL	(2)	AP
	157	DBF	Gate, NAND	1A	Twelve 2-input NAND gates, LPTTL	(2)	AP
	158	DBG	Gate, NAND	1A	Two 3-input and six 4-input NAND gates, LPTTL	(1)	AP
	159	DBH	Gate, NAND	1A	Four 8-input NAND gates, LPTTL	(1)	AP
	160	EBH	Shift Register	1A	Two 8-bit left/right parallel in/out shift registers, LPTTL	(1)	AP
	161	AKE	Network, Terminator	1A	Eighteen 150Ω differential line terminators with bias		AP
	162	EKB	Driver, Interface	1A	Eight 28V to 5V optically isolated level shifters		DC
	163	EKC	Driver, Interface	1A	Six 5V to 28V optically isolated level shifters		DC
	164	SQT	Receiver, Interface	1A	Relay/SHP interface, Class 1 (SBT[2]) (SGT[1])		UD
	165	ABD	Counter, Up/Down, BCD, presettable	1A	Three BCD, presettable up/down counters, LPTTL		AP
	166	BBJ	Counter, Up/Down, Binary	1A	Three binary up/down counters, LPTTL		AP
s	167	TRS	Relay	1A	Five DPDT 0.5A relays		UD
	168	GYC	Memory, Read Only, Programmable	1A	Two 256 x 8-bit PROMs w/3-state outputs, TTL		AP
	169	GYF	Memory, Read Only, Programmable	1A	Two 512 x 4-bit PROMs w/3-state outputs, TTL	A*	AP
	170	EBA	Gate, AND-OR-INVERT	1A	Six AND-OR-INVERT gates, LPTTL	(1)	AP
	171	EBB	Gate, EXCLUSIVE OR	1A	Twelve 2-input exclusive OR gates, LPTTL		AP
	172	EBC	Flip-Flop, J-K	1A	Six J-K flip-flops, LPTTL	(1)	AP
	173	EBE	Multiplexer	1A	Six 4-input digital multiplexers, LPTTL		AP
	174	FBA	Arithmetic Logic Unit	1A	Two 4-bit arithmetic logic units, LPTTL	(1)	AP
	175	FBG	Adder, Discrete Sum	1A	Discrete sum adder, adds number of 1's at 12 inputs, TTL	(1)	AP
	176	FBH	Register, Programmable	1A	Four programmable shift registers, 1 to 64 bit length, MOS and TTL	(1)	AP
	177	FGC	Amplifier, Operational	1A	Two general purpose operational amplifiers	A	AP
	178	GDP	Driver, FET Switch	1A	Twelve FET switch drivers	(1)	AP
	179	GGD	Capacitor, Programmable	1A	Eight 50V, nonpolarized, capacitors	A	AP
	180	GGG	Network Resistor, Programmable	1A	Four resistor networks 0-11K ohms in 100-ohm steps	(1)	AP
	181	-	Not assigned				

SLASH SHEET NO. M28787/	KEY* CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
182	VGS	Demultiplexer, Analog	1A	Two 1-line into 1 of 8 output lines	(1)	AP
183	ZSW	Switch, Analog	1A	Dual expandable, 4 lines out of 6 switches matrix		AP
184	SES	Amplifier, Power	1C	D/S converter, two power amplifiers	A	AP
185	STT	Transformer, Scott-T	1C	S/D converter, Scott-T/reference transformer	A	AP
186	SHY	Generator, Function, MSB	1A	S/D converter, MSB function generator	B*	AP
187	SHU	Generator, Function, LSB	1A	S/D converter, LSB function generator	(1)*	AP
188	SHV	Octant/Quadrant	1A	S/D converter, octant/quadrant detector	A	AP
189	SHX	Processor, Error, S/D	1B	S/D converter, error detector	B*	AP
190	BAC	Buffer-Limiter	1A	Four Channel buffer-limiter	(2)	AP
191	PEE	Sample and Hold	1A	Three sample and hold circuits	(1)	AP
192	ARN	Regulator, Negative	1B	-5V or -15V regulator		AP
193	SYT	Memory, Random Access	1A	Two 256 x 4-bit RAMs, LSTTL		AP
194	UHX	Generator, Function	1A	Two 4-bit arithmetic logic units, STTL		AP
195	FLC	Converter, RMS to DC	1A	VRMS to DC converter (FLL[1])		AP
196	BDM	Receiver, Line	1A	Four 2-input NAND gates, optically isolated, open coll, TTL		DC
197	EBD	Inverter	1A	Eighteen inverter buffer/drivers; hi-volt open coll output, TTL		AP
198	BYM	Memory, Read Only	1A	Vertical scan ASCII-7 graphic subset ROM, MOS		UD
199	NEC	Amplifier, Power, Audio	1E	Audio power amplifier, 4 watt		UD
200	QQA	Register File	1A	8 x 4-bit multiport register, TTL		UD
201	QQD	Multiplier, Digital	1A	2 x 8 +8 multiplier, 2's complement, TTL		UD
202	MAD	Driver	1A	Programmable gain, 300 mA, output driver		AP
203	HRA	Relay	1B	Low level relay, 1 mA maximum (5 Form 2C)		UD
204	RUN	Network, Resistor	1A	Thirteen sets of 2 (20KΩ resistor) ea, one side tied together		AP
205	BED	Amplifier, Summing	1A	Six independent summing amps, 2 input resistors plus node	(1)	AP
206	FQB	Driver, Lamp/Relay	1A	Twelve lamp/relay drivers, TTL input, 180 mA at 5 VDC		DC
207	-	Not assigned				
208	HQE	Timer, Programmable	1B	Four 0.125 to 64 sec programmable timers		DC
209	GZC	Fuse	1A	Fuse, one 1A, two 2A, two 5A, three 4A; like PMN	A	AP
210	CZH	Test Point	1A	Test point (Similar to CMH)	(1)	AP
211	FZJ	Test Point, Isolated	1A	Isolated test point (Similar to FLA)	(2)	AP
212	DQD	Standard Serial Output	1A	Standard serial output element (with EQG), LSTTL		AP
213	EQG	Converter, Parallel/Serial	1A	Dual rank parallel/serial converters using 8 4-bit registers, LSTTL		AP
214	EQF	Converter, Serial/Parallel	1A	Dual rank serial/parallel converters using 8 4-bit registers, LSTTL		DC
215	EQJ	Standard Serial Input	1A	Standard serial input element (with EQF), LSTTL		DC
216	ADL	Resistor, Pull-up	1A	Two sets of 18 (2200Ω resistors) ea, one side tied together	(2)	AP
217	HPK	Regulator, Series	1B	Low level voltage power supply, regulator series		AP
218	EEE	Filter, Low Pass, Active	1A	Analog input, 14 volt P-P; upper 3 dB frequency is 18.5 kHz		AP
219	HEE	Amplifier, Power	1B	High gain, internally-compensated, hybrid power, operational amplifier	(2)	AP
220	KAD	Modulator, Synchronous	1A	Synchronous modulator	(1)	AP
221	LEE	Amplifier, Phase Shift	1A	Two amplifiers with outputs 90° apart		AP
222	JQM	NAND/Schmitt	1A	Twelve 2-input NAND functions and/or Schmitt trigger functions		AP
223	KDC	Multiplexer	1A	Two groups of four and one group of two 2-input multiplexers	(1)	AP
224	JDF	Flip-Flop, J-K	1A	Digital Storage, high-speed J-K flip-flop, HSTTL		AP
225	HUH	Switch, S/D, Multispeed	1A	Crossover detector and switch	A(1)	AP

SLASH SHEET NO. M28787/	KEY* CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
226	PTE	Transformer, Scott-T	1B	Scott-T transformer; converts 3-wire synchro data into sin and cos		DC
227	PTF	Transformer, Resolver	1A	Isolation resolver transformer; converts 4-wire resolver information at 11.8V; converts and isolates it to 7.0, 3.5, and 1.0V RMS	(1)	AP
228	PEG	Integrator, S/D	1D	Dual matched signal integrator S/D application; two analog input signals and three output signals (and one multiplexer)		UD
229	BEE	Amplifier, Summing		Analog summing circuit for DC or sine wave input up to 100 kHz		AP
230		Not Assigned				
231	GEE	Comparator, Analog	1A	Two nonlinear voltage level comparators	(1)	AP
232	QQQ	Converter, Analog/Digital	1A	Converts analog voltage -10 to +10 to a 12-bit digital output (parallel and serial)		AP
233	FBE	Amplifier, Clipper	1A	Clipping amplifier; provides a gain of 160 dB	A(2)*	AP
234	GVQ	Oscillator, Crystal	1A	Crystal oscillator, 12.2880 MHz, square wave		AP
235	QVG	Oscillator, Crystal	1A	Crystal oscillator, 6.63552 MHz, square wave, Q and $\bar{Q}$ outputs		AP
236	QVQ	Oscillator, Crystal	1A	Crystal oscillator, 7.3728 MHz, square wave, Q and $\bar{Q}$ outputs		AP
237	HRH	Microprocessor	1A	8-bit parallel central processor unit		UD
238	GHM	Gate, NAND	1A	Twelve 2-input positive NAND, open collector output; can perform wired OR and simultaneously drive 1 to 30 TTL loads		UD
239	QBQ	Driver, NTDS slow	1A	Two drivers and two flip-flops, TTL	A*	AP
240	CGR	Transformer, Signal	1B	Six circuits, primary and secondary tapped, input/output impedance 1K ohms	(1)	AP
241	QDR	Driver, Interface, NTDS ANEW	1A	Four circuits, each has an input, strobe, and output, TTL		UD
242	QDF	Receiver, Interface, NTDS ANEW	1A	Four circuits, 2 inputs/circuit, inverting and noninverting, TTL		UD
243	DQK	Gate, AND	1A	Twelve 2-input AND gates, TTL		DC
244	DQJ	Gate, AND	1A	Six 4-input and two 3-input AND gates, TTL		DC
245	DPA	Amplifier, AGC	1B	-60 dB to 0 dB; output is constant 0 dB; gain, pin programmable	(1)	AP
246	MUM	Isolator, Optical	1A	Eight circuits		DC
247	-	Not assigned				
248	AMC	Buffer	1A	Level translator from CMOS to DTL or TTL		UD
249	AME	Gate, NOR	1A	Six 4-input and two 3-input, CMOS		UD
250	AMF	Counter, Binary	1A	Two 12-bit with buffered outputs, CMOS		UD
251	AMG	Latch, D-Type	1A	Three 4-bit latches with common clock, CMOS		UD
252	AMH	Gate, AND-OR-INVERT	1A	Six 2/2 input gates, CMOS with 3-state outputs		UD
253	BMA	Gate, NAND	1A	Twelve 2-input gates, CMOS		UD
254	BMB	Gate, NAND	1A	Four 8-inputs, CMOS		UD
255	BMC	Gate, EXCLUSIVE-OR	1A	Twelve 2-inputs, CMOS		UD
256	BMD	Flip-Flop, D-Type	1A	Six flip-flops with independent set and reset, CMOS		UD
257	BME	Multivibrator, Monostable	1A	Four retriggerable, resettable monostable vibrators, CMOS		UD
258	BMH	Decoder, BCD to Decimal	1A	Two 4-input BCD to decimal, or binary to octal decoders; consists of pulse shaping circuits on all four inputs, CMOS		DC
259	EMJ	Gate, NOR	1A	Four independent 8-inputs, CMOS		UD
260	EMK	Gate, NAND	1A	Six 4-input and two 3-input, CMOS		UD
261	EMM	Inverter	1A	Eighteen inverters, CMOS		UD
262	EMN	Buffer, Inverting	1A	Eighteen inverter level translator buffers; may be used as level shifter from CMOS to TTL or DTL		UD
263	EMP	Gate, NOR	1A	Twelve 2-input, CMOS		UD
264	EMQ	Flip-Flop, J-K	1A	Five independent J-K flip-flops with set or reset, CMOS		DC
265	-	Memory, Read Only	1A	Two, 256 x 8-bit ROMs w/3-state outputs, PTL, programmed version of GYC		AP

SLASH SHEET NO. M28787/	KEY* CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
266	GQB	Driver, Bus	1A	Eighteen, non-inverting drivers w/3 state outputs, STTL		DC
267	YBZ	Buffer, Three State	1A	Sixteen, buffers w/3 state outputs, TTL		DC
268	AGA	Multiplier, Digital	1A	2 x 8-bit, 2's complement multiplier, TTL		AP
269	FGH	Amplifier, Differential	1A	Four differential amplifiers with pin programmable gain		UD
270	ZRX	Relay	1A	Five solid state SPST relays, TTL compatible		UD
271	RQB	Converter, Binary/BCD	1A	Two 6-bit binary to BCD converters, TTL		DC
272	ZEZ	Converter, BCD/Binary	1A	Two 6-bit BCD to binary converters, TTL		DC
273	SJS	Shift Register	1A	Two 16-bit shift registers, TTL		DC
274	YKV	Timer	1A	Two programmable timers		UD
275	BMG	Counter, Binary/BCD	1A	Three 4-bit, synchronous, presettable, binary/BCD counters, CMOS		UD
276	EMH	Latch	1A	Three 4-bit, three state latches, CMOS		UD
277	EML	Shift Register	1A	Six 4-bit, static, serial/parallel shift registers, CMOS		UD
278	FQD	Driver, Lamp/Relay	1A	Six lamp/Relay driver, TTL input, 300 ms at 30V DC		DC
279	RRF	Relay	1B	Ten, 2 Form C (DPDT), relays, 1 amp		UD
280	AWA	Central Processing Unit	2A	8-bit slice CPU with Look-Ahead, multiplexing, and shift register, STTL and LSTTL		UD
281	BNB	Counter and Decoder	2A	Four 3-of-8 decoders, 4-bit counter, 4-bit holding register, four 3-state buffers, and four SLTTL buffers; STTL and LSTTL		UD
282	CWC	Microprogram Memory	2A	512-by-32-bit ready-only memory microinstruction table and 3-bit microcode source, selection, STTL and LSTTL.		UD
283	DWD	System and Interrupt Controller	2A	Microinstruction sequencer and interrupt controller, STTL and LSTTL.		UD
284	EWE	Timing and Control	2A	CPU clock and control logic, STTL and LSTTL.		UD
285	FQF	Microprocessor	2A	Microprocessor with data bus, address and clock drivers, NMOS and TTL.		UD
286	KYF	Random Access Memory	1A	4K-by-4-bit static random access memory, NMOS and TTL.		UD
287	HRL	Bidirectional Buffer	1A	Sixteen bidirectional, 3-state buffers, TTL.		UD
288	JRH	Microprocessor Clock	1A	Microprocessor clock and power failure/restart function, STTL.		DC
289	CRC	Cyclic Code Generator/Checker	2A	Generates and checks 12-bit cyclic code, STTL and LSTTL.		UD
290	-	Programmable Logic Array	1A	16-by-8-bit programmable logic array, MOS.		UD
291	AFA	Decoder	1A	Three 1-of-8 decoders, LSTTL.		UD
292	BHA	Binary Up/Down Counter	1A	Three binary up/down counters, LSTTL.		UD
293	CHH	NAND Gate	1A	Four 4-input and four 3-input NAND Gates, LSTTL.		UD
294	CHP	NAND Gate	1A	Four 8-input NAND Gates, LSTTL.		UD
295	FEA	Synchronous Binary Counter	1A	Three 4-bit synchronous binary counters, LSTTL.		UD
296	GHK	J-K Bar Flip-Flop	1A	Eight J-K flip-flops, LSTTL.		UD
297	RHF	NAND Gate	1A	Twelve 2-input NAND Gates, LSTTL.		UD
298	RHG	Investor	1A	18 inverters, LSTTL.		UD
299	-	Memory, Read Only	1A	Two 1024-by-8-bit read-only memories, TTL.		UD
300	HFB	Comparator, Magnitude	1A	One 8-bit and one 4-bit expandable magnitude comparators, LSTTL.		UD
301	ERO	Microprocessor	1A	4-bit bipolar microprocessor slice, TTL.		UD
302	ZJS	Memory, Random Access	1A	Two 16K-by-4-bit dynamic random-access memories, NMOS and LSTTL.		UD
303	ZJT	Memory, Random Access	1A	4K-by-14-bit static random-access memories, NMOS.		UD
304	ZJU	Controller, Microprogram	1A	Microprogram address sequencing and branch/ loop control, LSTTL.		UD
305	ZJX	Controller, Interrupt	1A	Vectored priority interrupt controller, LSTTL.		UD
306	MJA	Microprocessor	2A	16-bit microprocessor and interrupt controller, IIL and TTL.		UD
307	MJB	Regulator, Current, Programmable	1A	Current source, programmable from 10 mA to 800 mA.		UD

SLASH SHEET NO. M28787/	KEY[4] CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	KEY	STATUS
308	MJC	Sequencer	1A	Microprogram address sequencing, stacking, and relative addressing functions, TTL.		UD

STATUS KEY

AP Module developed and qualification completed; specification is available from Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

UC Module qualification completed; specification is currently being coordinated by the Defense Electronics Supply Center, Dayton, OH 45444. Contact DESC-ECT.

UD Module under development; contact Naval Avionics Center, Indianapolis (NAC), IN 46218, Code D924, (317) 353-3807 for specific information.

* Denotes proposed revision/amendment in process; contact Naval Weapons Support Center, Crane, IN 47552.

- Denotes a change from last issue.

( ) Denotes an amendment

NOTES:

1 Indicates the previous key code assignment which is no longer valid as a SEM standard module.

2 Indicates the Class I equivalent key code assignment.

3 Indicates the Class II equivalent key code assignment.

4 All modules are Class I unless otherwise specified.

5 Module not recommended for use in a new system design.

KEY TO ABBREVIATIONS

HSTTL - High Speed TTL
LPTTL - Low Power TTL
LSTTL - Low Power Schottky TTL
STTL - Schottky TTL
DTL - Diode Transistor Logic
TTL - Transistor Transistor Logic
NMOS - N Channel Metal Oxide Semiconductor
CMOS - Complementary Metal Oxide Semiconductor
MOS - Metal Oxide Semiconductor
IIL - Integrated Injection Logic

APPENDIX G THE MILITARY MICROCIRCUIT PROGRAM

The Military Microcircuit Program provides for the necessary quality and reliability assurements that must be met in the procurement of microcircuits. The microcircuits covered by the program are monolithic, multi-chip, and hybird devices. The general specification is MIL-M-38510D "Microcircuits, General Specification for." Detail specifications for individual microcircuit devices are contained in "slash-sheets" to MIL-M-38510D. A supplement to the specification lists the microcircuits by number and indicates the available functions; a portion of the supplement is reproduced in the following pages. The other portion of the supplement provides a cross reference between the military microcircuits and the commercial devices which are functionally and pin-layout equivalent.

MIL-M-38510D
SUPPLEMENT 1A
28 June 1978
SUPERSEDING
MIL-M-38510D
SUPPLEMENT 1
28 February 1978

MILITARY SPECIFICATION

MICROCIRCUITS

GENERAL SPECIFICATION FOR

This supplement forms a part of Military Specification MIL-M-38510. 1/

Detail specification	Title	Device type(s)
MIL-M-38510/1B (Amendment 3)	Microcircuits, Digital, TTL, NAND Gates, Monolithic Silicon.	M38510/00101---thru M38510/00109---.
MIL-M-38510/2E *(Amendment 3)	Microcircuits, Digital, TTL, Flip-Flops, Monolithic Silicon.	M38510/00201---thru M38510/00207---.
MIL-M-38510/3B (Amendment 3)	Microcircuits, Digital, TTL, NAND Buffers, Monolithic Silicon.	M38510/00301---thru M38510/00303---.
MIL-M-38510/4C	Microcircuits, Digital, TTL, Multiple NOR Gates, Monolithic Silicon.	M38510/00401---thru M38510/00404---.
MIL-M-38510/5A (Amendment 6)	Microcircuits, Digital, TTL, AND-OR-INVERT Gates, Monolithic Silicon.	M38510/00501---thru M38510/00504---.
MIL-M-38510/6C (Amendment 1)	Microcircuits, Digital, TTL, Binary Full Adders, Monolithic Silicon	M38510/00601---thru M38510/00604---.
MIL-M-38510/7B (Amendment 1)	Microcircuits, Digital, TTL, Exclusive - OR Gates, Monolithic Silicon.	M38510/00701---.
MIL-M-38510/8B (Amendment 3)	Microcircuits, Digital, TTL, Buffers/ Drivers, Open Collector Output, High Voltage, Monolithic Silicon.	M38510/00801---thru M38510/00805---.
MIL-M-38510/9C (Amendment 4)	Microcircuits, Digital, TTL, Shift Registers, Monolithic Silicon.	M38510/00901---thru M38510/00906---.
MIL-M-38510/10B (Amendment 1)	Microcircuits, Digital, TTL, Decoders, Monolithic Silicon.	M38510/01001---thru M38510/01009---.
MIL-M-38510/11B (Amendment 3)	Microcircuits, Digital, TTL, Arithmetic Logic Units/Function Generators, Monolithic Silicon.	M38510/01101---and M38510/01102---.
MIL-M-38510/12D (Amendment 2)	Microcircuits, Digital, TTL, Monostable Multivibrators, Monolithic Silicon.	M38510/01201---thru M38510/01205---.
MIL-M-38510/13C *(Amendment 3)	Microcircuits, Digital, TTL, Counters, Monolithic Silicon.	M38510/01301---thru M38510/01309---.
MIL-M-38510/14B(USAF) (Amendment 2)	Microcircuits, Digital, TTL, Data Selectors/ Multiplexers, Monolithic Silicon.	M38510/01401---thru M38510/01406---.
MIL-M-38510/15 (Amendment 4)	Microcircuits, Digital, TTL, Bistable Latches, Monolithic Silicon.	M38510/01501---thru M38510/01504---.

1/ Cross reference listings provided herein relating Military device type numbers to a similar commercial device type numbers shall not be construded as providing substitutability information.

Detail specification	Title	Device type(s)
MIL-M-38510/16(USAF) (Amendment 2)	Microcircuits, Digital, TTL, AND Gates, Monolithic Silicon.	M38510/01601---and M38510/01602---.
MIL-M-38510/17(USAF) (Amendment 3)	Microcircuits, Digital, TTL, Flip-Flops, Monolithic Silicon.	M38510/01701---and M38510/01702---.
MIL-M-38510/18(USAF) (Amendment 1)	Microcircuits, Digital, TTL, Registration File, Monolithic Silicon.	M38510/01801---.
MIL-M-38510/19(USAF) (Amendment 2)	Microcircuits, Digital, TTL, Parity Generators/ Checkers, Monolithic Silicon.	M38510/01901---.
MIL-M-38510/20A (Amendment 2)	Microcircuits, Digital, TTL, Low Power, NAND Gates, Monolithic Silicon.	M38510/02001---thru M38510/02006---.
MIL-M-38510/21C	Microcircuits, Digital, TTL, Low Power, Flip-Flops, Monolithic Silicon.	M38510/02101---thru M38510/02105---.
MIL-M-38510/22B (Amendment 1)	Microcircuits, Digital, High-Speed, TTL, Flip-Flops, Monolithic Silicon.	M38510/02201---thru M38510/02206---.
MIL-M-38510/23A (Amendment 4)	Microcircuits, Digital, TTL, High-Speed NAND Gates, Monolithic Silicon.	M38510/02301---thru M38510/02307---.
MIL-M-38510/24 (Amendment 3)	Microcircuits, Digital, TTL, High-Speed NAND Buffers, Monolithic Silicon.	M38510/02401---.
MIL-M-38510/25B (Amendment 1)	Microcircuits, Digital, TTL, Low-Power, Counters, Monolithic Silicon.	M38510/02501---thru M38510/02505---.
MIL-M-38510/26(USAF) (Amendment 4)	Microcircuits, Digital, TTL, Low Power Exclusive - OR Gates, Monolithic Silicon.	M38510/02601---.
MIL-M-38510/27(USAF) (Amendment 3)	Microcircuits, Digital, TTL, Low Power, Multiple NOR Gates, Monolithic Silicon.	M38510/02701---.
MIL-M-38510/28B(USAF) (Amendment 2)	Microcircuits, Digital, TTL, Low Power Shift Registers, Monolithic Silicon.	M38510/02801---thru M38510/02806---.
MIL-M-38510/29B(USAF) (Amendment 1)	Microcircuits, Digital, TTL, Low Power, Decoders, Monolithic Silicon.	M38510/02901---thru M38510/02907---.
MIL-M-38510/30A (Amendment 1)	Microcircuits, Digital, DTL, NAND Gates, Monolithic Silicon.	M38510/03001---thru M38510/03005---.
MIL-M-38510/31 (Amendment 1)	Microcircuits, Digital, DTL, NAND Buffer/ Extender, Monolithic Silicon.	M38510/03101---thru M38510/03105---.
MIL-M-38510/32 (Amendment 2)	Microcircuits, Digital, DTL, Monostable, Multivibrator, Monolithic Silicon.	M38510/03201---.
MIL-M-38510/33 (Amendment 1)	Microcircuits, Digital, DTL, Flip-Flops, Monolithic Silicon.	M38510/03301---thru M38510/03304---.
MIL-M-38510/35(USAF) (Amendment 2)	Microcircuits, Digital Clock Drivers, Monolithic Silicon.	M38510/03501---.
MIL-M-38510/40(USAF) (Amendment 5)	Microcircuits, Digital, TTL, High-Speed, AND-OR-INVERT Gates, Monolithic Silicon.	M38510/04001---thru M38510/04005---.
MIL-M-38510/41(USAF) (Amendment 3)	Microcircuits, Digital, TTL, Low Power, AND-OR-INVERT Gates, Monolithic Silicon.	M38510/04101---thru M38510/04103---.
MIL-M-38510/42A(USAF) (Amendment 1)	Microcircuits, Digital, TTL, Low Power, Monostable Multivibrators, Monolithic Silicon.	M38510/04201---thru M38510/04202---.

Detail specification	Title	Device type(s)
MIL-M-38510/43(17) (Amendment 1)	Microcircuits, Digital, TTL, Low Power, Priority Encoders, Monolithic Silicon.	M38510/04301---.
MIL-M-38510/44(USAF) (Amendment 1)	Microcircuits, Digital, TTL, Low Power, Comparators, Monolithic Silicon.	M38510/04401.
MIL-M-38510/45(17) (Amendment 1)	Microcircuits, Digital, TTL, Low Power, Bistable Latches, Monolithic Silicon.	M38510/04501---and M38510/04502---.
MIL-M-38510/46(17) (Amendment 1)	Microcircuits, Digital, TTL, Low Power Data Selectors/Multiplexers, Monolithic Silicon.	M38510/04601---thru M38510/04603---.
MIL-M-38510/50C *(Amendment 1)	Microcircuits, Digital, CMOS, NAND Gates, Monolithic Silicon.	M38510/05001---thru M38510/05003---.
MIL-M-38510/51C	Microcircuits, Digital, CMOS, Flip-Flop, Monolithic Silicon.	M38510/05101---thru M38510/05103---.
MIL-M-38510/52B *(Amendment 2)	Microcircuits, Digital, CMOS, NOR Gates, Positive Logic, Monolithic Silicon.	M38510/05201---thru M38510/05204---.
MIL-M-38510/53B *(Amendment 1)	Microcircuits, Digital, CMOS, Complementary Pair Plus Inverter, AND-OR-Select, Exclusive OR Gates, Monolithic Silicon.	M38510/05301---thru M38510/05304---.
MIL-M-38510/54B *(Amendment 1)	Microcircuits, Digital, Positive Logic CMOS, Four-bit Full Adder Monolithic Silicon.	M38510/05401---.
MIL-M-38510/55D	Microcircuits, Digital, CMOS, Buffer/ Converter, Monolithic Silicon.	M38510/05501---thru M38510/05505---.
MIL-M-38510/56C	Microcircuits, Digital, CMOS, Counters/ Dividers, Monolithic Silicon.	M38510/05601---thru M38510/05605---.
MIL-M-38510/57B *(Amendment 1)	Microcircuits, Digital, Positive Logic CMOS, Static Shift Register, Monolithic Silicon.	M38510/05701---thru M38510/05706---.
MIL-M-38510/58	Microcircuits, Digital, CMOS, Switches, Monolithic Silicon, Positive Logic	M38510/05801---and M38510/05802---.
MIL-M-38510/59	Microcircuits, Digital, CMOS, Decoder Monolithic Silicon, Positive Logic	M38510/05901---.
MIL-M-38510/60(USAF) (Amendment 3)	Microcircuits, Digital, ECL, Multiple NOR Gates, Monolithic Silicon.	M38510/06001---thru M38510/06006---.
MIL-M-38510/61A(USAF) (Amendment 1)	Microcircuits, Digital, ECL, Flip-Flops, Monolithic Silicon.	M38510/06101---thru M38510/06104---.
MIL-M-38510/62(USAF) (Amendment 1)	Microcircuits, Digital, ECL, AND/NAND Gates, Monolithic Silicon.	M38510/06201---and M38510/06202---.
MIL-M-38510/70(USAF) (Amendment 3)	Microcircuits, Digital, Schottky TTL, NAND Gates, Monolithic Silicon.	M38510/07001---thru M38510/07010---.
MIL-M-38510/71A(USAF) (Amendment 1)	Microcircuits, Digital, Schottky TTL, Flip-Flops, Monolithic Silicon.	M38510/07101---thru M38510/07106---.
MIL-M-38510/72(USAF) (Amendment 2)	Microcircuits, Digital, Schottky TTL, NAND Buffers, Monolithic Silicon.	M38510/07201---.
MIL-M-38510/73(USAF) (Amendment 2)	Microcircuits, Digital, Schottky TTL, Multiple NOR Gates, Monolithic Silicon.	M38510/07301---.

Detail specification	Title	Device type(s)
MIL-M-38510/74(USAF) (Amendment 2)	Microcircuits, Digital, Schottky TTL, AND-OR-Invert Gates, Monolithic Silicon.	M38510/07401---thru M38510/07403---.
MIL-M-38510/75(USAF) (Amendment 2)	Microcircuits, Digital, Schottky, TTL, Exclusive-OR Gates, Monolithic Silicon.	M38510/07501---and M38510/07502---.
MIL-M-38510/76(USAF) (Amendment 1)	Microcircuits, Digital, Schottky, TTL, Shift Registers, Monolithic Silicon.	M38510/07601---and M38510/07602---.
MIL-M-38510/78(USAF) (Amendment 2)	Microcircuits, Digital, Schottky TTL, Aritnmetic Logic Unit/Function Generators, Monolithic Silicon.	M38510/07801---and M38510/07802---.
MIL-M-38510/79(17) *(Amendment 3)	Microcircuits, Digital, Schottky, TTL, Data Selectors/Multiplexers, Monolithic Silicon.	M38510/07901---thru M38510/07907---.
MIL-M-38510/80A(USAF) *(Amendment 2)	Microcircuits, Digital, Schottky, TTL, AND Gates, Monolithic Silicon.	M38510/08001---thru M38510/08004---.
MIL-M-38510/81A(USAF)	Microcircuits, Linear, Schottky, Line Drivers, Monolithic Silicon.	M38510/08101---.
MIL-M-38510/82(USAF) (Amendment 1)	Microcircuits, Digital, Schottky TTL, Magnitude Comparators, Monolithic Silicon.	M38510/08201---.
MIL-M-38510/101E *(Amendment 2)	Microcircuits, Linear, Operational Amplifiers, Monolithic Silicon.	M38510/10101---thru M38510/10107---.
MIL-M-38510/102A(USAF) *(Amendment 2)	Microcircuits, Linear, Voltage Regulator, Monolithic Silicon.	M38510/10201---.
MIL-M-38510/103B(USAF) (Amendment 1)	Microcircuits, Linear, Voltage Comparators, Monolithic Silicon.	M38510/10301---thru M38510/10305---.
MIL-M-38510/104A(USAF) (Amendment 4)	Microcircuits, Linear, Line Drivers and Receivers, Monolithic Silicon.	M38510/10401---thru M38510/10407---.
MIL-M-38510/106A *(Amendment 1)	Microcircuits, Linear, Voltage Follower Operational Amplifiers, Monolithic Silicon.	M38510/10601---and M38510/10602---.
MIL-M-38510/107A(USAF) *(Amendment 2)	Microcircuits, Linear, Voltage Regulator, Monolithic Silicon.	M38510/10701---thru M38510/10709---.
MIL-M-38510/108(USAF)	Microcircuits, Linear, Transistor Arrays, Monolithic Silicon	M38510/10801---and M38510/10802---.
*MIL-M-38510/109(USAF)	Microcircuits, Linear, Precision Timers, Monolithic Silicon.	M38510/10901---and M38510/10902---.
*MIL-M-38510/110	Microcircuits, Linear, Quad Operational Amplifiers, Monolithic Silicon	M38510/11001---thru M38510/11005---.
MIL-M-38510/150B(USAF) (Amendment 2)	Microcircuits, Digital, TTL, Magnitude Comparators, Monolithic Silicon.	M38510/15001---and M38510/15002---.
MIL-M-38510/151(USAF) (Amendment 5)	Microcircuits, Digital, TTL, Schmitt-Trigger NAND Gates, Monolithic Silicon.	M38510/15101---thru M38510/15103---.
MIL-M-38510/152(17) *(Amendment 4)	Microcircuits, Digital, TTL, Data Decoders/Demultiplexers, Monolithic Silicon.	M38510/15201---thru M38510/15206---.
MIL-M-38510/153(USAF) (Amendment 2)	Microcircuits, Digital, TTL, Quadruple Bus. Buffer Gates with Three-State Outputs, Monolithic Silicon.	M38510/15301 and M38510/15302---.

Detail specification	Title	Device type(s)
MIL-M-38510/155A(USAF)	Microcircuits, Digital, TTL, High-Speed, AND Gates, Monolithic Silicon.	M38510/15501---thru M38510/15504---.
MIL-M-38510/156(USAF) (Amendment 3)	Microcircuits, Digital, TTL, Data Encoders, Monolithic Silicon.	M38510/15601---thru M38510/15603---.
MIL-M-38510/157(17) (Amendment 1)	Microcircuits, Digital, TTL, Multiple Port Registers, Monolithic Silicon.	M38510/15701---.
MIL-M-38510/158(USAF) (Amendment 2)	Microcircuits, Digital, TTL, Decoders, Monolithic Silicon.	M38510/15801---and M38510/15802---.
MIL-M-38510/159(USAF) (Amendment 2)	Microcircuits, Digital, TTL, Shift Regieters, Monolithic Silicon.	M38510/15901---and M38510/15902---.
MIL-M-38510/160(USAF) (Amendment 1)	Microcircuits, Digital, TTL, Addressable Latches, Monolithic Silicon.	M38510/16001---.
MIL-M-38510/161(USAF) (Amendment 1)	Microcircuits, Digital, TTL, Common OR Gates, Monolithic Silicon.	M38510/16101---.
MIL-M-38510/162(USAF) *(Amendment 1)	Microcircuits, Digital, TTL, NOR Buffers, Monolithic Silicon.	M38510/16201---.
MIL-M-38510/163(USAF) *(Amendment 2)	Microcircuits, Digital, TTL, Hex Bus Drivers With 3-State Outputs, Monolithic Silicon.	M38510/16301--- thru M38510/16304---.
MIL-M-38510/170	Microcircuits, Digital, CMOS, AND Gates, Monolithic Silicon, Positive Logic	M38510/17001---thru M38510/17003---.
MIL-M-38510/201(USAF) (Amendment 1)	Microcircuits, Digital, Prom, 512 Bit Bipolar Programmable Read Only Memory (P-ROM), Monolithic Silicon.	M38510/20101---and M38510/20102---.
MIL-M-38510/202(USAF) (Amendment 1)	Microcircuits, Digital, 1024-Bit Bipolar, Programmable, Read only Memory (P-ROM), Monolithic Silicon.	M38510/20201---and M38510/20202---.
MIL-M-38510/203(USAF) *(Amendment 1)	Microcircuits, Digital, 1024 Bit Schottky Bipolar, Programmable Read-Only Memory (PROM) Monolithic Silicon.	M38510/20301---and M38510/20302---.
MIL-M-38510/204(USAF) *(Amendment 1)	Microcirucits, digital, 2048 Bit Schottky Bipolar, Programmable, Read-Only Memory (PROM) Monolithic Silicon.	M38510/20401---and M38510/20402---.
*MIL-M-38510/206(USAF)	Microcircuits, Digital, 4096 Bit Schottky Bipolar, Programmable, Read-Only Memory (PROM) Monolithic Silicon	M38510/20601---thru M38510/20603---.
*M38510/38510/209(USAF)	Microcircuits, Digital, 8192 Bit Schottky Bipolar, Programmable, Read-Only Memory (PROM) Monolithic Silicon.	M38510/20901---thru M38510/20904---.
MIL-M-38510/235A(USAF)	Microcircuits, Digital, MOS 4096 Bit Random Access Memory (RAM) Monolithic Silicon.	M38510/23501---thru M38510/23506---.
MIL-M-38510/300A(USAF) *(Amendment 2)	Microcircuits, Digital, Low-Power Schottky TTL, NAND Gates, Monolithic Silicon.	M38510/30001---thru M38510/30009---.
MIL-M-38510/301A(USAF) *(Amendment 1)	Microcircuits, Digital, Schottky, TTL, Low Power, Flip-Flops, Monolithic Silicon.	M38510/30101---thru M38510/30110---.
MIL-M-38510/302B(USAF)	Microcircuits, Digital, Low Power Schottky TTL, Buffers, Monolithic Silicon.	M38510/30201---thru M38510/30204---.

Detail specification	Title	Device type(s)
MIL-M-38510/303A(USAF) (Amendment 1)	Microcircuits, Digital, Low Power Schottky TTL, NOR Gates, Monolithic Silicon.	M38510/30301---thru M38510/30303---.
MIL-M-38510/304(17) (Amendment 4)	Microcircuits, Digital, Low Power Schottky TTL, AND-OR-INVERT Gates, Monolithic Silicon.	M38510/30401---and M38510/30402---.
*MIL-M-38510/305A(USAF)	Microcircuits, Digital, Low Power Schottky TTL, OR Gates, Monolithic Silicon.	M38510/30501---and M38510/30502---.
MIL-M-38510/306A(USAF) *(Amendment 1)	Microcircuits, Digital, Low Power Schottky TTL, Shift Registers, Monolithic Silicon.	M38510/30601---thru M38510/30607---.
MIL-M-38510/307A(USAF) *(Amendment 1)	Microcircuits, Digital, Low-Power Schottky TTL, Decoders, Monolithic Silicon.	M38510/30701---thru M38510/30704---.
MIL-M-38510/308(17) *(Amendment 4)	Microcircuits, Digital Low Power Schottky TTL, Arithmetic Logic Units/Function Generators, Monolithic Silicon.	M38510/30801---.
MIL-M-38510/309A(USAF) *(Amendment 1)	Microcircuits, Digital, Low Power Schottky TTL, Data Selectors/Multiplexers, Monolithic Silicon.	M38510/30901---thru M38510/30908---.
MIL-M-38510/310A(USAF)	Microcircuits, Digital, Low Power Schottky TTL, AND Gates, Monolithic Silicon.	M38510/31001---thru M38510/31004---.
MIL-M-38510/311A(USAF))	Microcircuits, Digital, Low Power Schottky TTL, *Magnitude Comparators*, Monolithic Silicon.	M38510/31101---.
MIL-M-38510/312(USAF) *(Amendment 2)	Microcircuits, Digital, Low Power Schottky TTL, 4-BIT Binary Full Adders with Fast Carry, Monolithic Silicon.	M38510/31201---and M38510/31202---.
MIL-M-38510/313(USAF) (Amendment 2)	Microcircuits, Digital, Low-Power Schottky TTL, Schmitt-Trigger Positive-Nand Gates and Inverters, Monolithic Silicon.	M38510/31301---thru M38510/31303---.
MIL-M-38510/314(USAF) (Amendment 1)	Microcircuits, Digital, Low Power Schottky TTL, Monostable Multivibrators, Monolithic Silicon.	M38510/31401---thru M38510/31403---.
*M38510/315(USAF)	Microcircuits, digital, Low-Power Schottky, TTL, Counters, Monolithic Silicon.	M38510/31501---thru M38510/31504---and M38510/31507---thru M38510/31513---.
MIL-M-38510/320(USAF) (Amendment 1)	Microcircuits Digital, Low-Power Schottky TTL, Counters, Monolithic Silicon.	M38510/32003---and M38510/32004---.
MIL-M-38510/321(USAF) (Amendment 1)	Microcircuits, Digital, Low Power Schottky TTL, Buffers/Drivers, Open Collector Output, High Voltage, Monolithic Silicon.	M38510/32102---.
MIL-M-38510/322(USAF) *(Amendment 1)	Microcircuits, Digital, TTL, Low-Power Schottky, Hex Bus Driver with Three State Outputs, Monolithic Silicon.	M38510/32201---thru M38510/32204---.
MIL-M-38510/323(USAF) (Amendment 1)	Microcircuits, Digital, Low-Power Schottky TTL, Quadruple Bus Buffer Gates with Three-State Outputs, Monolithic Silicon.	M38510/32301---and M38510/32302---.
M38510/400(USAF) *(Amendment 1)	Microcircuits, Digital, N-Channel, Silicon-Gate, Monolithic 8 Bit Microprocessor (Fixed Instruction).	M38510/40001---.
M38510/420(USAF)	Microcircuits, Digital, N-Channel, Silicon Gate, Monolithic 8 Bit Micorprocessor (Fixed Instruction).	M38510/42001---.

APPENDIX H - FLEET EXPERIENCE WITH THE PSNS HYBIRD CONTROLLER

The Puget Sound Naval Shipyard (PSNS) has designed an elevator controller that utilizes small low power electromagnetic relays to sense input signals from external input devices; it uses solid state relays (SSR) to drive external output devices, hence the name "Hybird Controller." PSNS installed one hybird controller on the U.S.S. SACRAMENTO (AOE-1) in January of 1977, and installed nine on the U.S.S. CAMDEN (AOE-2) in September of 1977. The controller was designed to accommodate the requirements of a seven level cargo elevator. Both of the ships on which the hybird controller was installed have reported satisfactory reliability and maintainability as indicated in the attached messages.

CO 559
RTTUZYUW RHHMSGG0731 2702359-UUUU--RUWMBWA. 21
ZNR UUUUU
R 271745Z SEP 78 Read Annual
FM COMSERVGRU ONE 100 200 300 1800
INFO RULSSAA/COMNAVSEASYSCOM WASHINGTON DC ACTION 1821 & 213
RUWDIAA/COMNAVSURFPAC SAN DIEGO CA 9-27-78
RUWDPAA/NAVSHIPWPNSYSENGSTA PORT HUENEME CA A08-1
RUWJAJA/PERA SAN FRANCISCO CA X 9558
RUWMBWA/PERA BREMERTON WA X A08-2
RUWMBWA/NAVSHIPYD PUGET SOUND WA Action 1821 & 213
R 322124Z AUG 78 B/fo - 1802-1802A-1821-
FM USS CAMDEN 1822-1841-1842-1842.216
TO COMSERVGRU ONE 2160-2445 (270.2
INFO USS SACRAMENTO
BT
UNCLAS //N03740//
WEAPONS ELEVATOR CONTROLLERS
A. COMSERVGRU ONE 251621Z AUG 78 NR
B. COMNAVSURFPAC SAN DIEGO CA 221929Z AUG 78
C. COMNAVSEASYSCOM WASHINGTON DC 221415Z AUG 78
1. IAW REF A, THE FOLLOWING IS SUBMITTED:
A. CAMDEN HAS ENJOYED EXCELLNT RELIABILITY OF HYBRID RELAY TYPE CONTROLLERS INSTALLED DURING OVERHAUL, REPLACING ONLY A FEW RELAYS OF THE OVR 400 ONBOARD.
B. PROXIMITY SWITCHES HOWEVER, APPEAR TO BE A SOURCE OF UNRELIABILITY. THIRTEEN SWITCHES HAVE BEEN REPLACED SINCE OVERHAUL, TWELVE OF WHICH HAD BEEN USED ONLY 4 TO 6 HOURS ON ELEVATORS 1 THRU 6. ELEVATOR 7 HAS BEEN USED MORE EXTENSIVELY REQUIRING ONLY ON REPLACEMENT. SEVERAL PROXIMITY SWITCHES ARE PRESENTLY LEAKING VOLTAGES TO THE HYBRID RELAYS ON ELEVATORS 1 THRU 6 AND MAY ALSO NEED REPLACEMENT. INCREASED RUNNING TIME AND HEAT APPEAR TO COMPOUND THE LEAKAGE. PSNS AND NSWSES ARE CURRENTLY INVESTIGATING THIS PROBLEM.
C. RELAY PANELS SHOULD BE HINGEDFOR ACCESS TO REAR OF PANEL. PRESENT DESIGN REQUIRES REMOVAL OF ALL WIRES PRIOR TO REMOVAL OF PANEL.
2. OTHER AREAS OF CONCERN INCLUDE SAFETY CHAIN SWITCH. THEY ARE CONNECTED IN SERIES AND SHOULD ONE FAIL SPECIFIC LEVEL OF FAILURE IS NOT INDICATED. THIS INVOLVES A LENGTHY DELAY WHILE FLASH DOORS ARE REMOVED AT EACH LEVEL TO PERMIT ACCESS TO THE SWITCHES FOR INVESTIGATION. IN ADDITION, THE ALUMINUM PLATES WHICH CLOSE THE SAFETY CHAIN SWITCHES ARE ARE NOT HEAVY ENOUGH. DURING ELEVATOR OPERATION THEY VIBRATE UP, OPENING THE SWITCH, CAUSING THE ELEVATOR TO STOP.
3. THE RUN/STOP SWITCHES ARE ALSO IN SERIES, REQUIRING INVESTIGATION OF EACH LEVEL TO DETERMINE WHICH ONE IS OFF OR DEFECTIVE.
4. IN SUMMARY, UPCOMING OPERATIONS COULD BE ADVERSELY AFFECTED BY ANY OF THE AFORE MENTIONED PROBLEMS. THE HYBRID RELAY TYPE CONTROLLERS APPEAR TO BE RELIABLE BUT MODIFIACTIONS TO THE OVERALL ELEVATOR SYSTEM MAY BE NEEDED TO INCREASE TOTAL RELIABILITY. PROXIMITY INDICATION THE FAULTY DECK OR SWITCH WOULD GREATLY EXPEDITE CORRECTION OF A SAFETY CHAIN SHITCH OR RUN/STOP SWITCH PROBLEM. HEAVIER ACTUATION PLATES MIGHT ALSO DECREASE SAFETY CHAIN SWITCH PROBLEMS. FINALLY, AN OVERHAUL/REVIEW OF SUPPLY COVERAGE SHOULD BE CONCURRENT WITH AN OVERHAUL/REVIEW IN EQUIPMENT.
BT
#0731

NNNN

CO 536 21

RTTUZYUW RHHMSGG0391 2702357-UUUU--RUWMBWA.

ZNR UUUUU

R 271745Z SEP 78 100 200 300 1800 9-27-78

FM COMSERVGRU ONE ACTION 1821 & 213

INFO RULSSAA/COMNAVSEASYSCOM WASHINGTON DC 9588

RUWDTAA/COMNAVSURFPAC SAN DIEGO CA X AOE-1

RUWDPAA/NAVSHIPWPNSYSENGSTA PORT HUENEME CA X AOE-2

RUWJAJA/PERA SAN FRANCISCO CA

RUWMBWA/PERA BREMERTON WA

RUWMBWA/NAVSHIPYD PUGET SOUND WA

R 282301Z AUG 78

FM USS SACRAMENTO

TO COMSERVGRU ONE

BT

UNCLAS //N24700//

WEAPONS ELEVATOR CONTROLLERS

A. COMNAVSURFPAC SAN DIEGO CA 221929Z AUG 78

B. COMNAVSEASYSCOM WASHINGTON DC 221415Z AUG 78

C. COMSERVGRU ONE 251621Z AUG 78

1. MAINTENANCE CREW HAS EXPERIENCED NO PROBLEMS WITH THE OPERATION AND MAINTENANCE OF SUBJ CONTROLLER. RELIABILITY HAS BEEN PROVEN OVER 2 YEAR PERIOD OF HEAVY OPERATIONS

PAGE 02 RHHMSGG0391 UNCLAS

INCLUDING WESTPAC DEPLOYMENT. PMS MAINTENANCE IS GREATLY SIMPLIFIED AND TRAINING REQUIRED IS MINIMAL, COMPARED TO CONTROLLERS INSTALLED ON REMAINING ELEVATORS. HYBRID CONTROLLER CONSIDERED EXCELLENT FOR RELIABILITY AND MAINTAINABILITY.

BT

#0391

Action 1821 & 213.

Info 1802-1862?-1820-1822-1841-
1842-1841 ... - 215 ... 2445-
270.2

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