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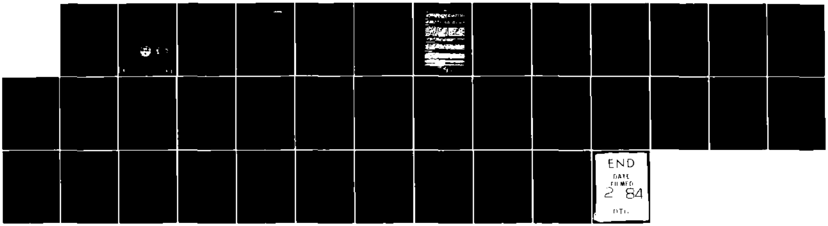

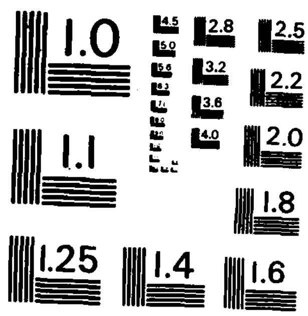

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NATO SEASPARROW SURFACE MISSILE SYSTEM (NSSMS) ORDNANCE PUBLICATIONS: A REVIEW AND RECOMMENDATIONS FOR REVISION

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER
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NATO SEASPARROW SURFACE MISSILE SYSTEM (NSSMS) ORDNANCE PUBLICATIONS: A REVIEW AND RECOMMENDATIONS FOR REVISION

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Human factors criteria were used to identify information presentation discrepancies in the NATO SEASPARROW Surface Missile System (NSSMS) ordnance publications (OPs). Concurrently with the human factors review, fleet personnel were sent questionnaires and were interviewed to determine if general usability problems exist and to identify specific problems fleet personnel have had with the NSSMS OPs. → over

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The following problems were identified: A systematic top-down approach was not used in presenting and organizing the NSSMS technical data; the format changes from manual to manual and even from chapter to chapter; information is difficult to locate and access; faults are difficult to isolate; the maintenance philosophy and the level of technical detail do not always match; and the coverage is redundant in some areas and incomplete in others. Suggestions for resolving these problems were made.

FOREWORD

This project was conducted for the NATO SEASPARROW Surface Missile System (NSSMS) project office (SEA-06P) in response to a request by Commander, Naval Sea Systems Command (NAVSEA 0141(3)). The project resulted from initial efforts that were conducted under the advanced development task area Z0828-PN (Enlisted Personnel Individualized Career System (EPICS)).

NSSMS ordnance publications were analyzed according to human factors document design criteria and fleet input. The results of this effort are intended for use by NSSMS project office to reformat the NSSMS ordnance publications.

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Technical Director

CONTENTS

LIST OF FIGURES

INTRODUCTION

Problem

Concern expressed by fleet commanders in chief regarding inadequate technical documentation of the NATO SEASPARROW Surface Missile System (NSSMS) and the extensive cost of updating the technical manuals in their current configurations prompted the NSSMS project office to consider the effectiveness of the NSSMS technical publications. With the Naval Ship Weapon Systems Engineering Station (NSWSES) assuring technical accuracy of the NSSMS data, a human factors review was initiated to identify content and organizational discrepancies in the technical information.

Purpose

The purpose of this effort was to identify specific problem areas in the NSSMS ordnance publications (OPs) and make recommendations for improving the usability of the NSSMS technical data.

Background

The technical data for the NSSMS comprise 48 OPs in the following seven major divisions: (1) overall system, (2) fire control subsystem, (3) launcher subsystem, (4) computer, (5) signal data converter, (6) low-level light television, and (7) system evaluation trainer.

Booher and Mroz (1981) reviewed the NSSMS documentation and found that most of the technical data in the OPs were oriented toward engineers rather than technicians. They concluded that the large NSSMS technical data base was poorly organized and indexed for the user. It was not readily apparent from the OPs if a top-down systems approach had been used to organize and sort the technical data.

APPROACH

The NSSMS OPs were reviewed using human factors criteria to identify information presentation discrepancies. Each category of information (e.g., function diagrams, schematics, troubleshooting tables, etc.) was reviewed and examined for completeness and overall usability. Samples of the NSSMS OPs were analyzed from the user's viewpoint to identify any technical content areas that are incompatible with user needs. To determine usability, the technical data were assessed according to (1) user access schemes required to locate specific sets of data, (2) completeness of the information for fault isolation, (3) consistency of data organization across and within subsystems, and (4) comprehensibility requirements of the user population.

The organization of the troubleshooting data was examined to determine if it provided a logical layout for the technicians to reference for fault isolation. The contribution of the automatic fault isolation circuitry to the troubleshooting data was examined. The following troubleshooting data were analyzed for completeness and consistency at the equipment, subsystem, and system levels: (1) troubleshooting indices, (2) mode block diagrams, (3) fault isolation and detection (FID) block diagrams, (4) fault-oriented interconnector diagrams (FOIDs), (5) power distribution diagrams, (6) reference (schematic) diagrams, (7) maintenance control and indicator tables, and (8) relay and lamp indices. Problems in packaging and accessibility of the data were noted and described.

The comprehensibility of the OPs was examined by assessing both reading difficulty and text layout of the OP material. In the readability analysis, narrative samples from five of the seven major OP divisions were analyzed using the "Writer's Workbench" text processing package developed by Bell Telephone Laboratories (Macdonald, Frase, Ginsrich, & Kennan, 1982). Reading grade levels (RGLs) were determined according to the method described by Kincaid, Rodgers, Fishburne, and Chissom (1975).

The quasi-random samples of materials selected from the various NSSMS manuals were passages of continuous text, preferably an entire paragraph, approximately 100 to 200 words in length, without tabular material, and with a minimum of symbols peculiar to the NSSMS system. The number of samples from any given volume was approximately in direct proportion to the amount of text in that volume.

Concurrently with the human factors review, fleet personnel were sent questionnaires and interviewed (see appendix) to determine if general usability problems exist and to identify specific problems fleet personnel have had with the NSSMS OPs. Twenty technicians--17 in the fire control technician (surface missile fire control) (FTM) rating and 3 in the gunner's mate (missiles) (GMM) rating--responded to the questionnaire. Their experience on the NSSMS ranged from 7 months to 4-1/2 years. Only three had less than 2 years experience, while nine had 3 or more years experience. During the interview phase, comments were obtained from nine FTMs and two GMMs. All of these had at least 2 years experience on the NSSMS; six had 3 or more years.

Because of the problems of obtaining field data, a randomized design was not possible. Rather, an "as available" basis was used to obtain both questionnaire and interview data from both Atlantic and Pacific Fleet personnel. The range of experience of respondents, however, indicated that the sample is representative of NSSMS technicians.

Upon completion of the review, a plan for reformatting the NSSMS technical documentation was defined. This plan provides for OPs that satisfy the users' needs and are consistent with the user's skills and knowledge, while making maximum use of current technical content. The objectives of the reformatted OPs are to provide a set of documents that (1) the schools can use readily to teach troubleshooting while also providing the operational information needed to understand how the NSSMS functions, (2) users can easily access for troubleshooting data, and (3) the NSSMS Project Office can update inexpensively when modifications are made to the NSSMS.

RESULTS AND DISCUSSION

General Problem Areas

Careful examination of the NSSMS OPs indicates that they were not systematically developed. Neither the separation nor the relationship of the operational and troubleshooting data are evident. It appears that an original core of technical data was developed first and then augmented with more detailed information. What emerges is a convoluted mix of operational and troubleshooting data that requires making a choice between teaching the system or teaching how to troubleshoot. A more integrated approach would use the operational data as the basis for understanding how the system works, while at the same time using the troubleshooting data to supplement the operational data and provide the user with the necessary information to operate and maintain the system.

Confusion between understanding how the system operates and how to *troubleshoot it* is apparent in OP 4004, the technical manual that should provide the overall structure to the technical data. Volume 1 presents an overall operational description, while Volume 2 attempts to integrate the various data in the subsystem OPs to provide the technician with a cohesive structure for troubleshooting. Unfortunately, the pattern that emerges is not what technicians use to fault isolate malfunctioning components.

Automatic Fault Isolation

Built-in test (BIT) and FID circuits, which are an integral part of the NSSMS circuitry, are designed to provide the technician with shortcuts to corrective maintenan-e by permitting the normal troubleshooting documentation to be bypassed for some fail. Supposedly, faults not isolated by the BIT-FID circuits are detected during the NS S system level test (i.e., the daily system operability test (DSOT)). Unfortunately, proportions of the NSSMS circuitry covered by BIT-FID circuits and DSOT are indicated. To compound the situation, an indication of failure by the BIT-FID circuit mean that either the operational or the BIT-FID circuitry failed. It is impossible to Therefore, regardless of initial fault indication, the basic troubleshooting procedure i same: Start with the indication and work backwards until the fault is discovered. The technical data do not provide the user with the information necessary to go directly to the suspected fault.

Trouble Isolation

In OP 4004, the user is lead to believe that the trouble isolation data are systematically organized with three levels or sets of trouble isolation documentation: system, subsystem, and equipment.

At the system level, system functional diagrams depict development and transfer of major system functions. A narrative, detailed functional description is also provided. Using these data facilitates checking interface signals and commands between the external designation source (e.g., search radar and NSSMS). At the subsystem level, design of the trouble isolation documentation is supposed to provide troubleshooting down to the ship replaceable assembly (SRA). Thus, at this level, only overall fault directories are used to categorize the trouble symptoms and reference the trouble isolation data for specific equipment.

At the equipment level, fault directories from either the system or subsystem levels provide additional references to the trouble isolation documentation needed to isolate the fault to a defective SRA and effect necessary corrective action. Descriptions are provided of these troubleshooting data (i.e., troubleshooting indices, mode block diagrams, FID block diagrams, FOIDs, power distribution diagrams, reference (schematic) diagrams, maintenance control and indicator tables, and relay and lamp indices) but not of their interrelationships.

Figure 1 is an attempt to illustrate the various relationships among these data. Several problems, however, must be noted. The usual entry points for troubleshooting are either DSOT or the BIT off-line tests and, although additional information sources are available, the usual troubleshooting path is directly from the indication to the FOID. For example, consider that a faulty filter-rectifier assembly (15/16A4) lights the AMPLIFIER ARC indicator on the control monitor. Technicians using the trace-back method would begin with FOID Figure 5-231, sheet 3 of 3 and trace back through sheet 3 to sheet 2 and eventually to sheet 1. From there, another book, the power distribution diagrams, has to

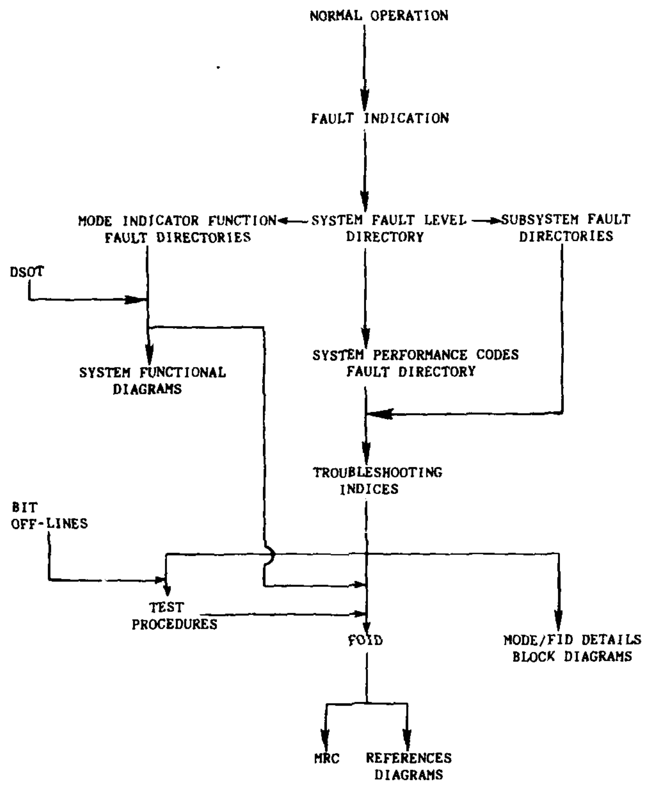

Figure 1. Overview of the NSSMS troubleshooting data categories.

be consulted to find Figure 5-411, sheet 6. Tracing back from sheet 6 to sheet 5 leads back to the first book to FOID Figure 5-239, sheet 7 of 14. Tracing back from sheet 7 to sheet 6 and finally to sheet 5, the filter-rectifier assembly can be isolated as the source. For additional technical information on that assembly, however, the technician must consult a third book, the reference diagrams, to find the schematic, Figure 6-110. Thus, technicians had to refer to nine pages of data not in a direct sequence and in three books. Since only figure numbers are referenced, technicians must know which figure numbers are in which book to avoid having to search through several books to locate a specific figure. With a more complicated problem, the laborious process of signal tracing through many pages can easily become confusing and it is easy for the technicians to lose their place going from one sheet to another. With many sheet and figure references involved, a typographical error can easily lead the technicians astray.

In addition to FOIDs, mode and FID data, both in narrative and diagrams, are available in the OPs to facilitate the troubleshooting process. The mode and FID diagrams are presented, at both the general and detailed levels, as separate types of data but integrated with each other. Both are important when troubleshooting beyond the BIT-FID circuitry and are usually referenced whenever a FOID is referenced. However, the mode and FID data are in the operational section of the technical manuals and are essentially redundant with the FOIDs. Their main differences are that (1) the FOIDs present all the relevant data together, based on indicator entries instead of first presenting the circuitry associated with a particular mode or FID circuit and (2) they identify test points, which the mode and FID diagrams do not. The end result is 15,000 or 20,000 pages of data, of which technicians only use about 5,000. While the mode diagrams may be useful in a school environment, time in that environment is limited. Since the school is designed to teach troubleshooting, use of the FOIDs is emphasized over the mode and FID data, even though narrative explanations are available for the mode and FID diagrams and not for the FOIDs.

Although the maintenance philosophy is to troubleshoot to the ship replaceable assembly (SRA), inconsistencies in the data do not always permit easy identification of the SRA. For example, the master oscillator power supply (MOPS) filament power supply (11/12A1A1A4) has been identified as an SRA in some, but not all, of the documentation. The FOID (Figure 5-233), power distribution diagrams (Figure 5-411), and the additional information on the schematic (Figure 6-384) do not identify the 11/12A1A1A4 as an SRA that can be replaced. The mode and FID·diagrams (Figures 2-47 and 2-127) illustrate the master oscillator power supply (11/12A1A1) as an identifiable unit and provide no further information.

Organization and Packaging

One of the more basic problems with the NSSMS OPs is that they are not designed for the technicians' use. One might assume that a logical breakdown of the NSSMS would include a system-level document, a document for each of the subsystems, and, within each of those documents, operational and troubleshooting data. In fact, there are a system-level document and subsystem documents. Unfortunately, there are also equipment documents organized at the subsystem level. For example, the computer complex and signal data converter, parts of the fire control subsystem, are presented in separate documents.

Each document consists of one, two, three, or five volumes with each volume consisting of one to ten parts. Why such a confusing organization was selected is not obvious or explained. To add further obfuscation, some of the classified parts contain large sections of unclassified material. Apparently, continuity was more important than was convenient user access.

Sizing is also a problem. While some material was easily packaged into an 8-1/2- by 11-inch book, the numerous oversized drawings necessitated the use of many 11- by 16-inch books. Unfortunately, these books have no identifying marks on their spine and the only way to store them is one on top of the other.

One might have assumed that, with so many books (48) and the problems arising from different security classifications and sizes, the designer would have provided extensive indexing to locate the numerous types of technical data. Unfortunately, this was not done. In fact, only a single table of contents is provided in any given volume. Thus, to locate a drawing in Part 7, the table of contents in Part 1 has to be consulted to obtain the page number. This is particularly troublesome for OP 4005, Volume 1, because Part 1 is classified and four of the remaining parts are not.

Readability Analysis

Analyses to determine reading grade levels (RGLs) do not take into account the reader's overall life experiences that have brought the reader into contact with words and ideas that have no true correlation with RGL. In addition, the vocabulary words peculiar to an individual's area of interest or vocation are learned independently of RGL and, therefore, do not contribute to the difficulty of written material regardless of length. Such words as superheterodyne, oscilloscope, or ionospheric inflate the RGL because they consist of so many syllables but are not difficult to read for those in the field of electronics. Therefore, the concept of RGL should be interpreted cautiously and not literally. To say that NSSMS technicians with an RGL of 12 cannot read technical material with an RGL of 14.5 is to interpret the facts much too literally.

Table 1 provides the number of words and sentences, the average sentence and word length, the longest sentence, and the RGL for the passages with the lowest and the highest RGL from each manual and the overall RGL for all passages from that manual. As can be seen from Table 1, passages analyzed in the total NSSMS documentation ranged from an RGL of 6.9 (OP 4006, paragraph 2-453) to 21.3 (OP 4007, paragraph 2-180). For comparison, these two passages are reproduced in Figure 2. The nature of the words used in the two passages does not vary extensively. However, the second sentence in Figure 2b places a very great burden on the reader in maintaining the train of thought because it is 67 words in length. That is, the critical characteristic of these passages for readability seems to be sentence length and not word length and its associated issue of the use of technical terminology.

Sometimes, however, word length is a problem that is not tied to the technical language of the system. Take, for example, paragraph 1.2 of OP 4005, which reads:

> 1.2. Guided Missile Fire Control System MK 91 Mods 0 and 1, <u>hereinafter</u> referred to as the GMFCS, together with Guided Missile Launching System MK 29 Mod 0, <u>hereinafter</u> referred to as the GMLS, and eight Guided Missiles RIM-7H, <u>hereinafter</u> referred to as the missile, comprise the NATO SEASPARROW Surface Missile System MK 57 Mods 0 and 1, <u>hereinafter</u> referred to as the NSSMS. The NSSMS and GMFCS Mod 0 is equipped with a single radar; the Mod 1 is equipped with dual radars.

This passage has an RGL of 20.8, an average sentence length of 41.5 words, and an average word length of 4.57 characters. The information in this paragraph is relatively straightforward and simple, but its "legalistic" language inflates the RGL considerably and probably confuses some of the personnel who must read and understand the paragraph. Such terminology has no place in Navy technical manuals.

The solution to the problem of such writing may be relatively simple. In cases where the RGL is too high, an experienced technical writer/editor should be able to lower the RGL as needed.

It should be noted that there is no evidence to show that the usability or compehensibility of technical writing has any one-to-one correspondence with its measured readability or RGL. However, warning flags should fly when the computed RGL reaches the

Table 1

Readability Data for Selected NSSMS Passages

Sample	RGL[a]	Sentences No.	Sentences Avg. Length (words)	Sentences Longest (words)	Words No.	Words Avg. Length (characters)
OP 4004						
Lowest RGL	10.0	6	20.2	22	121	4.68
Highest RGL	19.4	4	31.5	56	126	5.32
Overall	13.4	62	22.2	56	1377	5.04
OP 4005						
Lowest RGL	9.5	5	15.6	26	78	4.54
Highest RGL	20.8	2	41.5	63	83	4.57
Overall	14.3	51	23.5	63	1200	5.11
OP 4006						
Lowest RGL[b]	6.9	8	21.3	44	170	4.09
Highest RGL	18.9	4	32.0	36	128	5.30
Overall	12.8	378	24.0	49	3785	4.81
OP 4007						
Lowest RGL	7.4	7	18.0	36	126	4.35
Highest RGL[c]	21.3	2	48.0	67	96	4.70
Overall	12.7	55	25.2	67	1388	4.83
OP 4036						
Lowest RGL	9.9	6	20.3	39	122	4.66
Highest RGL	21.1	2	40.0	42	80	5.47
Overall	12.6	76	23.1	51	1756	4.97

[a]RGL=reading grade level.

[b]See Figure 2a for paragraph 2-453.

[c]See Figure 2b for paragraph 2-180.

2-453. Controlling the RAM during STAA. In the DECODER (B3) the RAM write enable is generated by an AND gate on receipt of CROM BIT 10, CROM BIT 11, CLOCK 3, and 4 MHZ CLOCK. This input combination produces a 125-nanosecond pulse in the second half of the third 4-MHZ CLOCK period. In the RAM (A7) and DATA RAM logic, the LOAD RAM ADDRESS COUNTER pulse is generated by a NAND gate on receipt of CROM BIT 11, Clock 2, and 4 MHZ CLOCK. This input combination produces a 125-nanosecond pulse in the second half of the second 4-MHZ clock period. The pulse sets the address counter to the value of CROM BIT 0-7. The RAM ADDRESS COUNTER output is the ADDRESS input to the RAM. Therefore, it can be seen that MUX OUTPUT BITS 0-7 are received by the RAM at the start of the instruction, the RAM is addressed in the second clock period and the word is written into the RAM in the third clock period.

a. OP 4006, paragraph 2-453: RGL = 6.9.

2-180. Although for each channel there are only two address registers, one associated with inputs and one with outputs, the output data may be normal data or external function code words. Therefore, for each channel, three separate address blocks must be used, each according to the type of data to be transmitted (i.e., input data, normal output data, or output of external function code words) and a command must be accompanied by one of nine output device addresses (three for each channel) to identify both the channel and type of data to which the new address block refers.

b. OP 4007, paragraph 2-180: RGL = 21.3.

Figure 2. Selected NSSMS passages with the lowest and highest RGL.

proportions found in these manuals. Assume for a moment that technicians can read any material written at the high school graduate level (i.e., RGL=12), which may or may not be a safe assumption. Table 2 illustrates what this cutoff grade indicates for the samples from the NSSMS manuals. If this assumption is correct (and the median RGL of Navy personnel in general is closer to 10 than 12), technicians have some problem in comprehending 60 percent or more of the NSSMS technical data.

The major issue in this effort is the improvement of comprehensibility and not just the measurement of readability. Because of the issues involved in the learning of the language of one's work and social milieu, RGL probably does not adequately reflect the comprehensibility of material. Rather, it is only an indication as to whether or not the material is comprehensible. It is safe to assume that RGL underestimates the reading potential of the incumbent technician. Unfortunately, there is no convenient method of assessing the comprehensibility of material as the readability formula assesses readability. The only true measure of whether or not material is comprehensible is to have the technician read the material and perform the task it prescribes. If the task is performed in an efficient and effective manner, it is safe to say that the technician comprehends the material.

Table 2

Percentage of Samples From NSSMS Technical Manuals
with RGLs Below and Above 12

Manual	Percentage of Samples	
	RGL = Below 12	RGL = Above 12
OP 4004	38	62
OP 4005	09	91
OP 4006	28	72
OP 4007	31	69
OP 4036	29	71

Organization is another characteristic of written material that is directly related to comprehensibility. There is no objective index, however, indicating how well the material is organized. Some aspects of organization are (1) indexing so that the location of all major topics can be readily located in the text, (2) logical flow of paragraphs within sections and of ideas within paragraphs, and (3) "formatting" so that single units (e.g., paragraphs) contain single major ideas.

In general, the NSSMS documentation suffers from a lack of sufficient breakdown of textual information. That is, many paragraphs attempt to cover an entire sequence of ideas that, with some forethought and a more suitable format, could be offered in a more organized manner. Take, for example, paragraph 2-184 from OP 4005, presented in Figure 3a, which was picked basically at random. This paragraph conveys a great deal of information without benefit of the pauses provided by a new paragraph. (This is not an isolated instance but is the rule rather than the exception.)

Note the difference in the ease with which the information can be accessed if suitable breaks are provided as shown in Figure 3b. No effort was made to perform other changes to make this material more readable. Further, there is no evidence that the revised version is any more comprehensible than the original. But intuitively, the revision appears to be more readily understandable than the original version.

Specific Problem Areas

OP 4004

1. Volume 1. Volume 1 does not refer the reader to the more detailed descriptions in the subsystem documents. Part 1 is classified but contains unclassified reference information (e.g., Tables 1-1 to 1-4) that may be more useful as an unclassified appendix. Part 2 is an oversized volume with excessive white space: Two-thirds of the pages contain text and tables on only one-half of the page. It contains oversized unclassified drawings that could be reduced and turned to fit on an 8-1/2- by 11-inch page. Volume 1 does not provide adequate information on how the entire OP suite is organized or how to use its components, although it is a general description document.

2. Volume 2. Volume 2 presents a confusing array of information on the organization of the NSSMS fault isolation data. System functional diagrams are

Missile Orders. During this function, the air designate mode circuit prevents a missile from recognizing low frequency signals which might be related to friendly ships. When the COMPUTER COMPLEX DIGITAL COMPUTER functions (A2) receive a FRIENDLY SHIP PROTECT signal from the ready mode EDS I/O function circuit, the functions interrupt the MISSILE SWEEP CONTROL signal. This signal is routed through the DC OUTPUT CHANNELS and provided to the GMLS where it commands the missile to disregard low doppler frequencies. The FRIENDLY SHIP PROTECT is provided by the ready mode EDS I/O function circuit when the director repeatback position related to the radar to which the launcher has been assigned is within 22.5 degrees of the FRIENDLY SHIP BEARING providing by the ready mode EDS I/O function circuit, or when friendly ship protect operation is commanded by the FOC operator. The FRIENDLY SHIP PROTECT signal is formatted by the DIGITAL COMPUTER functions as part of the 30-bit FOC DOC DATA word, routed through the SDS OUTPUT CHANNELS, and decoded by the FOC DOC TRANSFER circuit (A5) as IND WORD 2 FRIENDLY SHIP PROTECT signal. This signal is applied to the FRIENDLY SHIP PROTECT CIRCUIT where it is displayed and provided to the GMLS and the RTDP track (A19) mode circuit. When the FOC operator initiates friendly ship protect operation, the FRIENDLY SHIP PROTECT CIRCUIT (B7) produces a FRIENDLY SHIP PROTECT signal which is displayed, supplied to the GMLS and the track mode circuit, and applied to the DD TRANSFER CIRCUIT. The DD TRANSFER CIRCUIT formats the signal as part of the 30-bit FOC DD WORD which is routed through the COMPUTER COMPLEX SDC INPUT CHANNELS (A2) and provided to the DIGITAL COMPUTER functions.

a. Without breaks.

Missile Orders. During this function, the air designate mode circuit prevents a missile from recognizing low frequency signals which might be related to friendly ships.

- When the COMPUTER COMPLEX DIGITAL COMPUTER functions (A2) receive a FRIENDLY SHIP PROTECT signal from the ready mode EDS I/O function circuit, the functions interrupt the MISSILE SWEEP CONTROL signal.
    - This signal is routed through the SDC OUTPUT CHANNELS and provided to the GMLS where it commands the missile to disregard low doppler frequencies.
- The FRIENDLY SHIP PROTECT is provided by the ready mode EDS I/O function circuit
    - When the director repeatback position related to the radar to which the launcher has been assigned is within 22.5 degrees of the FRIENDLY SHIP BEARING provided by the ready mode EDS I/O function circuit, or
    - when friendly ship protect operation is commanded by the FOC operator.
- The FRIENDLY SHIP PROTECT signal is formatted by the DIGITAL COMPUTER functions as part of the 30-bit FOC DOC DATA word, routed through the SDS OUTPUT CHANNELS, and decoded by FOG DOC TRANSFER circuit (A5) as IND WORD 2 FRIENDLY SHIP PROTECT signal.
    - This signal is applied to the FRIENDLY SHIP PROTECT CIRCUIT where it is displayed and provided to the GMLS and the RTDP track (A19) mode circuit.
    - When the FOC operator initiates friendly ship protect operation, the FRIENDLY SHIP PROTECT CIRCUIT (B7) produces a FRIENDLY SHIP PROTECT signal which is displayed, supplied to the GMLS and the track mode circuit, and applied to the DD TRANSFER CIRCUIT.
        - The DD TRANSFER CIRCUIT formats the signal as part of the 30-bit FOC DD WORD which is routed through the COMPUTER COMPLEX SDC INPUT CHANNELS (A2) and provided to the DIGITAL COMPUTER functions.

b. With breaks.

Figure 3. OP 4005, paragraph 2-184, without and with breaks.

presented, but the narrative explaining the diagrams is in a separate book, Part I of Volume 1. In the sample problems described in Volume 2, the system performance-codes fault directory has much of the same information as the performance fault troubleshooting indices of the subsystem OPs. The sample problem implies that the troubleshooting procedure will ensure the fault is isolated, but that the FOIDs have to be consulted to determine if a maintenance requirement card (MRC) is available to describe the corrective maintenance procedures. A more concise approach would have deleted the redundant information and reduced the amount of page turning.

OP 4005

1. Volume 1. Part 1 repeats the introductory material of OP 4004. Although Part 1 is supposed to be the introductory document for the NSSMS fire control system, it contains no information on the signal data converter or the low-light level television. Part 1 is a classified document that contains the mostly unclassified, general functional narrative description that supports the function description diagrams presented in Part 2.

Part 3 is also classified and contains the detailed functional description. However, the mode diagrams that this descriptive narrative supports are in Part 4.

Part 5 is the narrative that supports the general block and detailed FID diagrams in Part 6. While it may be important to know that there are FID circuits and operational circuits, it is not readily apparent why the FID is presented separately from the mode circuitry. To know how both the FID and mode circuits are integrated in the NSSMS, the reader has to refer back and forth between six different books.

2. Volume 2. Volume 2 has ten parts and is the primary source for troubleshooting data for the fire control subsystem. It contains at least ten categories of useful troubleshooting data, which are very difficult to use because of inconsistent presentation methods and poor organization schemes.

Troubleshooting flowcharts are described in Part 1 but without location information. The format of fault directories for each equipment varies from two to three columns while that of troubleshooting indices, which the fault directories reference, varies from three to four columns. Column headings differ from equipment to equipment (see Figure 4). Those on the BITs differ from those on the MRCs. Maintenance turn-on procedures are included only for selected equipment. The format of the relay and lamp indices varies from four to six columns (see Figure 4). The maintenance controls and indicators are described as reference indices and illustrated in another book. References to these illustrations are sometimes omitted.

The FOIDs are the basic data used to troubleshoot. Unlike the other troubleshooting data, the FOIDs are organized separately by cabinet and placed into individual books. The ship replaceable items index in each FOID book lists much of the same information listed in the parts breakdown in Volume 3. The power distribution diagrams, on the other hand, are separate from both the FOIDs and the other troubleshooting data and are organized into a single volume. The reference diagrams (mostly schematics) are organized by drawing number and not by cabinet. As the schematics are assigned new drawing numbers, a blank page with a reference to the new drawing number is used as a marker for the old schematic, thus adding time and confusion to searches for a specific schematic.

Ref. Des.	Function	Control Voltage	FOID	Reference Sheet	Zone
A3DS1	POWER ON	+25V	5-22	1	A3
A3K1	Control Power On	+25V	5-22	1	A3
A3K2	Heaters Off	+25V	5-390	1	A2
A2S4	Manual Test	+25V	5-26	2	A7
A2S3	Manual Test	+25V	5-26	2	B7

TABLE 5-17. RSC RELAY AND LAMP INDEX

Reference Designation	Function	Control Voltage	FOID or Pwr Distribution Fig.
5/6 A1K1	HV Power Supply Interlock	115VAC	5-117 B19
A2A139K1	Designate ready	+5V	5-149 B3
K2	Null fill	+5V	5-150 A3
K3	Tuner enable	+5V	5-151 A3
K4	Velocity Match Bit 0	+5V	5-152 A3

TABLE 5-60. FOC RELAY AND LAMP INDEX

Ref. Des.	Function	Control Voltage	FOID
	SYSTEM PERFORMANCE READOUT		
19A3DS1	4	+25V	5-343 B7
19A3DS2	2	+25V	5-343 B8
19A3DS3	1	+25V	5-343 B7

Figure 4. Relay and lamp indices: Examples of inconsistent column headings and entries.

3. Volume 3. The group assembly parts list is poorly organized for accessing information. Since it is ordered by ascending part number, the technician has to move continually from one spot in the book to another even when looking for parts or parts numbers within a single cabinet. In addition, illustrations identifying components are not always available. Use of the conventional illustrated parts breakdown would make it easier for the technician to identify both the part and part number.

OP 4006

Volume 1 of OP 4006 presents some of the same problems as OP 4005. Part 1 contains the detailed function descriptions that support the mode and FID diagrams in Part 2.

Since OP 4005 covers the fire control subsystem and OP 4006 covers the launcher subsystem, their layout and organization should be the same. Unfortunately, they are not. For example, the signal is more difficult to trace in the OP 4006 FOIDs than in the OP 4005 FOIDs since the test points are not as easy to find. As a result, the technician has to use the reference diagrams (schematics) in conjunction with the FOIDs to troubleshoot.

References to a particular schematic includes the zone coordinates. The dawings, however, have no zone identification marks.

OP 4007

The foreword to OP 4007 indicates its unusual layout (see Figure 5). It introduces five volumes to OP 4007, but a footnote informs the reader that Volumes 2 and 4 have been incorporated into Volumes 1 and 3, respectively. Therefore, the reader is confronted with a document that has only three volumes, which are numbered Volumes 1, 3, and 5.

FOREWORD

Ordnance Publication 4007 (PMS/SMS) explains the principles of operation and provides information necessary for operation and maintenance of Digital Computer MK 157 Mod 0.

This publication consists of five volumes:

Volume 1 (PMS/SMS)	- Description and Operation
Chapter 1	- Introduction
Chapter 2	- Description
Chapter 3	- Operation
* Volume 2 (PMS/SMS)	- Scheduled Maintenance
Chapter 4	- Scheduled Maintenance
Volume 3 (PMS/SMS)	- Trouble Isolation and Reference Diagrams
Chapter 5	- Trouble Isolation
Chapter 6	- Reference Diagrams
* Volume 4 (PMS/SMS)	- Corrective Maintenance, Yard and Tender Repair
Chapter 7	- Corrective Maintenance
Chapter 8	- Yard and Tender Repair
Volume 5 (PMS/SMS)	- Replacement Parts
Chapter 9	- Replacement Parts

* Chapter 4, Volume 2 is incorporated into Volume 1. Chapters 7 and 8, Volume 4 are incorporated into Volume 3 Part 4.

Figure 5. Foreword for OP 4007 describing its confusing organization.

OP 4007 differs greatly from OP 4005 and OP 4006 in format and level of detail presented. The text of OP 4007 is presented in a double column instead of in a single column and is in smaller type. Rather than having the illustrations in separate books, the illustrations for OP 4007 are integrated with the narrative. Instead of having general block, detailed block, and FID diagrams in separate books, the block-text diagrams are integrated with the narrative to provide the reader with an operational understanding of the computer.

Fault isolation data are limited to fault response tables. In other words, the fault indices, troubeshooting indices, and FOIDs that facilitate troubleshooting on the other parts of the fire control subsystem are not used for the computer. The technician has to use a different troubleshooting strategy that requires starting at the beginning of the fault response table and proceeding until a condition fails and the faulty component is identified.

OP 4036

Like OP 4007, OP 4036 is a complete departure from the formats used in both the fire control and launcher subsystem volumes (OP 4005 and OP 4006). Test procedures are embedded in the narrative. The coordinate system used to locate areas on the drawings is completely different from that used on other fire control subsystem drawings (see Figure 6); neither system complies with the specification. Function diagrams are used instead of detailed description diagrams. FID diagrams are not used. Connection diagrams are used instead of FOIDs. Only partial reference designations are used. Schematics are also in a different format.

OP 4053

OP 4053 is similar in format to OP 4007 and in organization to OP 4036. It does not resemble OP 4005 or OP 4006. The illustrations are integrated with the text with detailed block diagrams supplemented with schematics. Its organization and integration of technical material are the best of the NSSMS documents.

System Evaluation and Test Manuals

The system evaluation and test (SEAT) manuals consist of an assortment of manuals whose format differs from manual to manual and even from chapter to chapter. Incorporating off-the-shelf manuals as NSSMS documents is economical for the acquisition cycle costs but may affect the life-cycle cost of the NSSMS greatly. The organization of the appendices make it extremely difficult to access information (e.g., there are three Appendix Js, each with its own table of contents). Because these are vendor manuals, much of the information has no relationship to SEAT operation and repair (e.g., the power supply information includes mounting instructions, which are unnecessary since the power supplies have already been mounted into the SEAT cabinet).

Illustrations

Overall, one of the more inconsistent and confusing areas for accessing troubleshooting information is the referencing system to go from one drawing to another. Figure 7 presents examples of some of the drawing reference schemes used in the OPs.

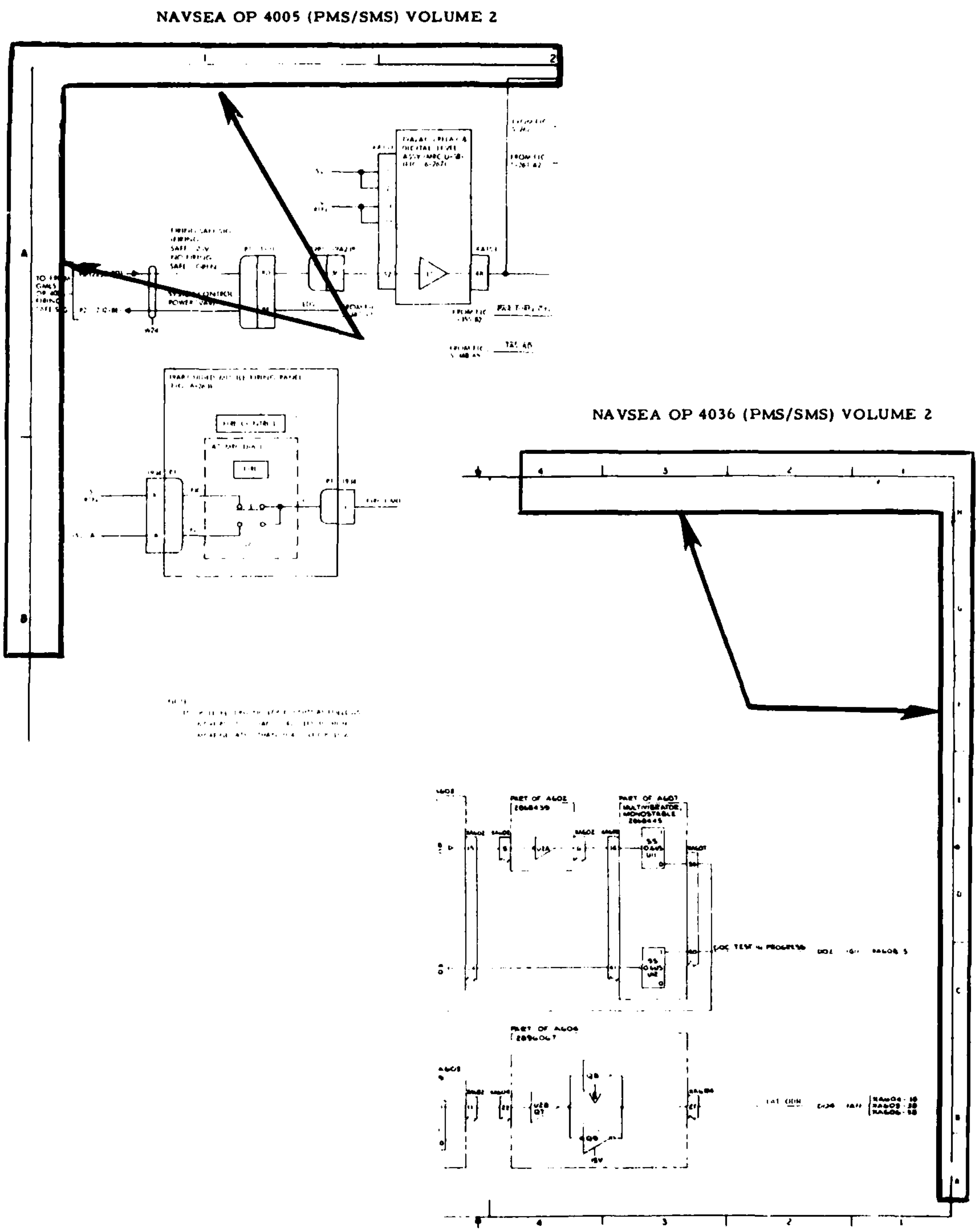

Figure 6. Comparing the grid coordinate referencing systems used in OP 4036 and OP 4005.

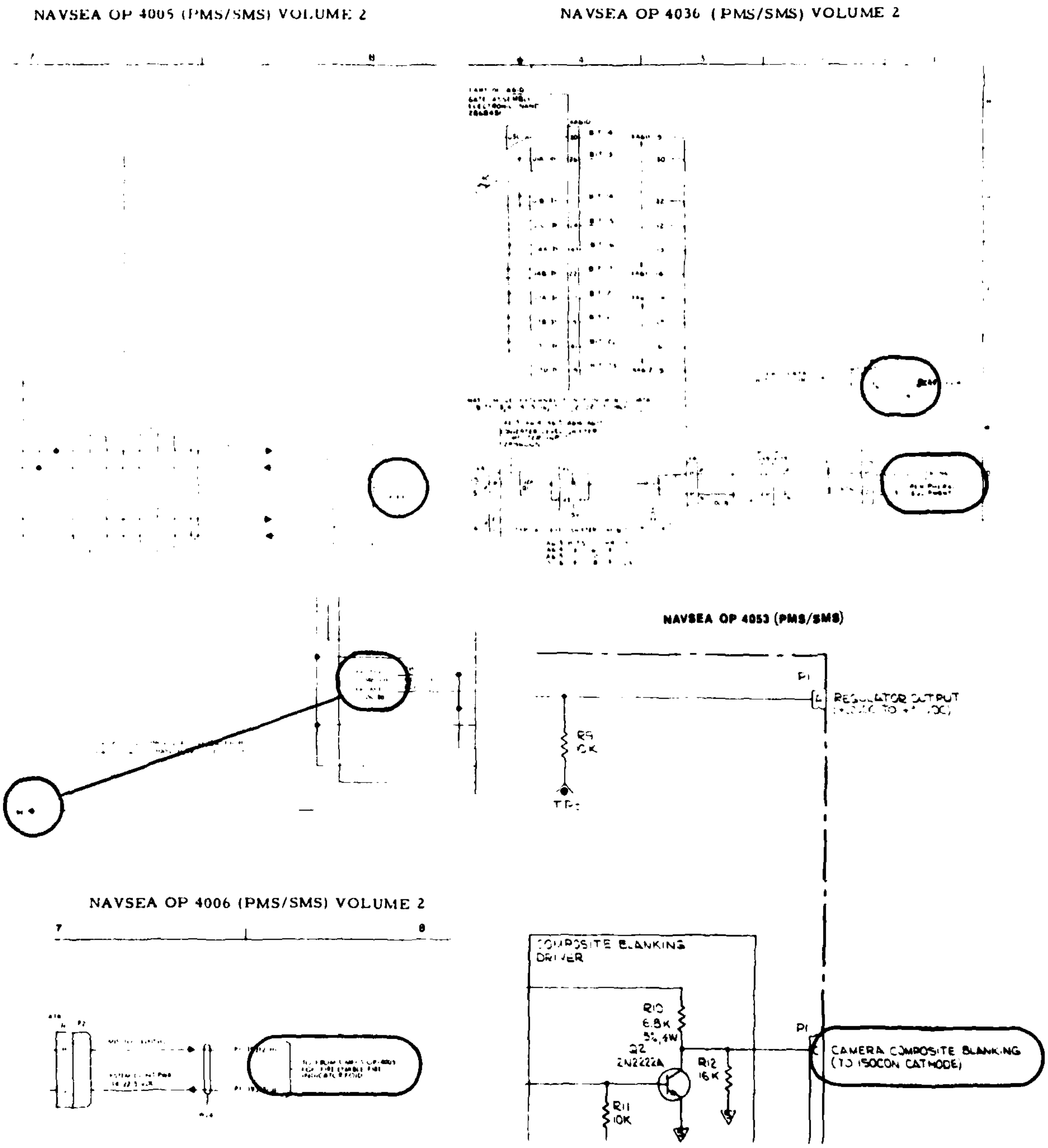

Figure 7. Examples of different referencing system used to trace a signal from one OP to another.

In OP 4005, reference to the same FOID is made by grid coordinates only. To refer to another fire control drawing, both the figure number and grid coordinates are given. References to OP 4036 include OP number, full figure title and drawing number, and grid coordinates, but no figure or page numbers. References to OP 4006 include only the OP number and the full figure title.

In OP 4006, the only difference from the reference system used in OP 4005 is the reference to OP 4005. In OP 4006, the drawings are identified as FOIDs.

Being a different design from either OP 4005 or OP 4006, OP 4036 has a different reference system. References to either the same drawing or other drawings within OP 4036 include the use of a "D" number to identify the figure, the sheet number of the figure, and the grid coordinates. References to drawings in other manuals use only the phrase "to/from peripheral equipment." The technicians have to find the signal path. In addition, drawings of similar cards are not repeated. Users have to identify the card they are troubleshooting and than refer to a table of values to determine what values apply in a given situation.

In OP 4053, the schematics provide no references between drawings. The technician is forced to follow the signal by name.

Fleet Input

Fleet Questionnaires

Packaging and Organization. The technicians did not like the intermixing of the sizes of the volume (8-1/2" x 11" vs. 11" x 16"). Many responded that experience was needed to understand the organization of data within the OPs. They wanted the troubleshooting information to be organized by cabinet, instead of providing all the fault indices, etc. in a single book, while the FOIDs are organized by cabinet and placed into separate books with one for each cabinet or cabinet group. A systems OP could illustrate the interconnections among the cabinets. With the schematics and parts information for all the cabinets also packaged together, the troubleshooting data are too spread out for the technicians to use efficiently.

Technicians expressed frustration at the inconsistent level of detail of the troubleshooting data. If more detailed schematics for specific ship replaceable assemblies (e.g., power supplies) were available, the technicians could identify and replace some of the failed components when SRAs are unavailable.

Using the OPs for Troubleshooting. Technicians stated that it was not always clear where the troubleshooting process should begin and sometimes the information flow within the OPs would mislead them. Necessary branching information was absent when one path failed to isolate the fault. All the technicians stated that good information was not available for troubleshooting multiple faults. OP 4036 was cited as an example for being very hard to find a starting place for troubleshooting the signal data converter. The technicians troubleshooting the computer disliked the way in which the troubleshooting data were organized in OP 4007.

Amount of Data. In response to questions concerning the amount of data in the OPs, the technicians wanted a more detailed breakdown to be able to identify the failed components. All agreed that insufficient guidance was given for evaluating specific waveform patterns. The description of what the waveform should look like is incomplete, incorrect waveforms are presented, or the waveforms are inadequately explained. All would like a narrative to explain the FOIDs.

Specific Problems. The specific problems cited by the 20 technicians who responded to the questionnaire are listed below:

1. In OP 4006, Volume 1, detailed functional descriptions are often difficult to follow due to the necessity to refer back and forth through the diagrams in Part 2 while trying to follow the functional descriptions in Part 1 (e.g., the initialization circuits, Figure 2-21). Tracing the ship's power requires seven sheet changes--from 1-6-5-1-5-1-6-1; the system control power, four sheet changes--from 1-8-13-1; and the stow lock operation, seven sheet changes--from 1-9-7-11-1-12-1.

2. In OP 4006, Volume 2, Part 2, Figure 5-123, voltages must be read at various test points when troubleshooting. However, actual voltages rarely equal the assigned BITE test mode value listed on the FOID and no tolerances are given to indicate an acceptable voltage range. Thus, technicians must guess if a circuit is functioning properly when, in fact, a lower or higher voltage might be an indication of other circuit problems. Due to the lack of replacement units for the servo electronics, troubleshooting is very limited and diagnosis cannot be verified by replacing suspected bad cards. Therefore, more time must be spent comparing input and output voltages of circuit components to determine the exact cause of system failures. Listing voltage tolerances under operational conditions at the test points on the FOID would facilitate trouble isolation and eliminate guesswork. Tolerances are needed at all fault test points in FID circuits and FOIDs.

3. If the waveforms for various components were provided on the FOIDs instead of on supplemental sheets, troubleshooting would be less confusing.

4. Waveform information was unclear and could not be used to evaluate the "air signal" in the radar target data processor (RTDP) FOIDs.

5. To troubleshoot the computer, the technician has to start at the beginning of the troubleshooting table and continue along until the fault is found. If the fault is not found, the technician is not provided with amplifying information such as what has been checked or what schematics to reference.

6. The launcher OP (4006) referenced a terminal board signal that was not measurable because the references were off by two and the signal that was referenced did not exist on the referenced terminal board.

7. Reference diagrams do not contain the parts number information needed to identify a specific component (e.g., resistors and capacitors) when the component either is missing or has burned.

8. Following a signal from the fire control system OP (4005) to the launcher OP (4006) is very difficult because the figure number for the continuation of the signal is not provided.

9. The RTDP FOIDs provide insufficient or inaccurate information for identifying specific signals.

10. Not enough information is provided at specific testpoints.

11. Parts breakdown illustrations do not identify specific components that have failed (e.g., the amplifier-oscillator cooling plate).

12. Not enough component information for areas of the transmitter (e.g., repairing the MOPS rather than replacing the entire assembly for a minor component).

Fleet Interviews

Using OPs to Troubleshoot (Appendix, Questions 1-7 and 11-14). While the majority of the 11 interviewees stated that, after initial indication of a fault, they run a BITE test or BIT off-line test to amplify the fault, all indicated they eventually use the FOIDs to troubleshoot. Regardless of the additional troubleshooting data that may be available in the mode, FID, or schematic diagrams, the basic troubleshooting procedure was to start with the fault light and trace the signal backwards from that light.

Only three technicians responded that they use the fault directories to help locate a FOID. Their responses were further qualified, however, because the directories' use was limited to the more difficult troubleshooting problems (e.g., the continuously monitored fault codes for the FOC or the fault light codes for the missile control unit).

Nine technicians stated that troubleshooting would be easier if a narrative was available for the FOIDs. Three of the eight technicians who had not used the mode diagrams for troubleshooting agreed that the mode was useful for teaching the system. Only one technician stated that he had used FID diagrams to troubleshoot; specifically, to help isolate a fault in the transmitter.

While all the respondents related that they use schematics, only four use the classified OPs, mostly for general NSSMS descriptive information. All stated that they use the group assembly parts list to identify part numbers. Four technicians, however, stated that they generally use the ship replaceable items indices (in the FOID books).

Changing the OPs (Appendix, Questions 8-10). All the technicians, except one, stated that a better indexing scheme would make the OPs easier to use. Several said that, if the information was indexed in a couple of different ways, a starting point could be located faster.

While all the technicians agreed that the oversized books presented a storage problem, only two expressed an interest in having foldout pages in place of oversized books.

When asked about specific changes to the OPs (question 8), the following responses were given:

1. Add narratives to the FOIDs.

2. Reorganize the data; there are too many different types of data.

3. Reduce the bulk; it is too easy to get lost in the data when troubleshooting.

4. Periodically review the OP suite aboard each ship to verify that the latest changes have been incorporated correctly.

5. Provide more information on the computer.

6. Redo OP 4036 in same format as OP 4005 because the information in existing OP 4036 is hard to follow.

7. Make OPs more consistent; the launcher OP (4006) is not as detailed as the fire control system OP (4005) and requires additional referencing to the schematics.

8. Both OP 4007 and OP 4036 need to be improved to facilitate fault isolation.

CONCLUSIONS

1. No systematic top-down breakdown approach was applied to the organization and development of the NSSMS technical data that were incorporated into the OPs. The evolution of the OPs produced documents that present functional and fault isolation information independently. Thus, the technician has to integrate both types of information to build a complete model of the system.

2. Technicians use, at most, 5,000 pages of the 15,000 to 20,000 pages of technical data to maintain NSSMS. Technical information relating to specific equipment is spread out within the OPs in a manner that makes it extremely hard to determine if all available information has been accessed. Redundant coverage exists in some areas, while gaps exist in others.

3. The maintenance philosophy and the level of detail of the technical data differ.

4. Trouble isolation almost always consists of tracing back from a fault indicator through many pages located in different books.

5. No narratives exist for the main troubleshooting data source, the FOIDs.

6. Overall packaging and organization of the OP documents are insensitive to the users' access requirements.

7. No comprehensive index or cross-indexing of the technical data is provided.

8. Only 15 of the 48 plus books have tables of contents.

9. The overall RGL for all the samples analyzed is over 13.0 with some sections as high as 21.0. Combining the high RGL with the poor layout and organization of the textual material provides a set of documents that cannot be easily accessed for specific information topics.

10. The overall system OP (4004) is too general with few references to the subsystem and equipment OPs.

11. To understand how the fire control subsystem functions in different modes, the user has to refer back and forth between six different books.

12. Different formats are used to present similar troubleshooting data (fault tables, troubleshooting indices, etc.).

13. Technical data in OP 4006 are presented at a different level of detail than are data in OP 4005.

14. OP 4007 is very different from either OP 4005 or OP 4006.

15. OP 4036 is also very different from either OP 4005 or OP 4006. The scheme for illustration references differs completely from that used in the rest of the NSSMS OPs.

16. The format and organization of OP 4053 are best; as a result, its format differs from the other OPs.

17. SEAT manuals are off-the-shelf vendor manuals that have not been integrated with the other NSSMS OPs. The technical data in the SEAT OPs are excessive, far more detailed than required for shipboard maintenance, and, in some sections, totally irrelevant.

18. Grid reference schemes for illustrations are inconsistent within and among the NSSMS OPs.

19. Fleet personnel have problems using the OPs. They prefer to have a more concise and usable set of OP documents. For some areas, more detailed information is desired; for others, less.

RECOMMENDATIONS

It is suggested that the NSSMS project office reformat the OPs to provide the fleet with a concise set of systematically designed documents that (1) can be used by both experienced and inexperienced NSSMS technicians, (2) fully integrate training requirements and the PMS procedures, and (3) provide fault isolation data that can also be used in the school to provide an operational understanding of the system.

To accomplish the systematic development of NSSMS OPs, the original task analysis should be reexamined to ensure that the function analysis has been completed and all personnel requirements have been identified.

A complete functional analysis is necessary to determine if the required source data are available for categorizing equipment types and complexity and for matching the best technical information format to them. From the personnel requirements, a user description can be developed to establish the level of detail required for the technical materials. The user should be described in terms of job relevant skills, knowledge, experience, and reading ability. The user description provides the basis for the assumptions concerning the technical capabilities of the NSSMS technician before and after training. The user description will have to be integrated with the maintenance philosophy to ensure that an NSSMS technician has the technical data, at the proper level of detail, to maintain the NSSMS.

An example of a systematic development and implementation effort for revision of the NSSMS technical data is given in Figure 8. To ensure the timely completion of this type of effort, the following tasks are recommended.

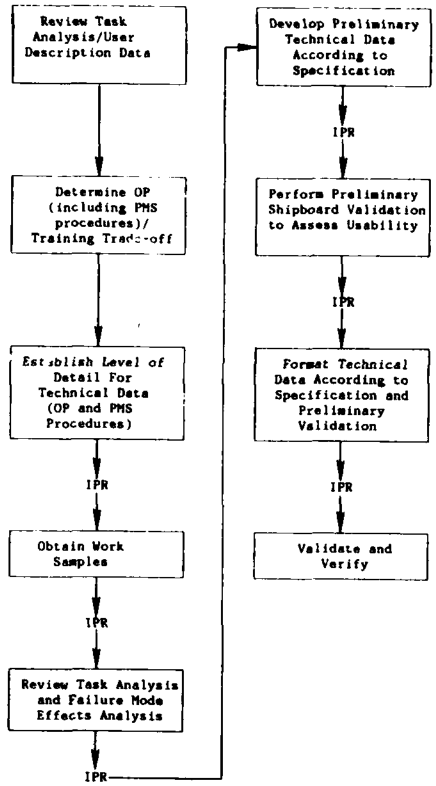

Figure 8. Example of development process for revising NSSMS technical data.

1. Organize and conduct an adhoc committee review of the NSSMS discrepancies. NAVPERSRANDCEN will organize and conduct an adhoc meeting with PACFLT and LANTFLT personnel to discuss the discrepancies with the existing OPs. Based upon the priorities assigned by the adhoc committee, NAVPERSRANDCEN will develop a specification.

2. Develop specification for design and development of NSSMS OPs. NAVPERSRANDCEN will combine the technical input from the Naval Ship Weapon Systems Engineering Station (NSWSES) with tested information presentation principles to design and develop a specification for NSSMS OPs. The specification will be designed to provide a technically accurate document at a level of detail that is usable and complete for a wide range of users. The quality assurance section will include the guidance needed to ensure that the revised OPs are validated and verified using a representative user population. NAVPERSRANDCEN will provide the necessary support to the NSSMS project office to ensure that the contractor understands all parts of the specification.

3. Attend IPRs. Upon issuance of the OP development contract, NAVPERSRANDCEN will provide the technical support required at in-process reviews (IPRs) to review and evaluate the contractor's product according to the behaviorally-oriented guidance of the specification. In coordination with NSWSES, NAVPERSRANDCEN will determine if the contractor's interim products are leading towards a document that is technically accurate,

complete, and usable by a wide range of users. In addition to the analytical review, preliminary validations will be conducted.

4. Preliminary validations and problem resolutions using fleet personnel. To ensure that the end document, a revised set of NSSMS OPs, is technically accurate, complete, and usable, NAVPERSRANDCEN will conduct preliminary validations using the contractor's interim products. Results and recommendations for changes will be provided to the project office upon completion of each validation. In addition, any problems that arise during the development cycle regarding the usability of a format will also be examined in an operational environment.

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APPENDIX

FLEET SURVEY INSTRUMENTS

FLEET SURVEY INSTRUMENTS

Questionnaire

1. Do the OPs provide you with enough introductory information on how the OPs are organized?

2. Do the OPs provide you with enough information on how to use the OPs for troubleshooting?

3. Do you like the way the OPs are organized?

4. Are there too much or too little technical data in the OPs?

5. If you could change the way the technical data are presented in the OPs, how would you change it?

6. Cite a specific problem you have had with the OPs (e.g., after identifying the initial symptoms for the malfunctioning widget, OP 400X was consulted, which led to a troubleshooting table that provided no additional data on the problem; i.e., it was a dead end).

Structured Interview Questionnaire

1. How do you use the OPs to troubleshoot?

2. Have you ever used the fault directories or troubleshooting indices in 4005 (4006) Volume II, Part 1 to help you locate a specific FOID?

3. If FOIDs had a narrative description, would that make troubleshooting any easier?

4. Have you ever encountered a fault where you used the mode diagrams to understand what was supposed to be happening in the system?

5. Do you ever use the FID diagrams?

6. Do you ever use the information contained in the CONFIDENTIAL OPs?

7. Do you ever use the schematics?

8a. Do you ever use the Group Assembly Parts List (GAPL) in Volume III?

8b. Would an IPB be easier than the GAPL to use?

9. How would you explain to another technician how a subsystem works (i.e., what parts of the OPs would you use, if any)?

10. Would the OPs be easier to use if each part had a table of contents or index?

11. Would the OPs be easier to use if the oversized books were composed of foldout pages?

12. What would you like to see added to or deleted from the OPs?

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