AN ANALYSIS OF THE NIKE AJAX MISSILE MAINTENANCE JOB

Robert A. Goldbeck
Emanuel Kay

AMERICAN INSTITUTE for RESEARCH
PITTSBURGH, PENNSYLVANIA

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This study describes the maintenance job activities of the launcher and assembly area personnel. The findings can be grouped into three major job categories: (1) missile assembly and servicing (2) preventive maintenance, and (3) trouble analysis and repair.

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AN ANALYSIS OF THE NIKE AJAX MISSILE MAINTENANCE JOB

Robert A. Goldbeck, Project Director

and

Emanuel Kay, Associate Project Director

American Institute for Research
Pittsburgh, Pennsylvania

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Robert Glaser, Principle Investigator
Murray Glanzer, Research Adviser

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

Maintenance activities in the launching area of a Nike Ajax battery were divided into three major work categories: (1) assembly and servicing, (2) preventive maintenance, and (3) trouble analysis and repair.

A survey of these maintenance activities and the personnel performing them is summarized in three charts. The chart titled Missile Assembly and Servicing Responsibilities shows the roles assumed by the mechanical technician (MOS 221), electrical technician (MOS 223), missile warrant officer (MOS 1185), and other MOS's who participate in the various job segments of the assembly and servicing procedure. A bar in the primary role row indicates that the MOS usually performs the job segment. Support role indicates that the MOS assists in the performance of the job segment, interchangeable role indicates that the MOS can substitute in the performance of the segment, and supervisory role indicates responsibility for determining that the job segment is properly performed.

The chart titled Preventive Maintenance Responsibilities shows which personnel usually perform the indicated checks. Where a check has a bar for more than one MOS, these personnel are equally likely to perform the check.

The chart titled Trouble Analysis and Repair Responsibilities indicates which of the two technicians has primary responsibility for diagnosing and repairing malfunctions in the different categories of launching area equipment.

Recommendations covering each of the three aspects of launching area maintenance were made with regard to job organization, training, and proficiency measurement as follows:

1. MOS 223 should be trained to participate in the assembly and servicing jobs which are performed by MOS 221, or some of the MOS 221 jobs should be assigned to MOS 223. With the present division of labor, MOS 221 is overloaded.

2. Preventive maintenance checks which cover items ordinarily observed by operators during regular drills should be the responsibility of operators each time they operate the equipment.

3. Preventive maintenance checks requiring more than a simple discrimination or not observed during regular equipment operation should be the responsibility of trained technicians.

4. Preventive maintenance check results should be summarized and reviewed by higher headquarters and by battery personnel.

5. The missile warrant officer should assume explicit responsibility for all preventive maintenance results.

6. Trouble diagnosis procedures which have been judged specifiable by a trouble analysis behavior survey should become the job area of the MOS 223 and MOS 221 Technicians who should be appropriately trained to handle these troubles.

7. The missile warrant officer should be responsible for diagnosing the more difficult troubles.

8. The authorized repair responsibilities of a battery should be revised to include those troubles which were found to occur frequently.

9. The nucleus of a training program for technicians should consist of the job activities outlined in the survey of battery maintenance activities.

10. Training to supply understanding and generalization should be based on the functional characteristics of the equipment system.

11. Capabilities to use tools and to make replacements for corrective maintenance should be given special emphasis in training.

12. Planning for the program of instruction should draw heavily on the data which describes the scope and difficulty of maintenance activities.

13. Proficiency measurement to evaluate school training should cover the entire range of on-site maintenance activities.

14. Actual performance should be measured for each technician on the assembly and servicing jobs assigned him as shown in the analysis of job responsibilities. Paper and pencil tests should be designed to insure that the technicians know why a task is important to the proper operation of the missile.

15. Periodic checks should be sampled on the basis of out-of-tolerance frequency for measurement of performance in detecting indications of malfunction.

16. The trouble analysis behavior survey should be used to provide a comprehensive coverage of malfunction indications for the testing of diagnosis proficiency.

17. Proficiency in tracing schematic relationships of the firing sequence circuits should be measured.

18. Capability to perform the repairs and replacements necessary for on-site corrective maintenance should be measured by actual performance of these procedures.

	Uncrating	Mating Tests	Assembly	Electrical Checkout	Booster Joining	Fueling	Warheading	Final Preparation
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]		
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1] These supervisory roles are secondary to that of the MOS 1185

PREVENTIVE MAINTENANCE RESPONSIBILITIES

	MISSILE CHECKS		FIRING EQUIPMENT CHECKS			
	Daily and Weekly Check	[illegible]	Launcher-Loader Assembly	Missile Transporting Rail	Storage Racks	Consoles
[illegible]						
[illegible]		[illegible]	[illegible]			
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		[illegible]		[illegible]	[illegible]

	[illegible]			[illegible]
	[illegible]	[illegible]	Propulsion [illegible] Tester	
[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			
[illegible]				
[illegible]				

TROUBLE ANALYSIS AND REPAIR RESPONSIBILITIES

	[illegible]	[illegible]	Missile Warhead System	Missile Propulsion System	Missile RF and Electrical System	Miscellaneous Missile Parts

	[illegible]	[illegible]	[illegible]	[illegible]	Assembly and Handling Equipment

I. INTRODUCTION

On the basis of previous work (1,2), which consisted of a survey and analysis of Nike Ajax operator personnel activities, the problem of providing effective maintenance for the missile and other equipment in the missile launching area was singled out for further study. Specifically, the present study is concerned with the performance and training of the launching area technicians. In order to determine the characteristics of the jobs performed by these technicians, an extensive survey of launching area maintenance activities was undertaken. On the basis of the detailed information obtained, the following questions will be answered.

1. What are the job requirements for the maintenance work of the launching area?

2. What are the implications of these requirements for the content of the technical training courses?

3. What are the implications of these requirements for the content of proficiency measures?

Since the organization of work, e.g., the assignment of work to personnel, often may be varied in order to increase overall effectiveness, the job survey was used as a basis for answering a fourth question.

4. How can the job organization be changed in order to increase the efficiency of the groups carrying out launching area maintenance procedures?

These four questions concerning job requirements, course content, test content, and job organization for launching area maintenance are considered in this report.

II. GENERAL BACKGROUND

This study is concerned with the job activities, training, proficiency standards and job organization for Nike Ajax launching area personnel. The purpose of this section is to describe the physical characteristics and functional organization of the launching area that are relevant to this study.

A. Physical Characteristics of the Launching Area

Each Nike battery has two physically separate areas, the battery control area and the launching area. The battery control area contains the radar and communication equipment to coordinate a Nike engagement. The launching area (which is usually several miles away from the battery control area) contains the facilities for preparing missiles for firing, for storing prepared missiles and for launching missiles. Its major function is to have Nike rounds "ready to go" at any time designated by the battery control area. In order to achieve this state of readiness, the launching area is provided with appropriate facilities, tools and equipment, and personnel.

The major units of the launching area which are the concern of this study are (1) the assembly area and (2) the launcher area. Figure 1 shows the major parts of the launching area.

The primary function of the assembly area is the conversion of newly received missiles into ready rounds which can be quickly prepared for firing by the launcher personnel. To achieve this end the assembly area contains an assembly building and an out-of-doors revetted area. The assembly building houses most of the equipment needed for assembling and checking out missiles. Such potentially dangerous operations as fueling, oxidizing, and warhead installation are done in the revetted out-of-doors area.

The primary function of the launcher area is to provide facilities for the storage and launching of missiles. These facilities include as many as four firing sections (each consisting of an underground storage area, firing panel, and above ground launcher-loader assemblies) and the Launcher Control Trailer (LCT) which contains a control console and the test responder.

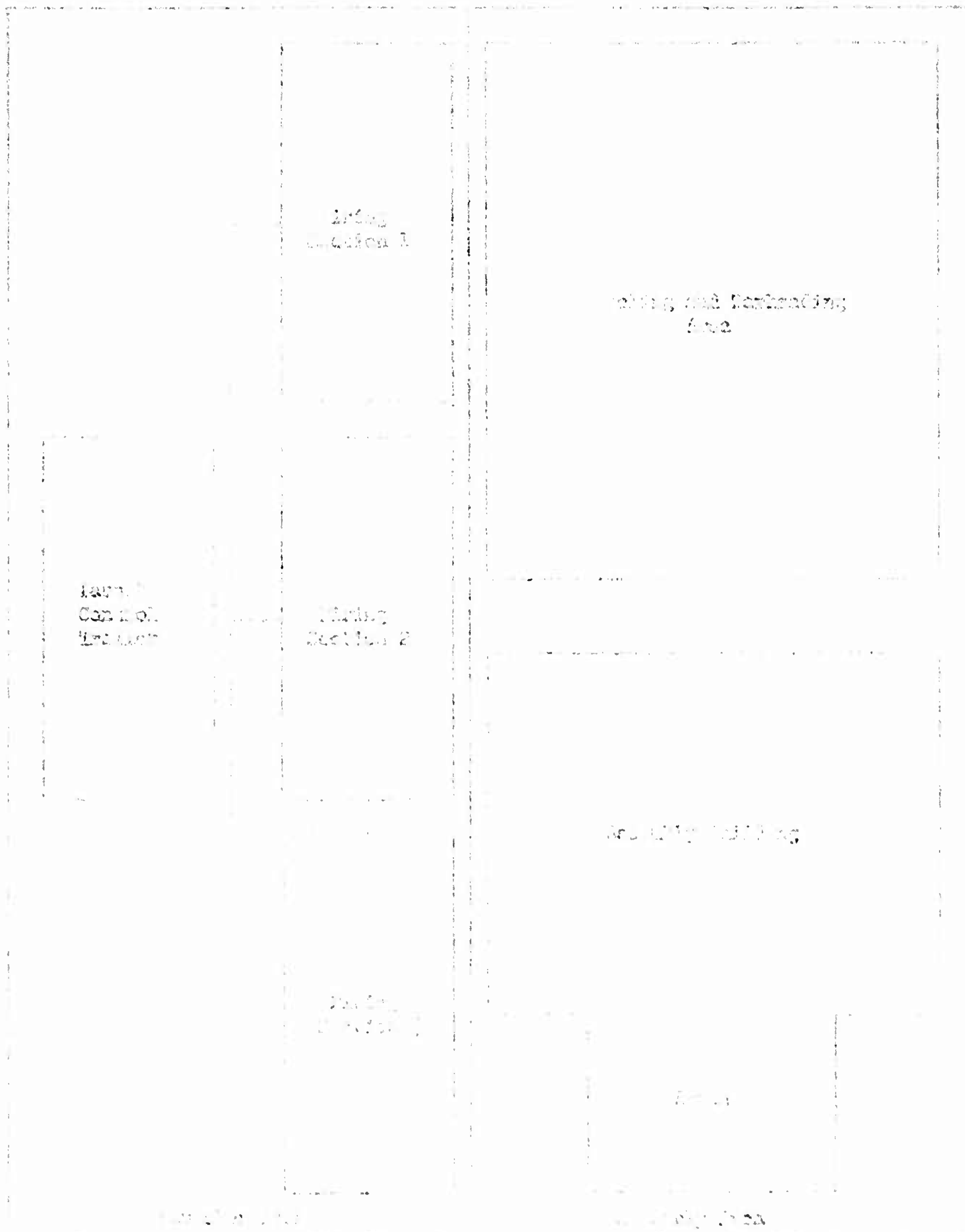
B. The Functional Organization in the Launching Area

The maintenance of equipment in the assembly and launcher areas and the preparation and maintenance of missiles are the responsibility of the launching area personnel. The MOS 1180 (Platoon Leader - commissioned officer) has overall command of the launching area.

1. Assembly Area Personnel

The assembly area personnel are responsible for preparing missiles and for maintaining equipment and missiles. The following MOS's are assigned to and perform a large portion of their work in the assembly area.

MOS 1185 - Missile Warrant Officer
MOS 223 - Electrical Maintenance Chief
MOS 221 - Mechanical Maintenance Chief
MOS 351 - Generator Operator
MOS 357 - Engineering Equipment Specialist
MOS 612 - Air Compressor Operator


Station 1
Area
Control
Station 2

In ten batteries surveyed in the New York Defense Area, the average number of the assembly area MOS's was as follows:

MOS	Average for Battery
1185	1.0
223	2.5
221	2.2
351	2.0
357	3.3
612	1.0

The 1185 is in charge of the assembly area. The 223 is an electronics specialist who has many important maintenance responsibilities. The 221 also has important maintenance responsibilities but to a lesser degree than the 223. The MOS's 351, 357, and 612 offer support services to the 223 and 221 but occasionally become involved in maintenance activities. The MOS's 223 and 221 will receive the greatest amount of attention in this study since they have the most critical maintenance responsibilities in the launching area.

2. Launcher Area Personnel

Launcher area personnel are assigned to the firing sections and to the LCT. Each of the four firing sections is supervised by a Section Chief (usually the highest ranking NCO) and is manned by operator personnel. Operator personnel also are assigned to the LCT. The MOS's in the launcher area are as follows:

MOS 225 - Section Chief
Fire Panel Operators
Senior Launcher Crewman
Launcher Crewman
MOS 220 - Launcher Helpers

In ten batteries surveyed in the New York Defense Area, the average number of the launcher area MOS's was as follows:

MOS	Average for Battery
225	14.1
220	24.4

Although the launcher area personnel are concerned mostly with operating equipment, they also become involved in maintenance and, therefore, need to be considered in a study of launching area maintenance responsibilities. There are two ways in which the section personnel become involved in maintenance. First, they are assigned the responsibility for periodic checks of equipment and missiles. Second, they are in the best position to observe indications of malfunction that occur while equipment is being operated.

As can be seen from the above description, launching area maintenance activities and responsibilities are distributed among two distinct units. It is therefore important to determine the functions performed in both units, in order to achieve a complete understanding of training, proficiency, and personnel utilization in the launching area.

III. RESEARCH METHOD

The general research approach of this study was to use job activity data to form a comprehensive picture of what site personnel are required to do. This information provides a basis for considering the training needed to perform these tasks, proficiency requirements required to insure performance standards, and the opportunities for cross-training to increase the flexibility of personnel. These data can also provide a basis for recommendations concerning an optimal distribution of work tasks. The approach employed entails two fundamental steps: (1) the identification of the specific kinds of work performed by on-site maintenance personnel and (2) the development of procedures and forms for collecting job activity data.

A. Major Work Categories

As a result of direct observations of on-the-job activities of launching area personnel and of interview sessions with site personnel the following three major job activities were delineated.

1. Missile Assembly and Servicing

These activities are concerned with the assembly and servicing of missiles. The amounts of this work which need to be done at any given time show wide variations. The arrival of new missiles at a site results in a heavy concentration of available personnel on assembly activities. Field changes and repairs will also result in a heavier commitment of personnel to this work.

2. Preventive Maintenance

These activities are concerned with the periodic checks on ready missiles and launching area equipment. The checks, which are described in greater detail in later sections of this report, vary in length and complexity. Both section and assembly area personnel perform these checks.

3. Trouble Analysis and Repairs

These activities are concerned with the analysis and repair of equipment malfunctions. The amount of work to be done at any given time also varies greatly. Malfunctions can occur any time during the course of periodic checks, drills, and other operation of equipment.

B. Collection of Data

In collecting information about the maintenance functions of an operating organization, many courses of action are available. These courses differ with respect to sources of data and data collection techniques. Information can be obtained from such sources as manuals, directives, records, observations of work activities, and interviews with technical personnel. Initially, it is important to focus on two aspects of the data collection approach: (1) the kind of information sought, i.e., what information is regarded as relevant to the aims of the study, and (2) the data collection forms and procedures used.

Before the collection of data begins, it is desirable to explore all readily available material and sources of data. Interviews, observation of procedures, and a survey of existing records are important steps in orienting the overall data collection program. This orientation has two main functions: (1) to structure the goals of data collection further and (2) to determine the availability of various classes of data. Special techniques are then developed to fill in gaps where data is not available in useable form. Thus in the initial information gathering procedures there is some interaction between establishing data collection goals and the development of data collection procedures. As a result of the initial information survey, data collection goals and procedures are formalized.

In the present study, it was considered desirable to collect information about the job activities of launching area technicians. After a review of Nike Ajax manuals and documents in order to become familiar with the launching site, Nike personnel and contractor field representatives were interviewed in order to determine the availability of relevant information. This led to the utilization of two records which are regularly kept by the military:

1. Maintenance Check Sheets

   These sheets are filled out whenever a piece of equipment is given its periodic preventive maintenance check. They contain a record of the malfunctions found during a check.

2. Status of Defense Reports (SOD Ports)

   These reports are submitted daily to Battalion Headquarters and include a listing of malfunctions which have affected the operability of battery equipment.

These two forms did not, however, cover all relevant aspects of the maintenance job. Three other data collecting forms were therefore designed to complete the coverage for the technician job activities.

1. Launching Area Maintenance Job Survey (LAMJS)

   This form was designed to obtain four different kinds of information: (1) estimates of common malfunctions for launching area equipment and reports on who repairs these malfunctions; (2) the number of different MOS's assigned at each battery; (3) personnel responsibilities for the missile assembly and servicing jobs; and (4) personnel responsibilities for the preventive maintenance checks.

2. Launching Area Maintenance Record (LAMR)

   The purpose of this form was to provide a record of launching area malfunctions and the amount of time required for the diagnosis and the repair of these malfunctions.

3. Trouble Analysis Behavior Survey (TABS)

   This device was developed in order to evaluate the trouble correction activities associated with as many different indications of malfunction as could be obtained from manuals, check sheets, and interviews with technicians. The data collection devices and procedures were used to gather job activity information in each of the three major work categories as follows:

1. Data Collection Procedures for Missile Assembly and Servicing Activities

On the basis of an examination of Nike manuals, missile assembly checkout sheets, and direct observations of missile assembly and servicing procedures, the complete assembly and servicing job was divided into nine job segments. Each segment represents a discrete portion of the assembly procedure and consists of relatively homogeneous job activities. Each of the nine job segments was further subdivided into sub-tasks to provide a total of 49 sub-tasks. In order to determine the assigned responsibilities of each of the MOS's for the assembly and servicing procedure, questions about the sub-tasks were included as part of the Launching Area Maintenance Job Survey (LAMJS). The four kinds of information obtained for the sub-tasks were (1) MOS usually performing the sub-task, (2) MOS's usually assisting in the performance of the sub-task, (3) MOS's who have also performed the sub-task, and (4) MOS's who usually supervise the sub-task.

The nine job segments are listed below. Details concerning the sub-tasks may be found in Appendix A.

a. Receiving, Uncrating, and Inspection

During this job segment the missile body and its booster are uncrated and examined. (Six sub-tasks)

b. Mechanical Systems Test

The missile air tanks are checked for low and high pressure air leaks. (Seven sub-tasks)

c. Missile Assembly

During this job segment various external parts of the missile are attached and adjusted. (Three sub-tasks)

d. Complete Missile Checkout

The missile RF and electrical system is checked. (Six sub-tasks)

e. Electrical Battery Installation[1]

The missile battery is installed and the guidance section pressure is checked. (Two sub-tasks)

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[1] After the data were collected it was found that this segment could be combined with segment (c) above, missile assembly. Therefore, when the results are presented in the Results Section, only eight job segments will be listed.

f. Missile-Booster Joining

During this job segment the missile body is joined to its booster. (Six sub-tasks)

g. Propellant Servicing

The missile is fueled and oxidized. (Seven sub-tasks)

h. Warhead System Installation

The warheads and arming mechanisms are installed. (Five sub-tasks)

i. Transporting to the Launcher; Final Preparation

During this job segment the missile-booster assembly is attached to the launcher-loader assembly. Booster fins are attached and the starting mix is inserted. (Ten sub-tasks)

2. Data Collection Procedures for Preventive Maintenance Activities

Preventive maintenance is an important aspect of the overall maintenance job in that it is the principle means of assuring a continuous operational capability of the battery. While the procedures involved are not particularly difficult, they require careful discriminations and an appreciation of their importance on the part of participating personnel. It is most relevant, therefore, to determine who performs the checks and how effective the checks have been in uncovering malfunctions.

In the present study this type of preventive maintenance data was obtained from two sources: answers to questions in the LAMJS and completed maintenance check sheets. Information about the MOS's involved in the checks was obtained from the LAMJS. For more important checks, the batteries were asked to give MOS's who (1) usually performed, (2) usually assisted in performing, (3) had also performed, and (4) supervised them. For the remaining checks, the batteries were simply asked to give the MOS's who performed the checks and who would make the repairs. The information concerning personnel responsibility for the checks was obtained from ten batteries in the New York Defense Area. Completed preventive maintenance check sheets showing the content of the check and the malfunctions found were obtained for equipment used in the launching area from two battalions in the Pittsburgh Defense Area and from two batteries in the New York Defense Area. The number and types of recorded checks obtained for each piece of equipment are shown in Appendix B.

3. Data Collection Procedures for Trouble Analysis and Repair Activities

The principle questions which are appropriately asked about trouble analysis and repair concern the possible malfunction indications that might confront the technician, the malfunctions which have some appreciable probability of occurrence, and the behavior associated with each of the above.

In order to collect and analyze malfunction data in some orderly fashion, it is helpful to classify equipment into discrete categories. In this study the launching area equipment was grouped into 11 categories:[1]

1. Missile Air System
2. Missile Oil System
3. Missile Warhead System
4. Missile Propulsion System
5. Missile RF & Electrical System and Test Responder
6. Miscellaneous Missile Parts
7. Launcher and Section Control Consoles
8. Miscellaneous LCT Equipment
9. Launcher-Loader Assembly
10. Test Equipment
11. Assembly and Servicing Equipment

These categories were established on the basis of generally used equipment classes. In the case of the missile, the categorization represents a breakdown of equipment into its functional parts. In the case of other launching area equipment, the categorization represents a combination of equipment. The equipments combined bear some functional similarity.

Trouble analysis and repair activity data were obtained by the use of several specially constructed data collection devices and from records kept by military organizations.

a. Common Malfunctions

Provisions were made in the LAMJS to list the malfunctions most frequently encountered by the battery in 16 equipment categories. Battery personnel also were asked to indicate for each common malfunction whether or not it was repaired by site personnel. The form used to collect this information can be seen in the LAMJS in Appendix A.

b. Launching Area Malfunction Record (LAMR)

In addition to estimates of common malfunctions reported by site personnel, a record was obtained of actual malfunctions found. The LAMR was developed for use by battery personnel to keep a record of launching area malfunctions encountered during a three week period. For each malfunction, the MOS making the diagnosis, the time to complete, the MOS making the repair, and the time to complete were reported. Completed records were received from 12 batteries in the New York and Pittsburgh Defense Areas. Six of the batteries returned a second form covering an additional three weeks making a six week sample for them. The LAMR form is shown in Appendix C.

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[1] The initial set of categories, which appear in the LAMJS form, consisted of 16 equipment categories. The test responder was combined with missile RF & electrical system and the launcher and section control consoles were combined because of equipment similarities. Magazine room equipment and power equipment were omitted because they are Engineering Corps responsibilities. Communications equipment was omitted because it is a Signal Corps responsibility.

c. Status of Equipment Reports (SOD PORTS)

These are daily records of equipment malfunctions submitted by eight batteries in the New York Defense Area. The SOD Ports reported those equipment malfunctions which lowered the effectiveness of the battery. The corrective actions generally took more than a working day and may have required the assistance of ordnance or the requisitioning of parts. These data were used to provide an estimate of battery repair activities.

d. Trouble Analysis Behavior Survey (TABS)

The TABS was developed to provide a comprehensive picture of steps taken by site technicians to isolate and correct a malfunction. The first step in the development of TABS was to state all of the initial indications of malfunction which may confront the on-site technician. This resulted in a list of 583 indications of malfunction for 11 equipment categories.

In the second step, battery personnel were asked to indicate the steps they would take for each indication of malfunction. These steps included such actions as:

1. Calling ordnance upon observing the indication of malfunction.
2. Adjusting, repairing, or replacing a part. This refers to cases in which the need to deal with a particular part is immediately apparent from the nature of the indication of malfunction.
3. Adjusting and/or checking one of a small number of parts. This refers to cases in which the need to deal with this small number of parts is immediately apparent from the nature of the indication of malfunction.
4. Trouble shooting. This refers to cases in which numerous sequential diagnosis alternatives pertain. Indications of malfunction which could be dealt with by the first three of the above diagnosis procedures were considered to be relatively easy diagnostic problems in that the steps to be taken could be clearly specified. Indications which required trouble shooting were considered to be difficult.

For each equipment category it was possible to develop a difficulty-of-diagnosis profile. The profile consists of the number of indications of malfunction which are relatively easy to diagnose and the number of indications of malfunction which are relatively difficult to diagnose. The indications of malfunction were also categorized according to whether or not site personnel could make the repair. These two kinds of data provided a maintenance profile which showed the equipment areas requiring little background and those requiring more extensive knowledge and training for site technicians. The TABS items also provide a source of troubles for use in testing trouble analysis proficiency in the 11 equipment areas. The indications of malfunction with their difficulty of diagnosis judgments and the indication whether or not they can be repaired by site personnel are shown in Appendix E.

4. Site Technician Training

The maintenance training received by site technicians for each of the three major job areas was determined from a study of materials provided by the Air Defense School, Ft. Bliss, Texas. During a visit to the school, programs of instruction, lesson plans, examinations and student texts for the 221 and 223 course were obtained. Instructors and supervisory personnel at the school were interviewed regarding course emphases, equipment, and training aids used. This information was used as a basis for evaluating on-site maintenance activities in terms of school training.

IV. RESULTS

The results of this study describe the maintenance job activities of the launcher and assembly area personnel. For convenience, the findings have been grouped according to the three major job categories: (1) missile assembly and servicing, (2) preventive maintenance, and (3) trouble analysis and repair. The findings for each job category will be described in detail and some of the immediate implications will be presented. A more general consideration of the results will be contained in the discussion section.

A. Missile Assembly and Servicing Activities

Missile assembly and servicing is an important activity of the launching area. The readiness of the battery to fulfill its ultimate mission depends to a large degree on this activity. The success of this work depends on the contributions made by a number of MOS's. In order to determine the part which each of the launching area MOS's plays in performing this work, different kinds of job responsibility will be analyzed for the various segments of assembly and servicing work.

1. Primary Responsibility

The primary responsibility among the MOS's for the missile and servicing work was determined from the answers to the question "Who usually does this job?" in the LAMJS. This question was answered at 10 batteries for each of the 52 sub-tasks which comprise the eight job segments in the assembly and checkout procedure. (See Appendix A for a listing of sub-tasks.)

The sub-task data was converted into an index which would represent MOS participation in each of the eight job segments. The index used was the median frequency with which the 10 batteries reported MOS utilization for the sub-tasks within a job segment. The procedure for developing a job segment utilization index is illustrated in the following example. The uncrating job segment contains six work tasks. The MOS 221 was reported as doing each of these six tasks by different numbers of batteries, e.g., the MOS 221 was reported as usually doing one of the tasks by three batteries, while for another task the MOS 221 was reported as usually doing the task by seven batteries. The median number of times the MOS 221 was reported for the six items was determined and used as an index of the MOS 221 participation in the uncrating job segment. This procedure was carried out for each of the eight job segments for the MOS's reported. Indices are shown in Table 1 for the MOS's who were reported as customarily carrying out each of the job segments.

The indices show that in general the MOS's 221 and 223 were most frequently reported as performing the assembly and servicing activities. This finding is in keeping with the intended organization of the launching area as the 223 and 221 are assigned to the assembly area.

Table 1 also indicates that the distribution of the work among the 223 and 221 generally corresponds with their specialties. The 223 is reported most frequently as performing the assembly, electrical checkout, and warheading job segments which are heavily loaded with electronic sub-tasks. The 221 is reported most frequently as performing the uncrating, mechanical tests, booster joining, and fueling job segments which are heavily loaded with mechanical related sub-tasks.

Table 1

Utilization Indices

MOS Usually Performing the Sub-tasks of the Assembly and Servicing Job Segments

Job Segment[1]	Utilization Indices		
	MOS 221	MOS 223	Other MOS's[2]
1. Uncrating	4.0	1.5	2.0
2. Mechanical Tests	6.0	2.7	3.0
3. Assembly	2.2	6.8	1.8
4. Electrical Checkout	0.1	8.5	1.5
5. Booster Joining	5.5	2.2	3.0
6. Fueling	5.9	1.9	2.1
7. Warheading	2.2	6.0	0.3
8. Final Preparation	1.2	1.9	6.0

The 225, 220, 612, 351, and 357 play a different role in the assembly and servicing work than do the 223 and 221. The latter generally receive mention for almost every sub-task within their respective job segments. In contrast to the 223 and 221, the Other MOS's (225, 220, 612, 351, and 357) are mentioned in respect to a few sub-tasks in a job segment except for final preparation where they receive strong mention. Since all the job segments are performed in the assembly area until the missile is moved to the launcher area for final preparation, the shift in personnel utilization reflects the transition of responsibility for the missile from assembly area to launcher area personnel. In order to explore further the role of Other MOS's, the data summarized in Table 1 for Other MOS's will be described in more detail.

The MOS 225 is reported as utilized throughout the first seven job segments, but with low median frequency. The frequency of utilization of this MOS is high in the final preparation job segment. The 225, therefore, performs some of the assembly and servicing tasks of the first seven job segments, but in most batteries his primary responsibility during assembly and servicing is for the final preparation.

The MOS 220 is reported infrequently throughout the first seven job segments. The number of reports for this MOS for the final preparation job segment also increases sharply. Like the 225, the 220 occasionally performs some of the assembly and servicing tasks, but his primary responsibilities are for the final preparation.

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1 Abbreviated titles for the job segments are used in the table to conserve space. These titles correspond to those given starting on page 6. Electrical battery installation is included in Assembly. This point also applies to the three tables which follow.

2 The MOS's represented in this category are the 225, 220, 612, 351, and the 357.

Among the Other MOS's, only the 225 and 220 are mentioned in the final preparation job segment. As Section personnel, it would appear that this is the stage at which they are assuming responsibility for the missile.

The MOS's 351, 357, and 612 receive more limited mention than the 225 and 220. The 351 is reported just once as operating a capping compressor. The 357 is reported as operating the capping compressor and as driving the transporter-trailer. The 612 is reported as operating the stagnation pressure pump and driving the transporter-trailer. The functions of the 351, 357, and 612 are limited in nature and tend to be support services.

2. Support Roles

In addition to assuming primary responsibility for certain work tasks, the MOS's also assist each other. The support roles played by the MOS's were determined from the answers to the question "Who usually assists in performing this job?" on the LAMJS. The median frequency with which batteries reported the MOS's for each work task again was taken as an index of utilization for the job segment. These medians are shown in Table 2.

Table 2

Utilization Indices

MOS Assisting in the Performance of the Sub-tasks of the Missile Assembly and Servicing Job Segments

Job Segment	Utilization Indices		
	MOS 221	MOS 223	Other MOS's[1]
1. Uncrating	2.2	1.0	5.5
2. Mechanical Tests	3.0	1.3	6.2
3. Assembly	1.2	1.0	4.2
4. Electrical Checkout	1.5	3.8	4.5
5. Booster Joining	2.0	0.9	10.0
6. Fueling	3.6	0.9	7.1
7. Warheading	3.0	0.3	7.2
8. Final Preparation	1.5	0.5	7.1

The data in Table 2 indicate that the Other MOS's play the largest role in assisting for the missile and servicing sub-tasks. In view of lack of specialized training received by these MOS's and the need for additional help during missile assembly and servicing, they are appropriately utilized. The details concerning the utilization of the Other MOS's can be seen in Table F2 of Appendix F. The 220 was reported most frequently as assisting

[1] The MOS's included in this category are the 225, 220, 612, 351, 357, and 227.

on almost all of the sub-tasks. This is appropriate in that there were found to be approximately twenty-four 220's available at each battery launching area. Thus the 220 has the role of generally assisting as far as the assembly and servicing sub-tasks are concerned.

The 225 was reported infrequently. No more than two batteries reported the 225 as assisting on any sub-task. In general, the 225 does not play a large role as an assistant during assembly and servicing nor does the small role which he does have seem limited to a specific area or set of functions.

The 612 is utilized by no more than three batteries for any sub-task. However, the sub-tasks for which he is mentioned tend to represent specific kinds of functions. The 612 shows a concentration of reports in the mechanical tests job segment. Except for the actual performance of the leak test, he is mentioned for every sub-task in this job segment. During the assembly job segment, the 612 is mentioned as assisting in the mechanical sub-tasks but not for the battery installation or for the centering of the fins. The 612 is mentioned as assisting in all of the booster joining sub-tasks, in all of the warhead installation sub-tasks, and in four final preparation sub-tasks. The latter four sub-tasks deal with driving the trailer and connecting ground power plugs and the arming mechanism. Thus it would seem that the 612 has a limited but somewhat specific function as an assistant. His specific function seems to be in the area of assisting in the performance of various mechanical sub-tasks. The number of 612's seems limited. Each battery reported having one of this MOS available.

The 351 was reported as assisting in the performance of assembly and servicing sub-tasks which are mechanical in nature. On the average, the batteries reported having two MOS 351's.

The 357 was reported as assisting in five sub-tasks. These tasks involve operating the capping compressor and driving the transporter-trailer. The batteries indicated that there were approximately three MOS 357's at each launching site.

In summary, the 220 was reported as having the largest and most general role as an assistant for the assembly and servicing sub-tasks. This role is suitable because of the availability of a relatively large number of personnel with this MOS and the general lack of special capabilities of this MOS. The 220's have the designation of helpers in their job title. The 225, 612, 351, and 357 seem to have a lesser role as assistants. This may be due in part to the smaller number of these personnel who are available (especially MOS 612 and MOS 351) and the fact that they have other specific functions assigned to them which may limit their general participation in the assembly and servicing work.

3. Interchangeability of Roles

In addition to performing their own work, the MOS's may be called upon to do the work usually performed by other MOS's. To the extent which MOS's are found to substitute for other MOS's, a need for cross-training is suggested.

The interchangeability of roles among the MOS's was determined from the answers to the question "Who else has done this job?" in the LAMJS. As in the case of the previous questions, the median number of times an MOS was reported by the batteries for sub-tasks in a job segment was used as a measure of his overall participation in this job segment. These indices are shown in Table 3.

Table 3

Utilization Indices

MOS Reported as Also Performing the Sub-tasks of the Missile Assembly and Servicing Job Segments

Job Segment	Utilization Indices		
	MOS 221	MOS 223	Other MOS's[1]
1. Uncrating	1.0	5.5	5.5
2. Mechanical Tests	0.4	4.8	5.9
3. Assembly	1.9	2.0	5.3
4. Electrical Checkout	0.8	1.5	3.5
5. Booster Joining	0.1	6.0	5.5
6. Fueling	0.9	4.8	3.8
7. Warheading	0.3	3.2	4.0
8. Final Preparation	1.2	3.2	6.5

The results in Table 3 indicate that both the MOS 223 and the Other MOS's show a sizeable amount of interchangeability in terms of having done the work usually done by other personnel. The MOS 221 was reported as having relatively little interchangeability with other personnel. In order to determine the nature of role interchangeability, each set of indices for an MOS in Table 3 (secondary responsibility) were correlated with those in Table 1 (primary responsibility) using rank-order correlation coefficients. These coefficients will give a picture of the relationship between the secondary jobs of one MOS and the primary jobs of another MOS. The correlations are shown in Table 4.

Table 4

Rank-Order Correlations of Primary and Secondary (Have Also Done) Indices

Primary Role	Have Also Done		
	MOS 223	MOS 221	Other MOS's
MOS 223	---	-.19	-.55
MOS 221	.74*	---	.25

* $.05 > p > .01$

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[1] The MOS's represented in this category are the 225, 220, 612, 351, and the 357.

As can be seen from the preceding table there is a significant tendency for the 223 to do the work which is usually performed by the 221. The reverse is not true. The Other MOS's show a positive but non-significant tendency to also do the work usually performed by the 221. The Other MOS's show a strong tendency not to do the work usually performed by the 223.

These findings support observations made at the batteries that the 223 tends to do 221 work but that the reverse is not true. These findings also support the recent decision to give the 223 some training which previously was unique to the 221 training course.

4. Supervisory Roles

In addition to performing missile assembly and servicing sub-tasks, site personnel assume varying degrees of supervisory responsibility for the sub-tasks. It is important to determine the nature of the supervisory role because this type of work may require training which is different than that normally received for performing the tasks. The supervisory roles played by the MOS's were determined from the answers to the question "Who usually supervises this job?" in the LAMJS. As with the other questions, the median number of times a MOS was reported supervising the sub-tasks in a job segment was used as an index of supervisory responsibility for that segment. These indices are given in Table 5.

Table 5

Utilization Indices

MOS Supervising the Sub-tasks of the Missile Assembly and Servicing Job Segments

Job Segment	Utilization Indices			
	MOS 221	MOS 223	MOS 1185	Other MOS's[1]
1. Uncrating	3.0	4.2	5.0	0.2
2. Mechanical Tests	3.0	3.9	6.2	0.4
3. Assembly	0.3	5.0	5.0	1.2
4. Electrical Checkout	0.1	5.5	6.5	0.0
5. Booster Joining	2.0	4.1	4.2	0.5
6. Fueling	2.2	3.1	7.6	0.0
7. Warheading	1.0	5.0	7.0	0.0
8. Final Preparation	1.0	2.0	3.0	6.0

The results in Table 5 show that supervision is distributed among the 221, 223, and the 1185. The 1185 is reported as having the major supervisory role, followed in order of overall mention by the 223 and 221. The Other MOS's were reported as having a high degree of supervisory responsibility in the final preparation job segment. This finding is consistent with the relatively large number of reports that the Other MOS's usually do these job tasks as shown in Table 1. As can be seen from Table F4 of Appendix F, the 225 (Section Chief) or 1180 (Platoon Leader) exercise supervisory responsibility in the launcher area where the final preparation takes place.

[1] The MOS's represented in this category are the 225, 220, 612, 351, and the 357.

In order to determine more specifically the nature of the 221, 223, and 1185 supervisory roles, the indices in Table 5 were correlated with the indices in Table 1 which show the MOS usually performing the job segment. These correlations will show the relationships between what the 221, 223, and 1185 supervise and the work done by the 221 and 223. The rank-order correlations are shown in Table 6.

Table 6

Rank-Order Correlations of the Utilization Indices Between Job Segments Which the MOS's Supervise and Job Segments Which They Usually Do

Primary Role	Supervisor		
	MOS 221	MOS 223	MOS 1185
MOS 221	.84**	-.45	.22
MOS 223	-.68*	.73*	.29

* $.05 > p > .01$

** $p < .01$

From the above table it is evident that the 221 and 223 have supervisory roles which are closely related to the work they usually perform, while the 1185 has a more general and non-specific supervisory role. The 221 shows significant tendencies to supervise 221 work and not to supervise 223 work. The 223 shows a significant tendency to supervise 223 work and a tendency not to supervise 221 work. The 1185 tends to supervise the work of both.

Thus the pattern of the supervision for the assembly and servicing job-tasks would seem to be one in which the 223 and 221 supervise the work in their respective job specialties under the general supervision of the 1185. When the missile is moved to the launcher area, the 225 and 1180 supervise the final preparation job-tasks.

5. Training Received for Missile Assembly and Servicing

Since a major purpose of collecting job activity information is to translate this information into recommendations about training, it is appropriate to consider the current school training program as it relates to the assembly and servicing work. The current school training was determined for the 223 and 221 since they are the key personnel in the missile assembly and servicing process. The course content for the 223[1] and the 221[2] was determined from the current AAA & GM School Programs of Instruction (POI's).

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1 SAM Electronic Material Maintenance Course, Nike. U.S. Army Air Defense School, Fort Bliss, Texas, March 1957.

2 SAM Missile Mechanical Material Course, Nike. U.S. Army Air Defense School, Fort Bliss, Texas, April 1957.

Analysis of the POI's shows that the 223 receives 154 hours of instruction which are related to missile assembly and servicing, while the 221 receives 122 hours of such instruction. The distribution of these hours are shown in Table 7.

Table 7

MOS 223 and MOS 221 Training Hours Relevant to Assembly and Servicing

	MOS 223	MOS 221
Description of procedures, equipment, and missile components	31	59
Practice in Assembly and Servicing	123	65
TOTAL:	154	124

Both MOS's receive training which describes missile components and which provides practice on single job segments and on the entire assembly and servicing process. However, the distribution of descriptive and practice training hours differs for the two MOS's.

For the MOS 223, approximately 20% of the training hours deal with the description of procedures, equipment, and missile components. Of the 31 hours of descriptive training, 14 deal with the description of missile components, 13 deal with the description of missile assembly procedures, and 4 deal with the description of test equipment. Approximately 80% of the training hours deal with practice on missile assembly and servicing procedures. Of the 123 hours allotted to this, 43 are spent on practice in assembling and disassembling missiles, 40 are spent on practice in performing the RF checkout procedure, and 40 are spent on practice in calibration and use of the RF test set.

Thus for the 223, the training emphasis is on the practice of procedures with which the technician will be most concerned on-site, i.e., the RF checkout. No special emphasis is given to missile assembly and warheading, for which the MOS 223 was also found to have a primary role.

For the MOS 221, training hours are distributed almost equally between description and practice. Approximately 48% of the training hours are concerned with the description of procedures, equipment, and missile components. Of the 59 hours of descriptive training, 24 are concerned with missile components, 12 deal with the description of missile assembly procedures, and 23 deal with assembly and servicing equipment. Approximately 52% of the training hours are concerned with practice. Of the 65 practice training hours, 35 are devoted to the assembly and disassembly procedures, 20 are devoted to practice on specific job segments (except the RF checkout), and 10 are devoted to practice in the use of assembly and servicing equipment.

Thus for the 221 descriptive and practice training are distributed over a number of job segments. This corresponds to the wide range of primary roles which the 221 was found to have. He does not, however, have primary responsibilities for the missile assembly and the warheading segments, for which he has received special training.

B. Preventive Maintenance Activities

As part of a standardized preventive maintenance program, all of the launching area equipment is checked on daily, weekly, and monthly schedules.

Preventive maintenance check sheets for the major pieces of launching area equipment were collected and analyzed in order to obtain an estimate of the number and kind of malfunctions uncovered by these periodic checks. These data are presented in Appendix H and summarized in this section. To determine what responsibilities are assigned to the various MOS's for the different checks, the responses to the Launching Area Maintenance Job Survey from ten batteries were summarized for presentation below.

1. Launcher Area Checks

The launcher area checks are performed on the missiles and the major pieces of equipment that are used in the firing of a missile.

a. The Missile

Since there is no way of actually flight testing the missile, the checking of its continued capability for successful flight assumes considerable importance. Daily, weekly, and monthly checks are scheduled for the missile.

(1) Daily Missile Maintenance Check

Each missile is checked daily for directly visible indications of trouble. The most frequent malfunctions uncovered by the daily checks are concerned with oil and air leaks, lanyard tightness, and missing flags. In general, the number of malfunctions uncovered by this check is relatively small. The reponsibility for performing this check was reported as being distributed among MOS's as shown in Table 8.

Table 8

Responsibility for Daily Missile Check[1]

Responsibility	MOS						
	223	221	1185	225	220	1180	Others[2]
Usually performed by	-	-	-	5	5	-	-
Usually assisted by	-	-	-	2	7	-	-
Has also been performed by	2	2	-	1	3	-	5
Usually supervised by	-	-	-	10	-	1	-

1 Although the data represents practices at ten batteries, row entries do not necessarily equal ten. Each battery could list more or less than one MOS as appropriate.

2 The Other MOS's mentioned as taking some part in performing checks are the TO&E MOS's 313 and 612 as well as MOS's 111, 550, and 835 who are not listed on the Nike TO&E.

As can be seen from the preceding data summary, the daily check is primarily the responsibility of the 225 and 220. It was indicated as also being performed by the 221 and 223, but not in sufficient frequency to suggest that they generally have major responsibility for this activity.

(2) Weekly Missile Maintenance Check

The weekly check on the missile is concerned with the lock-on by the missile tracking radar (MTR), a battery test at the launcher operating panel (LOP), and the overboard dump port valve. The lock-on by the MTR is performed by sending commands from the battery control area to the missile while it is in an erect position on the launcher. The section control panel operator monitors indicators on his panel and reports from a crewman who observes fin responses of the missiles. The battery test at the LOP consists of reading the missile battery current on the voltmeter provided on the LOP. The overboard dump port valve check is a visual check made to insure that the valve is cocked.

The maintenance check responsibilities for the MTR lock-on and LOP battery checks were found to be distributed among the MOS's as shown in Tables 9 and 10.

Table 9

Responsibilities for the MTR Lock-on Check

Responsibility	MOS						
	223	221	1185	225	220	1180	Others
Usually performed by	-	-	-	6	2	-	1
Usually assisted by	-	-	-	2	8	-	1
Has also been performed by	4	2	-	2	3	-	1
Usually supervised by	3	-	2	6	-	1	1

Table 10

Responsibilities for LOP Battery Check

Responsibility	MOS						
	223	221	1185	225	220	1180	Others
Usually performed by	-	-	-	5	5	-	-
Usually assisted by	-	-	-	2	7	-	-
Has also been performed by	4	2	-	1	3	-	5
Usually supervised by	1	-	-	10	-	1	-

The 225's and 220's have primary responsibility for the weekly missile checks. All of the malfunctions reported were concerned with the MTR check and they were found to occur in approximately 4% of the checks made.

(3) Missile Monthly Maintenance Check

This check consists of a review of the daily and weekly check sheets, an RF checkout, the removal and cleaning of the battery, the cleaning of the battery box, and a check on fuel leaks by means of a sniff test. The sniff test produced four indications of malfunction in 297 monthly checks for 81 missiles. The RF checkout, which is the major part of the monthly check, is described in the next section.

(4) Missile Monthly RF Checkout

This check is an abbreviated version of the RF and Electrical check which is performed when the missile is assembled. It is performed at the launcher with a portable RF and Electrical test set. The distribution of responsibilities among the MOS's for this check is shown in Table 11.

Table 11

Responsibilities for RF and Electrical Check

Responsibility	MOS					
	223	221	1185	225	220	Others
Usually performed by	10	-	-	-	-	-
Usually assisted by	3	1	-	4	2	-
Has also been performed by	3	2	1	-	2	-
Usually supervised by	6	-	6	1	-	-

The 223 has the primary responsibility for this check. He shares the supervision of the check with the 1185.

It is noteworthy that in contrast with the daily and weekly missile checks which are performed by the launcher personnel, the monthly RF checkout is primarily the responsibility of the 223 technician. While no indications of out-of-tolerance missile current were found for the weekly check, these out-of-tolerance indications were reported for a high proportion of monthly RF checks. This suggests that the launcher personnel were not performing an adequate checkout of the missile.

The three most frequent malfunctions reported during the RF monthly checkout were for missile current, missile voltage, and response time. The missile current malfunction occurred in approximately 35% of the checks made; the missile voltage malfunctions occurred in approximately 13% of the checks made; and the response time malfunctions occurred in approximately 5% of the checks made.

Although there are no particularly difficult procedures performed in the daily and weekly missile checks, the discriminations which must be made are of definite importance. It is pertinent therefore, to consider carefully the wisdom of leaving the responsibility for missile condition in the hands of personnel without technical training. The MOS 223 checks the missile only once each month and the MOS 221 has no prescribed responsibility for the checking of the missile after it leaves the assembly area.

b. Firing Equipment

(1) Weekly Launcher-Loader Maintenance Check

The launcher-loader assembly includes the hydraulic erection system, missile test package, and electrical junction box. The launcher hydraulic erection system and the missile testing hydraulic power package checks consist of operating the units to determine adequacy of operation, checking for correct fluid level, pressure, valve positions and looking for evidence of leaks. The junction box is checked by examining it for evidence of damage and determining that its voltage distributing and feedback functions are accomplished. Table 12 summarizes the maintenance check and repair responsibilities for the launcher-loader assembly check.

Table 12

Responsibilities for Launcher-Loader Check

Responsibility	MOS						
	223	221	1185	225	220	Others[1]	ORD.
Checked by	4	2	-	4	4	-	-
Repaired by	9	7	1	1	1	-	3

The maintenance checks for the launcher-loader were found to be evenly distributed among the assembly building and section MOS's. The repair responsibilities are primarily in the hands of the 223 and 221. Ordnance is also active in making repairs in this area.

The most frequent malfunction encountered during this check was for the launcher operating panel. This malfunction was encountered in approximately 4% of the checks made. All other malfunctions occurred 1% of the time or less.

Three of the more important parts of the launcher-loader check were listed separately on the questionnaire. The personnel responsibility data for the launcher hydraulic erection system, missile testing hydraulic power package, and launcher electrical junction box are contained in Appendix I. These data provide an opportunity to determine whether any special second order responsibilities exist for this heterogenous check which includes both electrical and hydraulic parts. For the hydraulic erection and missile testing units, the results are essentially the same as for the overall launcher-loader check. For the electrical junction box, however, a marked shift of responsibility to the 223 is found. This most likely reflects the responsibility of the 223 to follow up any possibility that the junction box may have an indication of malfunction.

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1 The Other MOS's mentioned as making repairs are the 351, 357, 612, and 631.

(2) Weekly Launching and Transporter Rail Maintenance Check

The rail is used as a supporting and handling unit for the complete Nike round during storage, transit, loading, testing, erecting, and launching. During the check the physical condition of the rail and its moving parts, and the hydraulic and electrical lines and connections are examined. The maintenance check and repair responsibilities for the launching and transporter rail were distributed among the MOS's as shown in Table 13.

Table 13

Responsibility for Launcher and Transporter Rail Check

Responsibility	MOS 223	221	1185	225	220	Others	ORD.
Checked by	3	3	-	4	5	-	-
Repaired by	8	8	1	1	2	-	3

The responsibility for the maintenance check is distributed among the assembly building (223, 221) and section MOS's (225, 220). The repair responsibilities are primarily the responsibility of the 223 or 221. The malfunctions which are reported occur in less than 10% of the checks made.

(3) Weekly Missile-Booster Storage Rack Maintenance Check

During the weekly check of the storage rack, the frames are examined for rust or damage and the pins are visually checked for rust and proper lubrication. In Table 14 are presented the distribution of the maintenance check and repair functions for the missile-booster storage rack.

Table 14

Responsibility for Missile-Booster Storage Rack Check

Responsibility	MOS 223	221	1185	225	220	Others	ORD.
Checked by	-	1	-	5	5	-	-
Repaired by	1	6	-	3	3	-	3

The section personnel, 225's and 220's, have the major responsibility for the maintenance check on the storage rack. The 221 has the major responsibility for the repair function. He shares this function with the section personnel and with Ordnance. Truss frame malfunctions were mentioned in approximately 43% of the checks made. Other malfunctions were mentioned in approximately 3% or less of the checks.

(4) Weekly Launching and Section Control Consoles Maintenance Check

The weekly check of the control consoles consists of visually inspecting the physical condition of these units including switches and indicator lights. The responsibility for performing the weekly check of the two consoles was distributed as shown in Tables 15 and 16.

Table 15

Responsibility for Launching Control Console Check

Responsibility	MOS 223	221	1185	225	220	Others
Usually performed by	3	1	-	5	2	-
Usually assisted by	-	-	-	1	6	-
Has also performed	3	1	-	2	2	2
Usually supervised by	5	-	2	7	-	1

Table 16

Responsibility for Section Control Console Check

Responsibility	MOS 223	221	1185	225	220	Others
Usually performed by	2	-	-	5	3	-
Usually assisted by	-	-	-	1	5	-
Has also performed	3	1	-	3	1	2
Usually supervised by	4	-	2	8	-	1

Major responsibility for performing these checks lies with the operator personnel. Supervision is assigned most frequently to the 225 with the 223 also having some responsibility for this function. Faulty switches and lights and missing fuses accounted for the preponderance of malfunctions found during the check of the section control console.

A review of the responsibilities for checking the firing equipment shows that the technical personnel (MOS's 223 and 221) are frequently reported by the batteries as performing these checks. Considering that the technicians are assigned to the assembly area and are not officially responsible for the firing equipment checks, this finding is interpreted as reflecting a need felt at the batteries for more technically competent personnel to handle this responsibility. This point will be expanded in the discussion section of this report.

2. Assembly Area Checks

The checks considered under this heading are all performed on the testing, servicing, and handling equipment which is used in the assembly area.

a. Test Equipment

(1) Weekly RF Test Set Maintenance Check

During the weekly check of the RF Test Set it is examined for excessive wear, for damage, dust, and it is calibrated. The maintenance check and repair responsibilities for the RF Test Set were found to be distributed among the MOS's as shown in Table 17.

Table 17

Responsibility for the RF Test Set Check

Responsibility	MOS 223	221	1185	225	220	Others	ORD.
Checked by	10	-	-	-	-	-	-
Repaired by	9	-	2	-	-	1	4

The 223 is responsible for the maintenance check of the RF Test Set. He also has a major responsibility for the repair work. The 1185 and Ordnance also share in the repair work.

The most frequent malfunctions reported were concerned with the visible condition of the interior of the set. This item was mentioned in approximately 6% of the checks made. The air filters were mentioned in approximately 4% of the checks. All other items were mentioned in 2% or less of the checks made.

(2) Weekly Hydraulic Test Stand Maintenance Check

During the weekly check of the hydraulic test stand it is examined for evidence of wear, damage, and dirt. The oil level is checked visually. The pressure level and operation of the solenoid valve are checked by operating the set. Table 18 shows the distribution of responsibility for the maintenance check and repair functions.

The 223's and 221's share in the maintenance check and repair responsibilities for the hydraulic test stand. The 1185 and Ordnance are also called upon for repair work. No malfunctions were reported for this piece of equipment.

Table 18

Responsibility for Hydraulic Test Stand Check

Responsibility	MOS						
	223	221	1185	225	220	Others	ORD.
Checked by	5	6	-	-	-	-	-
Repaired by	5	5	2	-	-	-	3

(3) Propulsion Plumbing Tester

The weekly check of the tester consists of examination for signs of damage, dirt, and wear. The motor cut-out is checked by operating it. The maintenance check and repair responsibilities were distributed among the MOS's as shown in Table 19.

Table 19

Responsibility for Propulsion Plumbing Tester Check

Responsibility	MOS						
	223	221	1185	225	220	Others	ORD.
Checked by	2	8	-	-	-	3	-
Repaired by	-	7	-	-	-	3	4

The 221 has the major responsibility for checking and repairing the propulsion plumbing tester. Ordnance also has a repair function in this area. No malfunctions were reported for this piece of equipment.

It is clear that the technicians are given full responsibility for checking the test equipment which they use. In no case were the operator personnel (MOS's 225 and 220) reported as performing these checks. Only for the propulsion plumbing tester were other personnel (MOS's 357 and 612) given some responsibility for the checks.

b. Servicing Equipment

(1) Weekly Fuel and Oxidizer Servicer Maintenance Check

The fuel and oxidizer servicer is checked for damage, wear, and dirt. The moving parts are operated to check for freedom of movement. The maintenance check and repair responsibilities were found to be distributed among the MOS's as shown in Table 20.

The 221 has the major share of the responsibility for checking and repairing the fuel and acid servicer. He shares the repair responsibilities with the 220, 1185, and Ordnance. The malfunctions reported occur in approximately 2% of the cases for each category in which malfunctions are reported.

Table 20

Responsibility for Fuel and Oxidizer Servicer Check

Responsibility	MOS 223	221	1185	225	220	Others	ORD.
Checked by	2	8	-	1	1	-	-
Repaired by	-	8	2	-	2	-	3

c. Handling Equipment

(1) Weekly Missile, Guidance Section, Booster, and Universal Dolly Maintenance Checks

During the weekly checks of the dollies, they are examined for damage, wear, dirt, and missing parts. The operation of wheels, casters, and brakes are checked. Table 21 shows the maintenance check and repair responsibilities for the four dollies.

Table 21

Responsibility for Missile, Guidance Section, Booster, and Universal Dolly Check

Responsibility	MOS 223	221	1185	225	220	Others	ORD.
Checked by	3	7	-	-	3	-	-
Repaired by	2	7	-	-	2	-	4

The 221 has the major responsibility for checking and repairing the dollies. The repair responsibility is shared by Ordnance. The malfunctions reported occur in less than 1% of the checks made.

(2) Weekly Missile and Booster Hoist Maintenance Checks

The missile and booster hoist beam links and pin assemblies are examined visually. The distribution of maintenance check and repair responsibilities for the hoist beams is shown in Table 22.

Table 22

Responsibility for Missile and Booster Hoist Beams Check

Responsibility	MOS 223	221	1185	225	220	Others	ORD.
Checked by	1	7	-	1	2	-	-
Repaired by	-	6	-	-	2	-	4

The 221 has the major maintenance check and repair responsibilities for the missile and booster hoist beams. He shares the repair responsibility with Ordnance. The malfunctions reported in this check occur approximately in 5% of the checks made.

(3) Weekly Missile Handling Rings and Warhead Handling Yoke Maintenance Checks

During the weekly checks of the missile handling rings and warhead handling yoke, the links, pins, and chains are examined visually and the pieces of equipment are examined for condition of paint and for dirt. The maintenance check and repair responsibilities for the missile handling rings and warhead handling yoke were found to be distributed among the MOS's as shown in Table 23.

Table 23

Responsibilities for Missile Handling Rings and Warhead Handling Yoke Checks

Responsibility	MOS						
	223	221	1185	225	220	Others	ORD.
Checked by	1	8	-	-	2	-	-
Repaired by	-	6	-	-	2	-	4

The 221 has the major responsibilities for the maintenance check and repair functions for the missile handling rings and for the warhead handling yoke. He shares the repair activities with Ordnance. The malfunctions for these checks occur approximately in 3% or less of the checks made.

(4) Weekly Booster Joining Hoist Maintenance Check

The booster joining hoist is examined for condition of paint, for dirt, and for bent, cracked, or broken parts. The pulleys, winch drum, and wheels are checked for freedom of movement and ease of operation. The wire rope is checked for rust and possible breaks. The maintenance check and repair responsibilities for the booster joining hoist were found to be distributed among the MOS's as shown in Table 24.

Table 24

Responsibility for Booster Joining Hoist Check

Responsibility	MOS						
	223	221	1185	225	220	Others	ORD.
Checked by	1	7	-	1	2	-	-
Repaired by	-	6	-	-	2	1	2

The 221 has the major responsibilities for the maintenance check and repair functions for the booster joining hoist. He shares the repair function with the 220 and Ordnance. The one malfunction reported for this check represents approximately 2% of the 54 checks made.

(5) Weekly Transporter-Trailer Maintenance Check

The transporter-trailer is checked for oil leaks, overall physical condition and for the condition of its appurtenances. The maintenance check and repair responsibilities for the transporter-trailer were found to be distributed among the MOS's as shown in Table 25.

Table 25

Responsibility for Transporter-Trailer Check

Responsibility	MOS						
	223	221	1185	225	220	Others	ORD.
Checked by	2	4	-	1	3	4	-
Repaired by	-	2	-	-	1	5	3

The maintenance check function is shared by the personnel in the assembly building section, and motor pool. The repair functions rest primarily with Ordnance and the motor pool.

The servicing and handling equipment confirm the division of responsibility set up between the launcher and assembly areas in that the technicians are given major responsibility for the checks. However, the operator personnel, primarily the MOS 220, are reported as having some responsibility for the checks. This finding probably reflects the relatively simple nature of these checks (see Appendix H) and the resulting reduction in the need for technical skill.

In considering the responsibilities reported for making repairs, the battery technicians are seen to play a dominant role for all equipment, with the MOS 223 heavily weighted for equipment having some electrical features and having little responsibility for other equipment. Ordnance shows a consistent secondary role indicative of their function as a support group.

C. Trouble Shooting and Repair Activities

Batteries have to be ready to carry out their missions at all times. Malfunctions interfere to varying degrees with this requirement. Some malfunctions impair the operational readiness only slightly while other malfunctions cause the battery to be declared temporarily out-of-action. It is therefore, important that malfunctions be diagnosed and repaired as quickly as possible. Both site personnel and ordnance support groups share in the work of diagnosis and repair, but within equipment and supply limitations, the batteries should strive to be as self sufficient as possible.

In order to study this aspect of the maintenance job, the nature and frequency of the on-site trouble diagnosis and repair activities were determined by four methods.

1. Estimates of the frequency with which different kinds of malfunctions occur were obtained in the Launcher Area Maintenance Job Survey (LAMJS).

2. A record of malfunctions encountered on-site for three week periods was obtained by use of the Launcher Area Malfunction Record (LAMR).

3. Status of equipment reports (SOD Ports) provided a record of malfunctions encountered by two battalions for a four month period.

4. The Trouble Analysis Behavior Survey (TABS) provided a comprehensive picture of the indications of malfunction encountered and the corrective actions which were taken.

Details concerning each of these methods have been presented in the Method Section. The findings for each of these methods will now be presented and discussed in detail.

1. Estimates of Common Malfunctions - Launcher Area Maintenance Job Survey (LAMJS)

The LAMJS was completed by 10 missile warrent officers at 10 batteries in the New York Defense Area. For each equipment category, the missile warrant officer was asked to list the common malfunctions encountered by his battery and to indicate whether or not they were repaired by battery personnel. Table 26 gives a summary of their 241 responses to these categories. A detailed breakdown of the common malfunctions reported for each equipment category is given in Appendix J.

Table 26

Common Malfunctions Reported for the Equipment Categories

Equipment Category	Number Reported	Repaired by Site Personnel		
		Yes	Sometimes	No
1. Missile Air System	23	9	3	11
2. Missile Oil System	21	13	0	8
3. Missile Warhead System	9	5	0	4
4. Missile Propulsion System	3	2	0	1
5. Missile RF & Electrical System and Test Responder	33	21	0	12
6. Miscellaneous Missile Parts	25	18	2	5
7. Launcher and Section Control Consoles	42	35	3	4
8. Miscellaneous LCT Equipment	19	13	2	4
9. Launcher-Loader Assembly	42	28	7	7
10. Test Equipment	13	3	2	8
11. Assembly and Servicing Equipment	11	4	0	7
TOTAL:	241	151	71	19
PERCENT:	100	63	29	8

As can be seen from the table, 63% of all the malfunctions cited are repaired by site personnel, 29% are not repaired by site personnel while 8% are sometimes repaired by site personnel. The preceding distribution of repair functions shows a high degree of self sufficiency but it is still estimated that 3 out of 10 "common" repairs require Ordnance assistance.

Comparison of the equipment categories according to frequency of malfunctions reported shows the launcher-loader assembly and the launcher and section control consoles to have the largest number of reported malfunctions. These are followed in order by the missile RF and electrical system and the test responder, miscellaneous missile parts, missile air system, missile oil system, miscellaneous LCT equipment, test equipment, assembly and servicing equipment, missile warhead system, and the missile propulsion system. The frequency of malfunction data obtained from the LAMJS will be compared with similar data from the LAMR and SOD Ports later in this section.

2. Reports of Actual Malfunctions - Launcher Area Maintenance Record (LAMR)

Eighteen LAMR's were completed and returned by 12 batteries in the New York and Pittsburgh Defense Areas. Six of the batteries returned one form (covering a three week period) while six batteries returned two forms (covering a six week period). The form contains records of malfunctions encountered during the time periods and gives the MOS making the diagnosis and repair as well as the time for each. The malfunctions were classified into 11 equipment categories. A detailed breakdown of the malfunctions, diagnosis and repair times, and MOS's participating for each equipment category is given in Appendix K.

Table 27 gives a summary of the diagnosis and repair activities of site personnel. It contains the percentage of the total diagnoses and repairs made by each MOS, the number of different equipment categories in which they made diagnoses and repairs, the median diagnosis and repair time for each MOS, and the range of diagnoses and repair times for each MOS. The equipment categories are those listed in Table 26. All times are in minutes (m) or days (d).

Table 27

Diagnosis and Repair Information Based on the LAMR

	Diagnosis				Repair			
MOS	% made (N=195)[1]	Number of categories	Median time (m)	Range of time	% made (N=185)[1]	Number of categories	Median time (m)	Range of time
221	16	4	10	0-20m	13	4	30	10-120m
223	65	8	15	0-4d	38	8	30	5m-7d
220	1	2	6	5-30m	1	2	15	15-60m
225	8	6	5	1-5m	0.5	1	1	1m
1185	3	3	9	0-1d	1.5	1	10	5m-1d
ORD.	7	5	60	10m-1d	46	9	120	10-30d

[1] There were 195 trouble diagnoses reported. Repair data were reported for 185 of these troubles.

MOS 221 - The 221 diagnosed indications of malfunction in four equipment categories. These accounted for 16% of all the diagnoses reported. These are (1) the missile air system, (2) the missile oil system, (3) miscellaneous missile parts, and (4) the launcher-loader assembly. In no equipment category was the median time spent in trouble diagnosis more than 10 minutes. The longest trouble diagnosis time was 20 minutes for a malfunction in the launcher-loader assembly. The shortest time was for 0 minutes (immediate diagnosis) in the missile oil system. In general the diagnosis times for the 221 are relatively short and show little variability. If diagnosis time can be taken as a criterion of difficulty, then in general, the 221's diagnostic efforts are limited to relatively simple malfunctions.

The 221 made repairs in the same four equipment categories in which he made diagnoses. His median repair time is 20 minutes with a range of 10 - 120 minutes. These findings indicate that the 221 also makes relatively simple repairs in a limited number of equipment categories. The 221 repaired 13% of the reported malfunctions.

MOS 223 - The 223 was mentioned as diagnosing indications of malfunction in eight equipment categories. From highest to lowest in terms of median diagnosis time they are (1) RF and electrical system and test responder, (2) launcher and section control console, (3) missile warhead system, (4) miscellaneous LCT equipment, (5) launcher-loader assembly, (6) test equipment, (7) assembly and servicing equipment, and (8) miscellaneous missile parts. In general, the individual diagnosis times reported for the 223 show considerable variability. They range from a zero diagnosis time for the missile RF electrical system and test responder to a period covering four days for miscellaneous LCT equipment. Again, if diagnosis time can be taken as a criterion of difficulty, then the 223 is involved in malfunctions which cover a wide range of difficulty. The 223 diagnosed 65% of the malfunctions reported.

The 223 made repairs in the same eight equipment categories in which he made diagnoses. His median time for all repairs was 30 minutes. However, the range in repair times from 5 minutes to 7 days suggests that he makes repairs covering a wide range difficulty. He was reported as repairing 38% of the reported malfunctions. The number of repairs is considerably less than the number of diagnoses made by the 223. This indicates that the 223 frequently calls upon some other person to make repairs for malfunctions which he has diagnosed.

MOS 220 - The 220 made diagnoses in two equipment categories. These are (1) launcher and section control consoles and (2) miscellaneous LCT equipment. Since only two diagnoses were reported for the 220, it is not possible to evaluate the difficulty of the diagnoses he makes. One required 30 minutes while the other required 5 minutes. In general, it seems that his role in diagnosing malfunctions is small. The 220's role in repair activities is also negligible.

MOS 225 - The 225 was reported as diagnosing malfunctions in six equipment categories. These are the (1) missile air system, (2) missile oil system, (3) missile RF and electrical system and test responder, (4) launcher and section control consoles, (5) launcher-loader assembly, and (6) test equipment. The median diagnosis time for these equipment categories is not more than 5 minutes. The highest diagnosis time mentioned is 5 minutes with the lowest being 1 minute. This suggests that the 225 diagnoses relatively simple malfunctions in a variety of equipment categories. The 225 diagnosed 9% of the malfunctions reported. The 225's role in repair activities is negligible. He made 0.5% of the repairs for the reported malfunctions.

MOS 1185 - The 1185 diagnosed malfunctions in three equipment categories. These are (1) missile air system, (2) missile RF and electrical system and test responder, and (3) launcher-loader assembly. The median diagnosis times range from 9 minutes to 1 day. In general, the 1185 plays a small role in diagnosing malfunctions. He was reported as diagnosing only 3% of the malfunctions reported. In all probability, the 1185 is called upon only when the other MOS's encounter unusual difficulties. The 1185 has a small repair function. He repaired only 1.5% of the reported malfunctions.

Ordnance - Diagnosis in five equipment categories was assigned to Ordnance. In order of decreasing median diagnosis time, they are (1) missile warhead system, (2) missile RF and electrical system and test responder, (3) miscellaneous LCT equipment, (4) missile oil system, and (5) launcher-loader assembly. The median diagnosis times for these categories range from 36 to 150 minutes. These are higher than the median diagnosis times for the site personnel. Ordnance diagnosed 7% of the malfunctions reported. These findings. are consistent with the concept that ordnance is called upon to diagnose the relatively difficult but small number of malfunctions which are beyond the limitations of site personnel.

Ordnance made repairs in all 10 of the equipment categories for which malfunctions were reported. The median repair time for all repairs was 120 minutes. The estimated repair times ranged form 10 minutes to 30 days.

Of general interest is the overall distribution of diagnoses and repair activities between site personnel and ordnance. Site personnel were reported as diagnosing 93% of the malfunctions reported with the MOS playing the major role in this activity. Ordnance diagnosed only 7% of the reported malfunctions. On the other hand, site personnel repaired 54% of the reported malfunctions, while ordnance repaired 46%. This indicates that site personnel are quite independent of ordnance for diagnosing equipment malfunctions but require ordnance support for almost half of the repairs which need to be made. Thus, for a sample of actual malfunctions, battery personnel are more dependent on ordnance for repair support than they are for their common malfunctions.

A comparision of the equipment categories according to the reported frequency of actual malfunction shows the launcher-loader assembly to be first. This is followed in order by missile RF and electrical system and test responder, launcher and section control consoles, missile oil system, miscellaneous LCT equipment, missile air system, miscellaneous missile parts, test equipment, assembly and servicing equipment, missile warhead system, and missile propulsion system.

3. Report of Actual Malfunctions - Status of Equipment Report (SOD Ports)

SOD Ports were obtained from two battalions covering the last four months of 1956. The SOD Ports are submitted daily and give the malfunctions which cause battery equipment to be non-operational and the period of time during the equipment was out-of-action. A detailed description of the malfunctions found in 11 equipment categories for the launching area and the periods of time during which the equipment was out-of-action are given in Appendix L.

Table 28 gives the number of malfunctions reported for each equipment category, the median number of days the equipment in each category was out-of-action, and the range of days the equipment in each category was out-of-action.

Table 28

Malfunctions from SOD Port Data

Equipment Category	Number of Reported Malfunctions	Days Out of Action	
		Median	Range
1. Missile Air System	14	2	1-14
2. Missile Oil System	17	3	1-30
3. Missile Warhead System	4	3	3-4
4. Missile Propulsion System	9	3	2-28
5. Missile RF and Electrical System and Test Responder	62	9	1-129
6. Miscellaneous Missile Parts	34	4	1-84
7. Launcher and Section Control Consoles	10	2	0-19
8. Miscellaneous LCT Equipment	4	2	0-22
9. Launcher-Loader Assembly	64	11	1-146
10. Test Equipment	12	10	1-46
11. Assembly and Servicing Equipment	7	29	2-61
TOTAL:	237		

As can be seen from Table 28, the eight batteries reported a total of 237 malfunctions during a four month period. For the eleven equipment areas, the medians for days out-of-action range from 2 days to 29 days. It is apparent that there are many malfunctions which go beyond the capabilities or authority of site personnel and which tend to reduce the operational capabilities of the launching area.

In terms of frequency of reported malfunctions the launcher-loader assembly ranks highest. It is followed in turn by the missile RF and electrical system and test responder, miscellaneous missile parts, missile oil system, missile air system, test equipment, section and launcher control consoles, missile propulsion system, assembly and servicing equipment, miscellaneous LCT equipment, and the missile warhead system.

4. A Comparison of the Malfunction Data Collection Procedures

Three different methods were used to collect malfunction frequency data. The Launching Area Maintenance Job Survey produced judgments of common malfunction frequency; the Launching Area Malfunction Record kept by the missile warrant officers produced actual frequencies of malfunctions for a six week period; and the status of equipment reports produced actual frequencies which were reported to a higher headquarters for a four month period. It is of interest to examine the comparability of these methods in giving a picture of the malfunction frequency for the equipment categories and the extent to which site personnel are self sufficient in making repairs.

In order to compare the three methods in terms of the reported frequency of malfunction, each equipment category was ranked within each of the three methods according to the total number of malfunctions reported. The agreement among the ranks was determined by means of W, the coefficient of concordance(3). W was found to be .80 (.01 > P > .001). This coefficient is high enough to indicate a significant degree of comparability between the three methods. In order to arrive at an overall ranking of the malfunction frequency for the equipment areas, the ranks for each equipment category obtained by the three methods were averaged. On the basis of the averages, the ranking of the equipment categories from highest to lowest in terms of reported frequency of malfunction is as presented in Table 29.

Table 29

Ranking of Equipment Categories According to Malfunction Frequency

Rank	Equipment
1	Launcher-Loader Assembly
2	Missile RF and Electrical System and Test Responder
3	Launcher and Section Control Consoles
4	Missile Oil System
5	Miscellaneous Missile Parts
6	Missile Air System
7	Test Equipment
8	Miscellaneous LCT Equipment
9	Assembly and Servicing Equipment
10	Missile Propulsion System
11	Missile Warhead System

Each data collection method was also compared with each of the others by intercorrelating the ranks obtained from each method. This resulted in the matrix of Spearman rank-order correlation coefficients presented in Table 30.

Table 30

Matrix of Correlation for the Three Malfunction Frequency Measures

	LAMJS	LAMR
LAMJS	-	.85
SOD Ports	.61	.72

The above findings indicate that the correspondence between estimates of common malfunctions and records of actual malfunctions is quite high. This suggests that the estimate of common malfunctions is a realistic one. The estimate of common malfunctions (LAMJS) and the actual record of malfunctions show somewhat lower, but nonetheless significant, relationships with the malfunction frequencies reported on the SOD Ports. Since only certain kinds of malfunctions are reported in the SOD Ports this is not an unusual finding.

The three malfunction data collecting devices, in somewhat different ways, give a picture of the degree to which site personnel are self sufficient in terms of dealing with malfunctions. It was estimated that site personnel correct 63% of their common malfunctions, 54% of malfunctions reported on the LAMR, and that malfunctions which reduce the operational readiness of the battery may at times require long periods of time to be corrected.

Whether or not site personnel can be considered to be self sufficient in terms of repairing malfunctions depends, of course, on the criterion used. It is somewhat unrealistic to expect them to be 100% self sufficient in view of their lack of specialized repair equipment and parts. However, some attention might be given to increasing their self sufficiency particularly when they estimate that they are dependent on outside assistance for 37% of their common malfunctions and for 46% of their actual malfunctions. Particular consideration might be given to the training, equipment, and logistic factors which tend to decrease their reliance on outside organizations.

5. Trouble Analysis Behavior Survey (TABS)

The TABS was developed to provide a comprehensive picture of the trouble analysis and repair activities of site personnel. The TABS contains 583 indications of malfunction for 11 equipment categories. The approach taken is based on the decision that it is more feasible to work with indications of malfunction than with malfunctioning parts as a starting point of investigation. This decision was founded on the following reasons:

1. There is a fewer number of malfunction indications than malfunction possibilities.

2. The site technicians should be familiar with and able to deal with all indications of malfunction but are not responsible for every malfunctioning part.

On the basis of responses by site personnel as to how they would deal with each indication of malfunction, the TABS items were categorized as being either easy or difficult to diagnose and as malfunctions which could or could not be repaired by site personnel. The classification of the individual items in the 11 equipment categories are shown in Appendix E.

The following rationale was used for judging the difficulty of diagnosis. An indication of malfunction was considered to represent a relatively easy diagnosis problem if (a) it was immediately apparent that ordnance needed to be called, (b) it was immediately apparent that a particular adjustment, repair, or part replacement was needed, and (c) it was only necessary to make a small number of specifiable checks in order to isolate the malfunction. The common factor in these three alternatives is the ability to be able to specify the exact steps which need to be taken when the indication of malfunction is observed. An indication of malfunction was considered to represent a relatively difficult diagnosis problem if the exact steps to be taken to determine the cause could not be specified. In these instances, there were many diagnosis sequences which might lead to the isolation of a malfunction.

If an indication is a symptom of several malfunctions and only some of these are repaired by site technicians, the item was placed in the "not repaired" category. This practice was followed since some routine repair such as tightening a connection was usually paired with the more difficult repairs.

The number of easy and difficult diagnoses for each equipment category are shown in Table 31. The table also shows the number of repairs in each equipment category which site personnel could or could not make.

As can be seen from Table 31, approximately 25% of the indications of malfunction were judged to be difficult by the criteria used. These more difficult diagnosis problems, however, are not evenly distributed among the 11 equipment categories. The launcher and section control consoles and the test equipment (the RF test set in particular) account for 121 of the 147 indications of malfunction which were judged to be difficult to diagnose. An examination of the indications of malfunction in these two categories shows that the diagnosis procedures require the use of schematics and the elimination of a relatively large number of alternative causes. The nine difficult malfunction indications for the missile RF and electrical system and test responder also require extensive circuit analysis. Five of the six miscellaneous LCT equipment difficult diagnoses require circuit analysis and the same is also true for five of the six launcher-loader difficult diagnoses. The four difficult diagnoses in the assembly and servicing equipment involve circuit difficulties in the battery charger while the one difficult diagnosis in the missile oil system stems from an interaction between the missile hydraulic and electrical symptoms.

Table 31

Malfunction Diagnoses and Repairs Made by Site Personnel for Eleven Equipment Categories

	Equipment Category	Number of Items	Number of Difficult Diagnoses	Number of Repairs Made
1.	Missile Air System	19	0	12
2.	Missile Oil System	26	1	19
3.	Missile Warhead System	4	0	1
4.	Missile Propulsion System	20	0	1
5.	Missile RF and Electrical System and Test Responder	100	9	94
6.	Miscellaneous Missile Parts	17	0	15
7.	Launcher and Section Control Consoles	128	92	45
8.	Miscellaneous LCT Equipment	14	6	14
9.	Launcher-Loader Assembly	44	6	26
10.	Test Equipment	119	29	108
11.	Assembly and Servicing Equipment	92	4	29
	TOTALS:	583	147	364
	PERCENT:	100	25	62

Thus the difficult diagnoses, which account for approximately 25% of all the indications of malfunction considered, are concentrated in two equipment areas. Almost all of the difficult diagnoses involve extensive circuit analysis in order to isolate the cause of the malfunction.

Table 31 also shows that site personnel were judged as being able to make 62% of the repairs which are required. Site personnel were judged as being able to make more than 50% of the repairs in each equipment category except for the missile warhead system, missile propulsion system, launcher and section control console equipment, and the assembly and servicing equipment.

Table 32 shows the distribution of difficult and easy diagnoses for which the 223 and 221 are responsible.

Table 32

Number and Difficulty of TABS Item Diagnoses Made by the MOS 221 and MOS 223

Equipment Category	MOS 221		MOS 223	
	Number of Items	Number of Difficult Diagnoses	Number of Items	Number of Difficult Diagnoses
1. Missile Air System	19	0	-	-
2. Missile Oil System	26	1	-	-
3. Missile Warhead System	-	-	4	0
4. Missile Propulsion System	20	0	-	-
5. Missile RF and Electrical System and Test Responder	-	-	100	9
6. Miscellaneous Missile Parts	17	0	-	-
7. Launcher and Section Control Consoles	-	-	128	92
8. Miscellaneous LCT Equipment	-	-	14	6
9. Launcher-Loader Assembly[1]	21	0	23	6
10. Test Equipment[2]	18	0	101	29
11. Assembly and Servicing[3] Equipment	83	0	9	4
TOTALS:	204	1	379	146
PERCENT:	35	-	65	39

As can be seen from Table 32, the 223 was judged as being responsible for 65% of all indications of malfunction, with sole responsibility for the missile warhead system, the missile RF and electrical system and test responder, launcher and section control consoles, and miscellaneous LCT equipment. The 221 was judged as being responsible for 35% of the indications of malfunction, with sole responsibility for the missile air, oil, and propulsion systems and for the miscellaneous missile parts. For equipment categories 9, 10, and 11 both the 223 and 221 have some diagnosis responsibilities.

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[1] For this category MOS 223 was given responsibility for items 1-9,11,13-18,20, 33-37, and 44 as listed in Appendix E.

[2] For this category MOS 223 was given responsibility for items 1-101.

[3] For this category MOS 223 was given responsibility for items 37-45.

As can be seen from Table 32, 39% of the diagnoses made by the MOS 223 were judged as being difficult. The 39% represent just one less than all of the difficult diagnoses shown in Table 31. Thus the 223 is responsible for almost all of the difficult diagnoses. As mentioned previously, the difficult diagnoses are primarily concerned with circuit analysis. The 221 was indicated as being concerned with only one difficult diagnosis.

Table 33 shows the repairs made and not made for the indications of malfunction for which the 223 and 221 are responsible.

Table 33

Number and Distribution of Repairs Made by the MOS 221 and MOS 223 for TABS Items

Equipment Category	MOS 221		MOS 223	
	Number of Items	Number of Repairs Made	Number of Items	Number of Repairs Made
1. Missile Air System	19	12	-	-
2. Missile Oil System	26	19	-	-
3. Missile Warhead System	-	-	4	1
4. Missile Propulsion System	20	1	-	-
5. Missile RF and Electrical System and Test Responder	-	-	100	94
6. Miscellaneous Missile Parts	17	15	-	-
7. Launcher and Section Control Consoles	-	-	128	45
8. Miscellaneous LCT Equipment	-	-	14	14
9. Launcher-Loader Assembly[1]	21	10	23	16
10. Test Equipment[2]	18	15	101	93
11. Assembly and Servicing Equipment[3]	83	54	9	5
TOTALS:	204	126	379	268
PERCENT:	35	62	65	71

The 223 was judged as being able to make repairs for 71% of the indications of malfunction for which he has diagnostic responsibility. It was found that the 221 could make repairs for 62% of the malfunction indications assigned to him.

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[1] For this category MOS 223 was given responsibility for items 1-9,11,13-18,20, 33-37, and 44 as listed in Appendix E.

[2] For this category MOS 223 was given responsibility for items 1-101.

[3] For this category MOS 223 was given responsibility for items 37-45.

An examination of Tables 32 and 33 shows that among the two launching area MOS's who are primarily responsible for the trouble analysis and repair work, the 223 is faced with all but one of the difficult diagnosis problems. The 223 was judged as being able to repair more than twice as many malfunctions as the 221.

The criterion used for deciding on the difficulty of diagnosis for the TABS indications of malfunction was somewhat different from the criterion which is ordinarily used. The criterion used was the specifiability of diagnosis performance instead of the complexity of the equipment involved. While these two measures are undoubtedly related, there is no necessary one to one relationship between them.

It is appropriate to examine the relationship of the judgments to another measure of diagnosis difficulty. There were enough malfunction data reported for MOS 223 on the LAMR to correlate median diagnosis time of six equipment categories with the percentage of difficult TABS diagnoses for these categories. The rank-order correlation coeficient was found to be .46($P > .05$). It appears that diagnosis difficulty estimates obtained from the TABS do not show a high degree of relationship with difficulty as it is experienced in the field. These data were examined further to determine the reason for the difference obtained. It was found that the greatest discrepancy in the ranked data was for the missile RF and electrical system and test responder. This category was tied for first with respect to diagnosis time but ranked fifth with respect to percentage of indications classified as difficult. The missile RF electrical system is generally considered by maintenance personnel to represent difficult diagnosis problems. It was found from the TABS analysis, however, that the diagnosis steps for 91% of the indications encountered can be specified. This finding suggests that a job oriented training approach would have a high likelihood of increasing diagnosis efficiency for this equipment category.

6. Training Received for Trouble Analysis and Repair

Analysis of the POI for the 223 shows 276 training hours relevant to trouble analysis and repair. The distribution of these hours is shown in Table 34. It should be noted that all of the types of training are not appropriate for all equipment categories.

Table 34

Training Hours Relevant to Trouble Analysis and Repair Work - MOS 223

Equipment Category	Type and Hours of Training					
	Description	Circuit Analysis	Wave Form Analysis	Block Analysis	Trouble Analysis	Total
1. Missile Air System	-	-	-	-	-	-
2. Missile Oil System	4	-	-	-	-	4
3. Missile Propulsion System	2	-	-	-	-	2
4. Missile Warhead System	4	-	-	-	-	4
5. Missile RF & Electrical System & Test Responder	8	28	12	8	16	72
6. Miscellaneous Missile Parts	-	-	-	-	-	-
7. Launcher and Section Control Consoles	8	40	-	4	56	108
8. Miscellaneous LCT Equipment	2	-	-	-	-	2
9. Launcher-Loader Assembly	4	-	-	-	4	8
10. Test Equipment	2	36	24	8	-	70
11. Assembly and Servicing Equipment	2	4	-	-	-	6
TOTALS:	36	108	36	20	76	276
PERCENT:	13	39	13	7	28	100

Although the 223 receives some training time covering description of 9 of the 11 equipment categories, the major training emphasis for trouble analysis and repair work is on a limited number of equipment categories. Circuit analysis training, which is limited to the missile RF and electrical system, the consoles, test equipment, and assembly and servicing equipment accounts for 39% of the training hours under consideration. Trouble analysis, which accounts for 28% of the training hours, is limited to the missile RF and electrical system, the consoles, and the launcher-loader assembly. Wave form analysis is limited to the circuits of the missile RF and electrical system and the test equipment and accounts for 13% of the total training hours. The remaining training hours are devoted to block analysis (7%).

The distribution of trouble analysis and repair training hours is a reflection of the trouble shooting role which the 223 is expected to carry-out on-site. The training hours for the missile RF and electrical system, the consoles, and the test equipment constitute 89% of the training hours. On the TAB survey, these three equipment categories constitute 84% of the possible indications of malfunction which the 223 may encounter. Thus, at least in terms of time, the training hours emphasis seems to correspond to the number of problems which the 223 may encounter on-site.

Analysis of the POI for the 221 shows 90 training hours relevant to trouble analysis and repair work. The distribution of these hours is shown in Table 35. The types of training found appropriate for use in this table for MOS 221 differ in part from those used in Table 34 for MOS 223.

Table 35

Training Hours Relevant to Trouble Analysis and Repair Work - MOS 221

	Type and Hours of Training				
Equipment Category	Description	Circuit Analysis	Trouble Analysis	Assembly and Disassembly of Parts	Total
1. Missile Air System	8	-	-	-	8
2. Missile Oil System	6	-	-	4	10
3. Missile Warhead System	4	-	-	-	4
4. Missile Propulsion System	12	-	-	4	16
5. Missile RF & Electrical System & Test Responder	4	-	-	-	4
6. Miscellaneous Missile Parts	2	-	-	4	6
7. Launcher and Section Control Consoles	-	-	-	-	-
8. Miscellaneous LCT Equipment	-	-	-	-	-
9. Launcher-Loader Assembly	9	5	5	-	19
10. Test Equipment	4	-	-	-	4
11. Assembly and Servicing Equipment	19	-	-	-	19
TOTALS:	68	5	5	12	90
PERCENT:	75	6	6	13	100

The 221 receives some description of all of the equipment categories with the exception of the consoles and miscellaneous LCT equipment. This training constitutes 75% of the training hours being considered. What additional training he receives is limited in scope and in equipment categories. Circuit analysis and trouble analysis training which constitute 12% of the training hours, are limited to the launcher-loader assembly. Assembly and disassembly of parts training is limited to the missile oil system, missile propulsion system, and to the miscellaneous missile parts. This training, which constitutes 13% of the training hours being considered, is closely related to repair work. Thus, for the 221, trouble analysis and repair training is 75% descriptive and 25% analysis and repair oriented. This distribution would seem to correspond to the limited role which the 221 has for trouble analysis and repair work.

V. DISCUSSION

In the Results Section of this report, the quantative data collected during the study have been presented. These data describe the maintenance activities in the launching area of a Nike Ajax battery. Data on the school training received by MOS 223 and MOS 221 was included to complete the picture of the maintenance performed since the activities found on-site are dependent on the training received by technicians to prepare them for their site jobs. The description of current maintenance together with ideas acquired from observations of these procedures and discussions with the personnel directly involved enables the development of three kinds of recommendations. These concern: (1) job organization; ways in which the batteries might better organize their maintenance procedures, (2) training; procedures for effectively equiping technicians for the jobs they must perform on-site, and (3) proficiency measurement; evaluation techniques most appropriate for assuring that technicians are effectively trained and are competent to perform their jobs.

A. Job Organization

The basic goal of job organization is the arrangement of job activities to accomplish work most effectively. The arrangement problem includes what is to be done, how to do it, and who should do it. The solution to the problem is interdependent with the solution to the training problem. What to do and how to do it provide the ingredients for a training program, while who does it determines the packaging of the training course for different personnel. If any aspect of the job organization imposes excessive training demands, alternative organizations should be considered.

1. Assembly and Servicing

The procedure of assembling and servicing a missile is a heterogeneous set of tasks, requiring the integrated efforts of several personnel who differ in kind and level of skill capabilities. For the batteries studied in this project an average of twelve personnel were assigned to the assembly area. In addition four or five launcher area personnel were used in the assembly area as needed. In actual practice, the number of personnel who participate in an assembly and servicing procedure depends on the number and experience of the personnel available at the battery. A typical crew consists of one 1185, two 223's, one 221, two 225's, two 220's, one 351, and one 612. The complete processing procedure takes approximately two days and two missiles are processed together. The pair of missiles is handled more efficiently since the setting up of equipment is minimized and personnel who would otherwise have intervals of inactivity can make use of their time on the second missile.

The point was brought out in the Results Section of this report that the MOS 223 also performs much of the work considered to be the primary responsibility of MOS 221 without the reverse being true. This finding can be explained in part by the reluctance to have anyone without extensive electrical training participate in any sort of electrical work. It also reflects however, the large proportions of non-electrical work required in the assembly and servicing procedure. Since much of this work demands the know-how and responsibility of someone with a solid background of missile training, one of the TAS trained personnel must assume the responsibility for the work. While the day-to-day activities in the launching area do not justify carrying more than the one MOS 221 assigned, those periods of missile assembly place a heavy load on the 221 and on the 223 who has not been trained to perform non-electrical tasks. Two alternative solutions to this problem are: (1) train the 223 to perform all of the activities necessary for assembly and servicing so that he may assist the 221, or (2) select certain activities for which the 221 is now primarily responsible and transfer them to the 223.

2. Preventive Maintenance

The program of periodic checks on the condition of launching area equipment should serve the purpose of assuring that all equipment is maintained at a high level of operability. There are several factors, however, which detract from this intended goal. First, there is no systematic procedure used to collate and evaluate the results of preventive maintenance. The many check sheets used are typically stored for a short period and then destroyed by the batteries. The information taken from the sheets for reports to higher headquarters is typically treated in the same manner, with the primary use of this information being that of keeping cognizant of the current operational capacity of the batteries. Any inadequacies in these reports is discovered principally by unscheduled observation by technical engineers or officers.

Second, the personnel who are assigned direct responsibility for performing the checks are for the most part personnel not provided with technical training as pointed out in the Results Section.

Third, many of the individual check items are not considered essential or critical by the personnel using the check list. This is because the item has never been found defective or because the checker is not aware of the implications of a defective item.

The result of these inadequacies in the preventive maintenance system at its worst is "paper" maintenance, i.e., checksheets filled out without anyone even looking at the equipment to be checked.

A plan for improving the present preventive maintenance program involves the development of two kinds of periodic checks. The first type of check would include check items which are directly observable during operation of the equipment system and do not require any special discriminations or judgments. They would be items which would necessarily be noticed by operator personnel in the regular performance of their duties. Each item could be noted on a check list, but to simplify record keeping, no marking of the list would be required. It would be the duty of the operator in charge to write out a report for any symptom observed or to sign a "no trouble" report. There would be no specified schedule for these checks but they would be used whenever the equipment is used. The principle purpose of the procedure would be to eliminate the routine check items from the periodic checks.

The second type of check would include those remaining items which would not necessarily be noticed during operation of the equipment or which require some special technical skill for their measurement. These checks would all be performed periodically by technicians with the specialized training required to perform them. Inasmuch as the number of items for this second type of check would be relatively small, it is feasible to assign the qualified technicians to perform them. The need for technicians to perform many of the checks now assigned to operator personnel is borne out by the data which show some batteries currently using technicians for these jobs.

As a further safeguard on the careful performance of periodic checks it would be good practice to require that all preventive maintenance check forms be countersigned by the Missile Warrant Officer. Since this man is the most responsible of personnel in the launching area with an adequate technical background, his direct involvement in the preventive maintenance program would do much to upgrade the quality of the program. While he would not be involved in the actual performance of the checks, it is expected that his increased participation in the processing of forms would exert a motivating influence.

An alternative to the plan for dichotomizing checks is providing all non-technical personnel who now perform checks with special training for this function. This plan would not only increase the skill of those operator personnel performing checks, it could also increase their motivation for performing the tasks carefully and with interest.

Whichever plan is adopted, its success will depend largely on the way in which the check sheets are processed once they have been filled out. A summary of check results should be prepared that can be easily reviewed by both higher headquarters and the men who perform the checks. Higher headquarters should review the summaries for the purpose of revising the preventive maintenance program as indicated in part by the frequency of out-of-tolerance reports. A revision should be considered now, on the basis of the summaries presented in Appendix H in conjunction with technical information supplied by equipment engineers.

Battery personnel should review the summaries for their battery in relation to the summaries of other batteries in order to obtain feedback concerning the adequacy of their checking procedures. The summaries would also serve as an aid to inspection teams evaluating the operational readiness of a battery.

3. Trouble Analysis and Repair

The current concept of trouble analysis is one which assumes that each technician possesses extensive knowledge about the missile system. This provides him with the capability of diagnosing and repairing any malfunction which might develop in his area of specialty. In particular, the MOS 223 is presumed to have a general knowledge of electronics beyond the needs of the missile system to which he is assigned.

Such a concept neglects the consideration of two practical facts. First, a large proportion of the malfunctions encountered are quite routine and simple in terms of diagnosis and repair. Given the symptom, the diagnosis of the malfunction and its correction can be exactly specified. Second, the site technician is limited in the scope of symptoms which he is authorized to handle, and to an even greater extent he is limited in the repairs which he is authorized to perform.

It is appropriate, therefore, to consider the population of specifiable diagnosis procedures and to consider training a technician to handle these problems on a step by step basis. In judging the difficulty of diagnosis of symptoms in the TABS analysis, just such a criterion was used. Those symptoms judged "not difficult" constitute the job area of a technician who might be referred to as a "mechanic" rather than as a "trouble-shooter". It is appropriate to give serious consideration to establishing the job definition of MOS 223 and of MOS 221 in these terms. They would be the personnel who would handle routine malfunctions. There remains a need for a technician to handle the difficult diagnoses and to provide generalizable know-how for changes in the system or changes in the authorized work of site personnel. This technician would be the 1185, Missile Warrant Officer.

With respect to limited authority of site personnel for corrective maintenance, to a large extent this limitation is based on limitations in test equipment which can be kept on-site and in the spare parts which can feasibly be stored on-site. These logistic decisions, however, are not in every case based on sound logical grounds. A reanalysis of these logistic principles should be undertaken with the goal of increasing the independence of the battery site for common functions. These have been specified in the Results Section of this report. The need for such a review of the boundary between site and ordnance responsibility is illustrated by the not uncommon occurrence of an ordnance team bringing out a called for part and telling the site personnel to make the repair, when the diagnosis and repair are designated as sole ordnance responsibility.

B. Training

The most important criterion of a training course for technicians is the adequacy of performance which the graduate exhibits when he is put on the job. As a first approximation to an effective training course, then, we can consider a course which consists of actual examples of all the job activities that have some probablity of occurrence in the field. The conditions which require these activities could be presented in the school and the student could be shown how to perform all necessary steps of the task. Such a course would be essentially a specially programmed on-the-job training course. It would provide capabilities for performing all of the equipment checks, the adjustments required for out-of-tolerance checks, the repair actions required when adjustment fails to bring checks into tolerance, and all of the assembly and disassembly procedures.

Before considering the adequacy of this kind of course, let us first consider its feasibility. This demands some definition of the scope of job activities, in order to determine whether the entire population of activities can be brought into the school situation and taught in a reasonable length of time. Since the definition of the Nike on-site maintenance jobs is circumscribed by the maintenance support provided by ordnance, a relatively large proportion of on-site activities could be taught without having to introduce job sampling procedures or highly generalizable training content. For those trouble analysis procedures involving many alternatives (those judged as difficult diagnoses in the TABS) it does not seem likely that all procedures could be feasibly included in the course as discrete items of instruction.

This problem raises the question of how to provide generalizable training content in order to cover the entire scope of maintenance activities. The price of providing this general knowledge is typically quite high in terms of time, qualifications of instructors, and student aptitude level. The conventional approach to the problem, especially for electronic equipment, is to provide an understanding of how the equipment operates. In the case of electronic equipment this understanding is based on an understanding of electronic theory.

A promising approach for developing a practical training course for technicians involves the use of what can be called functional knowledge to supplement the learning of specific job operations. Functional knowledge has two special characteristics. First, it is job oriented in that information is incorporated into training on the basis of its direct relevance to the job activities. For example, if the job definition does not include replacement of resistors, the function of a resistor does not need to be considered. Second, the knowledge is function oriented in that equipment and equipment components are described in terms of what they do instead of how they do it. For example, an oscillator would be described as providing the means for changing the frequency of a received signal so that it can be more easily amplified. Its operating characteristics w would not be described. The advantage of this training approach lies in the larger number of personnel available for training due to the reduced aptitude requirements. Yet the product of training is a high level technician with respect to the particular equipment and job concerned.

This same approach applies to the more routine trouble analysis tasks and to the assembly and servicing and preventive maintenance tasks. By giving a task meaning in terms of the purpose it serves for the operational functions of the equipment system, understanding and incentive to perform well can be attained.

In considering some of the specific training problems which exist for the current Nike Ajax program, several items stand out as deserving special attention.

For the assembly and servicing jobs the most pressing need is for increased practice in using the hand tools associated with this work. As shown in Appendix G, the technicians have a large number of tools at their disposal. New school graduates have considerable trouble in making a proper selection of tools for specific jobs and frequently have not had sufficient practice in using these tools correctly.

For preventive maintenance, a frequently expressed deficiency is familiarity with the kinds of periodic checks required and the forms which must be used when performing checks. While it is reasonable that this is the sort of information which can most efficiently be learned on-site, it is probably true that the school is the best place to impress upon the technician the importance of these checks. This can be accomplished effectively only if the specific checks are considered in detail.

For trouble analysis and repair, the MOS 223 has special difficulty in isolating troubles in the control consoles. The problem is one of being able to trace relatively simple diagrams. The problem is complicated by the fact that the schematics are laid out on several different pages in technical manuals. Either some redesign of schematics is required or some integrative instruction on the interconnections between chassis and between consoles.

Another area of need is for instruction in the assembly and disassembly of missile components for purposes of repair. In particular, instruction and practice is needed in replacing the guidance components.

The more specific content for training is obtainable from the assembly and servicing job procedures as described in Appendix A, the preventive maintenance check sheets presented in Appendix H, and the TABS items.

In preparing a work oriented training course, it is appropriate to allot training time to different equipment on some empirical basis. For assembly and servicing and for preventive maintenance, the number of tasks involved can be readily determined, making the distribution of time a relatively direct procedure. For trouble analysis, however, the procedure would be somewhat more involved. Following the rationale associated with the TABS, the number of malfunction indications for each equipment and the difficulty of diagnosing each symptom can be used to assign relative training time for each equipment category. The greater the number of possible malfunction indications for an equipment category, the greater will be the amount of training needed to insure that a site technician will be able to deal with these problems. Also, the greater the number of difficult problems, a greater amount of training will be needed by the site technician. Since difficulty is partly of function of the number of malfunctions possible, the procedure for distributing training time is related to both number of symptoms and number of things that can be wrong. A third factor which has to be considered is the number of repairs that can be made by site personnel. All three of these factors are contained in the TABS presentation.

A further use that can be made of the TABS is that of a job support. This support would contain a list of the indications of malfunction for each equipment category and would list the specific steps to be taken for the simple items. For the difficult items, reference would be made to the appropriate schematics and other pertinent information. A support of this type could be used during training and in the field and would represent a body of experience which the technician would ultimately acquire in the field.

C. Proficiency Measurement

In selecting job activities upon which to base proficiency measures, a primary consideration is the occurrence of the immediate goals of school training with the proficiency expected of a technician after some amount of experience on-site. It is commonly assumed that the purpose of school training is to prepare a technician to learn his specific jobs in the course of serving some sort of apprenticeship in the field. While it is true that there are activities for which training is more economically carried out in the field, it is also true that there must be some personnel in the field who are capable of supplying the knowledge for field learning. In the case of a newly formed Nike battery, all technical knowledge must be supplied by newly trained personnel. In addition, there is an initial work load for a new battery which does not allow for a period of field training. It follows, therefore, that proficiency measurement to evaluate the effectiveness of school training should include a comprehensive sampling of on-site job activities and should be administered shortly after training.

In the sections below the format and content of proficiency measurement is considered for the areas of assembly and servicing, preventive maintenance, and trouble analysis and repair.

1. Assembly and Servicing

The most adequate way of measuring proficiency for this set of job activities is to measure actual performance on the assembly and servicing procedure. Since the work of any one MOS is performed as part of a team, it seems easiest to carry out the testing on a group basis with a separate evaluation of each of the personnel. There are two problems associated with this procedure. First, more than one evaluator would be required since many of the activities are performed concurrently. Second, the testing would take a considerable amount of time since the assembly and servicing job requires approximately two work days.

The alternative to a comprehensive testing is the use of a sampling procedure by which a missile is taken to a point in the assembly and servicing process at which a particular task is appropriate. The relative disadvantage of this approach is that several missiles (at different stages of assembly) are required to accomplish the testing.

Inasmuch as precautions in the assembly and servicing procedure may be followed during the testing but might not be followed without the high motivation associated with testing conditions, the use of paper and pencil items is appropriate. Questions concerning the reasons for performing specific procedures could be used, where the answers would be in terms of the consequences of malpractice. This would insure that personnel are aware of the reasons for performing a task in a particular way.

2. Preventive Maintenance

As with assembly and servicing, proficiency measurement for preventive maintenance should employ both actual job activities and paper and pencil items. The equipment used for testing should contain a sample of malfunction indications. Indications would be selected on the basis of their frequency of occurrence in actual use as indicated by the data in Appendix H and by the characteristics which would make them easily overlooked.

3. Trouble Analysis and Repair

The TABS data provide a convenient nucleus for proficiency test material in this area of maintenance. The malfunction indications contained in these data represent an attempt to list all of the trouble-shooting problems which might confront a site technician. A broad sampling of these items, presented in a paper and pencil format, would test the technician's knowledge of what to do when diagnosing equipment malfunctions. For the items that have been judged to be simple, a complete answer covering how to correct the indicated malfunction should be required. For the items judged difficult, several types of questions could be posed. Some of the questions would describe the initial indication and would ask for only the first step of trouble diagnosis. Other questions would describe the initial indication plus some of the steps taken toward diagnosis and ask what the next step should be.

In order to measure the technician's capability to make discriminations and to use test equipment and tools, some malfunctions would be put into actual equipment. The testee's job would be to locate and repair the trouble. In selecting this type of test item, the frequency data presented in the Results portion of this report for actual malfunctions could be used.

This use of field data would enhance the realism of testing, a consideration which is frequently neglected in testing situations. It would probably be necessary, to the testees that the malfunctions they are trying to locate are not "school"malfunctions" but malfunctions actually found in the field since it is likely that the students have developed certain restrictive biases during conventional training.

Inasmuch as some of the repairs for some malfunctions take a substantial amount of time, it will probably be desirable to require correction of the trouble for only some of the equipment problems. The selection of these repair problems can be made on the basis of the TABS data showing which malfunctions are repaired by site personnel and on the basis of the times presented for repairs as reported in the Results Section.

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