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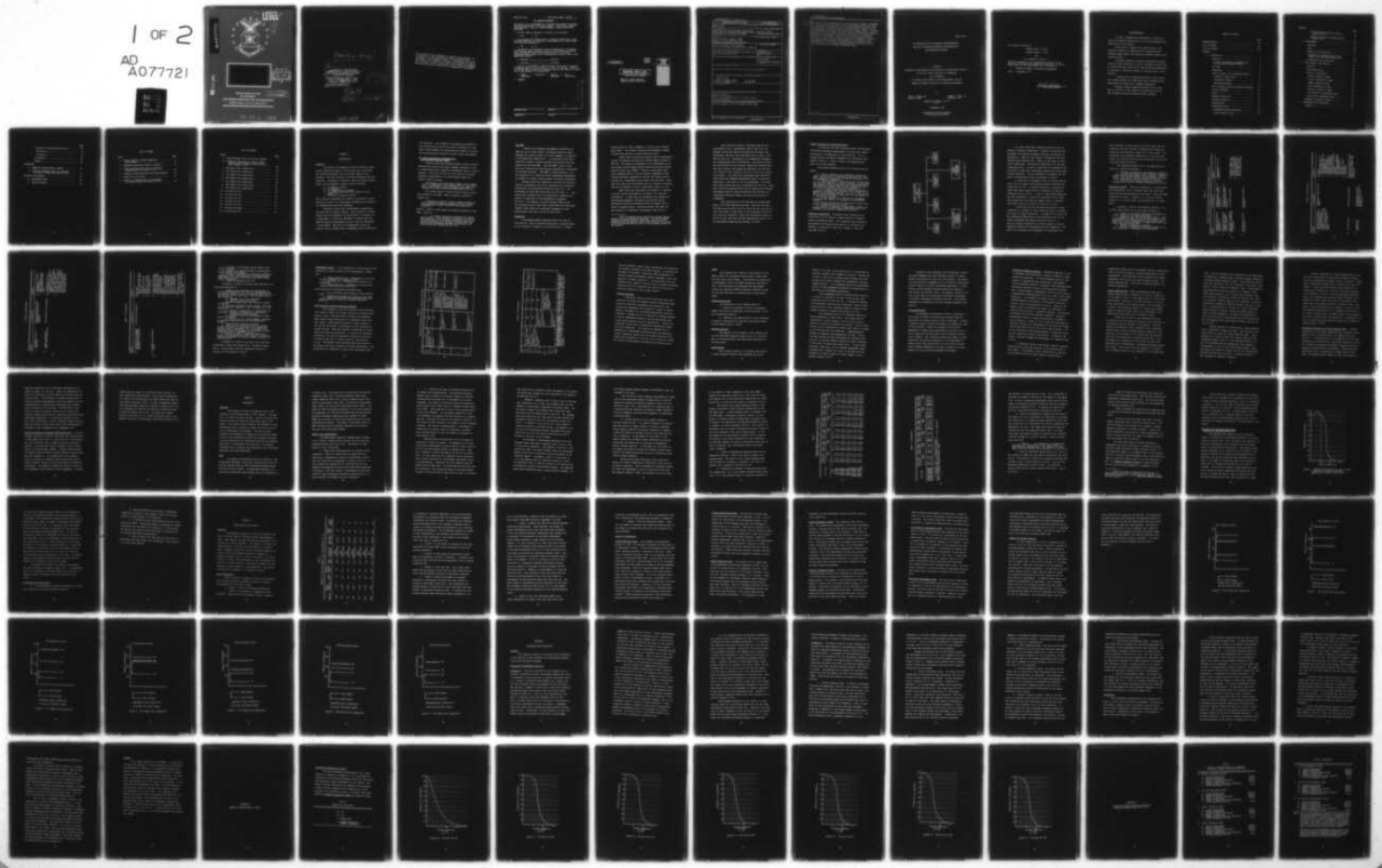

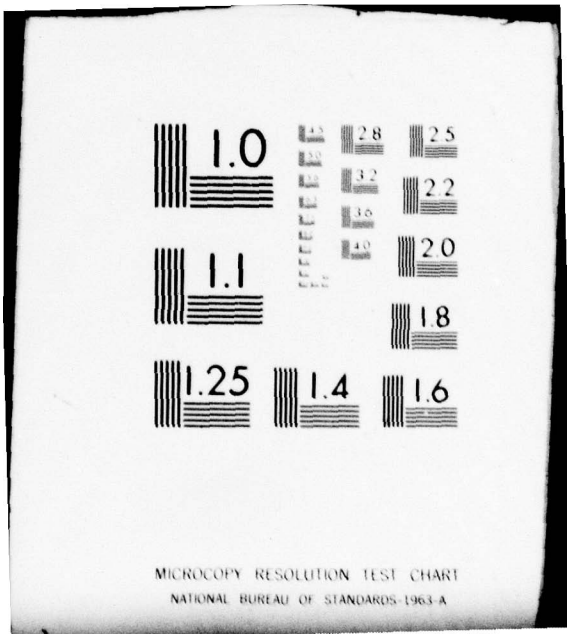
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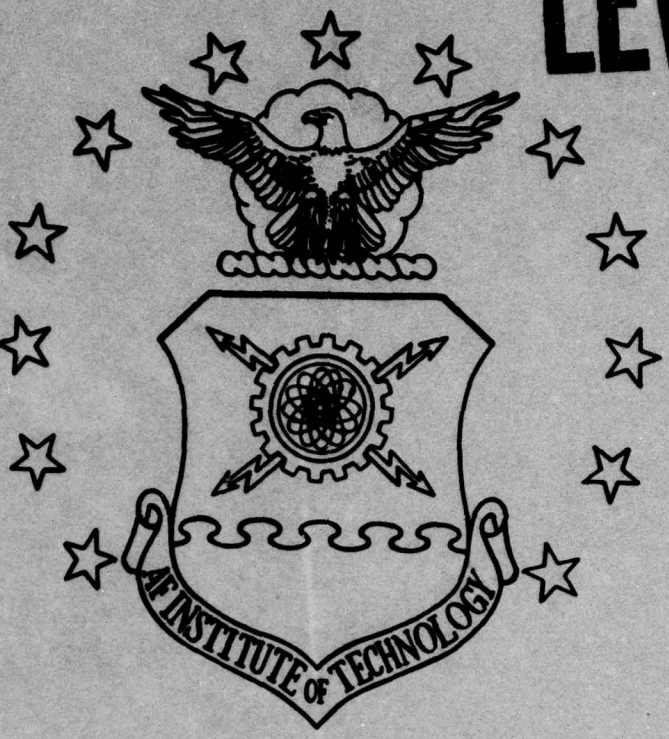

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AN ANALYSIS OF THE MINUTEMAN INTERCONTINENTAL BALLISTIC MISSILE MAINTENANCE STANDARDIZATION AND EVALUATION PROGRAM.

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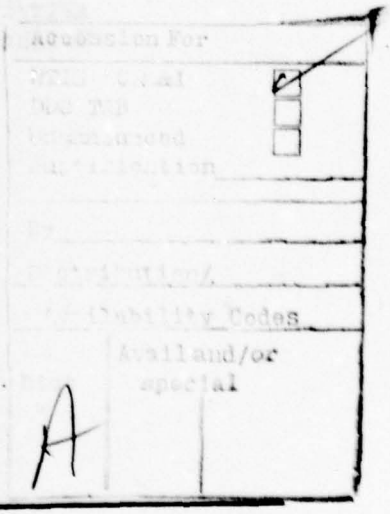

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The Maintenance Standardization and Evaluation Program is designed to evaluate personnel proficiency and equipment condition within the maintenance organization. This study examines the role and contributions of the Maintenance Standardization Program within the Minuteman Intercontinental Ballistic Missile System. Evidence is presented which shows that the current inspection directives in SACR 66-6 do not provide the most efficient or effective sampling method for the amount of maintenance produced. An improved procedure is provided, based on statistical sampling methods, which will improve the effectiveness and efficiency of existing Minuteman Quality Control organizations. An example of the improvement in efficiency and effectiveness is given through the analysis of maintenance production and associated quality control activity at a sample Minuteman base.

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AN ANALYSIS OF THE MINUTEMAN INTERCONTINENTAL BALLISTIC MISSILE MAINTENANCE STANDARDIZATION AND EVALUATION PROGRAM

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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CHAPTER 1

INTRODUCTION

Overview

The process of management involves planning, organizing, assembling resources, motivating, and controlling. The controlling process was the central theme of this research. The word "control" has several meanings and connotations. According to Fremont E. Kast and James E. Rosenzweig, noted management authors, control can mean:

1. to check or verify,
2. to regulate,
3. to compare with a standard,
4. to exercise authority over (direct or command), or
5. to curb or restrain [4:466].

This study was concerned with control in relation to insuring that the quality of maintenance performed was according to predetermined plans and standards.

Generally, every type of maintenance organization has some form of control process. Since control is a basic process used by management and maintenance of equipment is a requirement, it would be redundant to expound upon the need for quality maintenance or that it must be controlled in some manner. What has to be emphasized is that the quality control program used by management must be efficient

and effective. This research investigated the effectiveness and efficiency of the Air Force's Strategic Air Command's (SAC) methods for controlling the quality of Minuteman Intercontinental Ballistic Missile (ICBM) maintenance.

Air Force Maintenance Standardization and Evaluation Program (MSEP)

The Air Force has developed general quality control measures and policies for major commands (MAJCOMS) to use in establishing their respective maintenance quality control programs. The intent of the Air Force quality assurance program is established in Air Force Manual (AFM) 66-1, Volume I where it states:

> Maintenance, as a functional element of the organization is responsible for insuring that Air Force material is serviceable, safely operable, and properly configured to meet the minimum requirements [14:1-1].

The pivotal point of the Air Force's quality assurance program is the MSEP. MSEP is defined in AFM 66-1, Volume I as:

> A quantitative quality control program designed to check individual technical competence and the quality of maintenance through evaluations and inspections [14:A2-2].

AFM 66-1, Volume I also states the overall objective of the MSEP. This is:

> . . . to improve technician competence and maintenance quality. This objective is realized by training the technician to use standard maintenance practices, strictly complying with accurate technical data, and periodically evaluating personnel and hardware with highly qualified technicians [14:1-2].

SAC MSEP

MAJCOMS have developed supplemental directives on MSEP for use at local levels. The major portion of SAC's guidance for quality control for local managers is contained in SAC Regulation (SACR) 66-12. In conjunction with this, SACR 66-6, Volume I provides specific SAC policies and procedures for the ICBM MSEP. The ICBM MSEP is SAC's focal point for insuring that satisfactory maintenance is performed on Minuteman missiles. ICBM MSEP's primary emphasis is on the evaluation of a technician while performing maintenance. It attempts to insure a high standard of quality maintenance ". . . through technician competence, accurate and efficient technical procedures, and strict compliance with technical publications and maintenance directives [12:1-1]." The development of ICBM MSEP stems from the fact that ". . . dispersed work locations limit the supervisor's capability to monitor a large part of the maintenance in progress [12:4-1]." For example, the 150 Minuteman ICBMs of the 321 Strategic Missile Wing (SMW), Grand Forks Air Force Base (GFAFB), North Dakota are dispersed throughout an area approximately 110 miles long by 60 miles wide.

Background

A Minuteman Missile Wing has either 150, 200, or 250 missiles. Each 50 missiles constitutes a squadron which in turn contains 5 flights of 10 missiles each. A Launch

Control Facility (LCF), managed by a launch crew, controls each flight. The flight's missiles are dispersed a number of miles from the LCF in Launch Facilities (LF).

Launch crews continuously monitor each LF maintenance status via computer printouts and display boards located in the LCF. The status is determined by an interrogation process between the LCF Weapon System Controller and the Missile Digital Control Unit (MDCU).[1] Should a maintenance fault occur anywhere within a critical missile component or supporting electronic apparatus at the LF, the launch crew is notified by a Maintenance Status Reply from the MDCU. Other ways that faults are discovered occur as a result of routine, periodic maintenance visits or supervisory visits to a LF.

When faults are discovered, the response is normally to notify missile maintenance Job Control (JC) with the information. JC then logs the information and updates the Maintenance Management Information and Control System. Maintenance teams are dispatched from the support base to the LF to remedy faults. The more critical the fault the more quickly JC dispatches a maintenance team (13:3-7).

---

[1]Both the Weapon System Controller and the Digital Control Unit are electronic computers. The Weapon System Controller monitors missile site activity for an entire squadron while the Digital Control Unit monitors the status of its own missile and also acts as the guidance system for the missile.

Many activities within a Minuteman Wing must be coordinated to get a maintenance team to the LF or LCF. Because the LFs and LCFs are located far from base, the maintenance team must take everything with it that it will need for the job. Accordingly, all appropriate equipment and transportation must be scheduled. The security police must be notified so that security guards are scheduled for the trip, security code pages are available, and the security forces in the vicinity of the LF or LCF to be visited are notified. The applicable maintenance shop chief must insure that the scheduled maintenance team is trained and proficient in the tasks it will be performing. All necessary repair parts must also be available for the job. Since many teams are dispatched each day to perform many different maintenance tasks at several different LCFs and LFs, the coordination required between the various activities is tremendous.

Most supervision of the team must be accomplished prior to the team departing the base. Once off the base, the team is on its own to get to the LF or LCF, get the job done, and return to base prior to the expiration of the 16 hour duty day limitation. While the maintenance team is at the LF or LCF, they have limited communication with JC via the Maintenance Communication Network (13:3-72).

Quality Control (QC) Responsibilities

QC sections have been organized within SAC Minuteman ICBM wing maintenance organizations to insure that quality maintenance is accomplished at the LF and LCF. QC is a division within the Deputy Commander for Maintenance (DCM) complex (13:10-1). Figure 1 depicts the organizational chart for the DCM complex.

The general responsibilities of QC include the following:

1. The QC inspection and evaluation program provides a capability for sampling the condition of equipment, the qualifications of maintenance personnel, and the soundness of management.
2. The evaluation of deficiencies and problem areas are also key functions of quality control. By determining probable causes of problems and recommending corrective actions to supervisors, quality control can significantly enhance the quality of maintenance.
3. QC is the primary advisory agency on matters of technical techniques and procedures in the Deputy Commander for Maintenance complex. As such, it assists the DCM and other maintenance supervisors in the resolution of maintenance problems.
4. QC must assure that technical and management procedures are adhered to throughout the maintenance complex.
5. Perform inspections of maintenance actions, procedures, equipment, and facilities.
6. Provide information to maintenance analysis for identification of significant trends during activity, technical, and special inspections [13:10-1].

Technical inspections. Maintenance team technicians are evaluated by the QC section on their ability to perform various maintenance tasks. QC's inspection and evaluation requirements for measuring the quality of technician performance is specified in SACR 66-6, Volume I, under the ICBM MSEP (12:2-7).

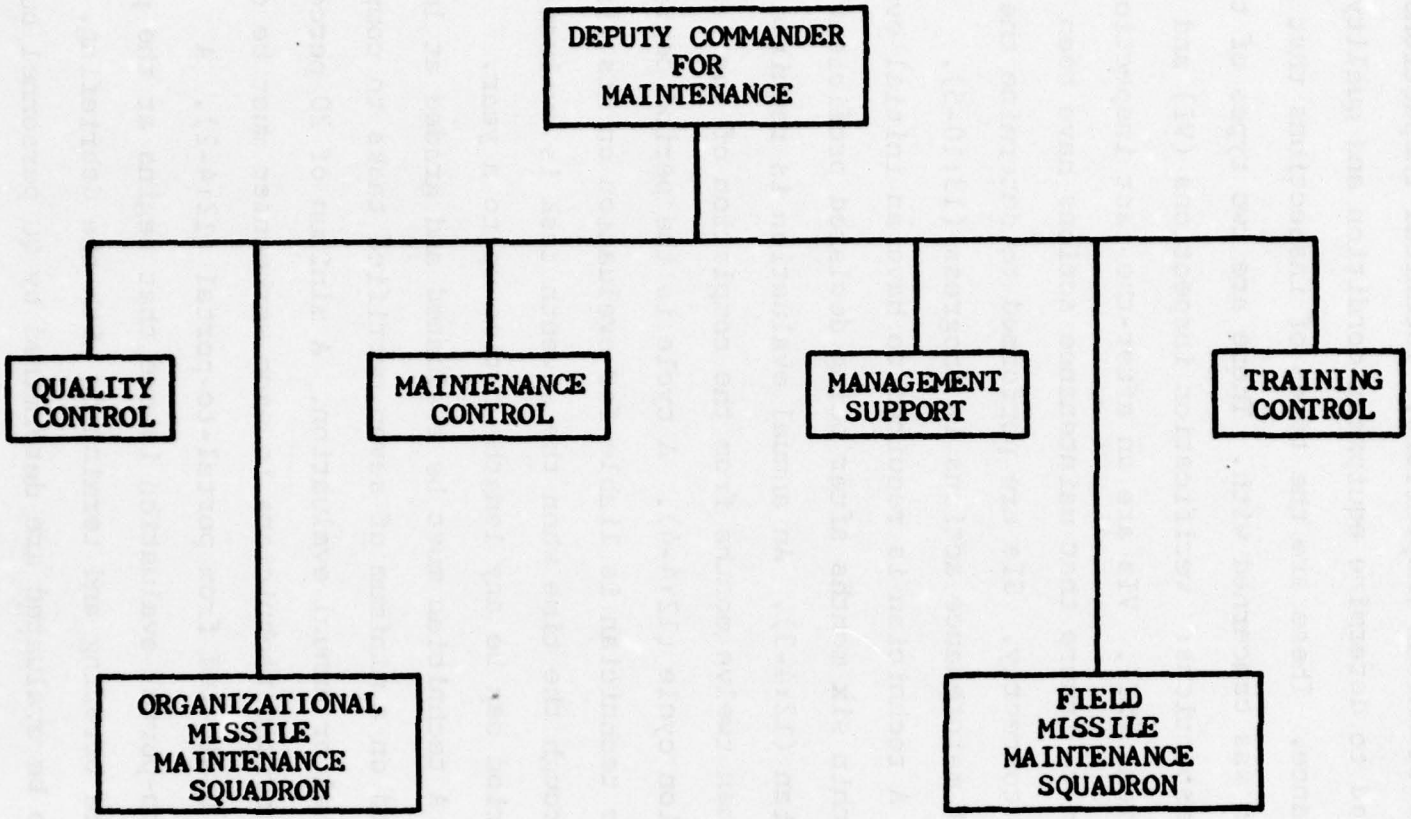

Figure 1. Organizational Chart for the DCM Complex (13:1-2)

To insure that their responsibilities are met, QC performs technical inspections. Technical inspections are performed to determine equipment condition and quality of maintenance. These are the types of inspections that this research was concerned with. There are two types of technical inspections: verification inspections (VI) and spot inspections (SI). VIs are an after-the-fact inspection and are used to insure that maintenance actions have been accomplished correctly. SIs are performed to determine the adequacy of maintenance actions in progress (13:10-5).

A technician is required to have an initial evaluation within six months after being declared proficient as a technician (12:4-3). An annual evaluation is required no later than twelve months from the completion of the last evaluation cycle (12:4-4). A cycle is the period beginning when the technician is liable for evaluation on his first task through the time when the seventh task is evaluated. This period can be any length of time up to a year.

A technician must be evaluated and graded at least qualified on a minimum of seven certified tasks to complete an initial or annual evaluation. A minimum of 20 percent of the authorized technicians in each workcenter must be completely evaluated from portal-to-portal (12:4-2). A portal-to-portal evaluation is one that begins at the predeparture briefing and terminates with the debriefing. The tasks to be evaluated are determined by QC personnel but

must represent a broad variety of all the tasks that the technician has been trained to perform and on which the technician has achieved at least a five skill level. The evaluations are generally conducted on a no-notice basis unless the evaluation will be the technician's initial one following training (12:3-1).

The responsibilities of QC in the performance of technical inspections include:

1. Meeting the inspection requirements of Table 1.
2. Checking applicable in-use inspection workcards, checklists, and code manuals during technical inspections. Those found outdated, unserviceable, or overdue verification checks will be removed from service.
3. Adjusting the scope and depth of technical inspections to satisfy changing requirements [13:10-6].

Performance errors. During an inspection of a technician's task performance, the QC inspector notes any errors performed during the performance of the tasks. There are three categories of errors: Category I is a critical error, Category II is a major error, and Category III is a minor error.

A Category I error is an automatic failure. It is an error that resulted in or could have resulted in:

1. Injury to any person preventing performance of duties during the task being evaluated.
2. Damage to any item which would prevent it from being immediately used for its intended purpose. This includes the item being worked on, all support equipment, and, with the exception of common hand tools, any other item in the work area.
3. Nuclear accidents or incidents.
4. Failure to accomplish critical portions of the task, resulting in incomplete task performance.

Table 1

Quality Control Minimum Inspection Requirements (13:10-7)

Inspect	A Minimum Of	Remarks
1. Lowering and mating of missile to launcher.	Representative sample of accomplished actions annually.	Accomplished by spot inspection.
2. Missiles processing through unit maintenance facility.	Representative sample of accomplished actions annually.	
3. Each type of support equipment (mobile and installed).	25 percent annually.	a. Exclude common PME (T033K-1-100), hand tools, and fixtures. b. Include currency of configuration documents, AFTO forms, and historical files.
4. In-shop and on-site maintenance.	Representative sample annually.	

Table 1 (Continued)

Inspect	A Minimum Of	Remarks
5. Munitions technical actions performed by RV Branch/Section. Inspect 25 percent of items a, b, e, f, and g, and representative sample of items c and d.	Applicable sample each month.	Include: a. Maintenance and recycle operations. b. Penetration aids system assembly or reconfiguration. c. Complete storage to dispatch sequence. d. Download and upload to and from transport aircraft. e. Handling, inspection, and installation of electroexplosive devices. f. Test and support equipment. g. Stockpile.
6. LFs and LCFs.	50 percent annually.	Include currency of configuration status documents, AFTO forms, and equipment.
7. Launch test facilities.	100 percent of each refurbishment or each facility at least biennially.	

Table 1 (Continued)

Inspect	A Minimum Of	Remarks
8. Configured van or vehicle.	One per month for each workcenter that dispatches.	a. Accomplish by spot inspection. b. Check configuration and equipment condition.
9. Launch capability test (LCT) (TMS only).	100 percent of all tapes.	a. Accomplish by VI. b. If printout is correct, annotate with name, grade, and date. Forward to Data Management. c. If printout is incorrect, attach tape to routing copy of inspection report. Incorrect printout information will be reported to maintenance control.

Table 1 (Continued)

Inspect	A Minimum Of	Remarks
10. Configuration managed maintenance training equipment (TO 00-20-4).	100 percent annually.	Check for: a. Current trainer hardware status and condition. b. Status/maintenance forms. c. Historical records. d. Status and utilization reporting.
11. Deferred maintenance files.		a. Review deferred discrepancies to insure malfunctions so identified meet the criteria specified in Chapter 3 of SACR 66-12. b. Make any recommendations to place specific discrepancies back in the active delayed discrepancy file to scheduling control through the DCM. c. Performed in conjunction with the maintenance control activity inspection.

5. Violation of the weapon system safety rules (AFR 122 series).

6. Failure to recognize/correct an unacceptable condition/check/test result.

7. Failure to recognize an acceptable condition/check/test result which resulted in an unacceptable time delay or in the rejection of serviceable components or equipment.

8. Security compromise [12:3-4].

A Category II error is an error that resulted in or could have resulted in:

1. Damage to any item which did not prevent it from being immediately used for its intended purpose, but required repair or had a detrimental effect on the operational life of that item. This includes, but is not limited to:
   a. Improper use of test equipment.
   b. Improper corrosion control.
2. Damage to common hand tools caused by misuse or neglect.
3. Excessive maintenance time; however, the task was successfully completed. This includes, but is not limited to:
   a. Delay(s) attributable to insufficient job knowledge, planning, coordination, or supervision.
   b. Unnecessary troubleshooting.
   c. Needless removal or replacement of components or equipment.
   d. Failure to, in a timely manner, recognize an acceptable/unacceptable condition/check/test results.
4. Administrative security deviation.
5. Injury to any person which did not prevent his/her performance of assigned duties (superficial injuries such as scratches, cuts, or bruises, not caused by misuse of equipment or violations of safety procedures are not considered errors).
6. Failure to make an inspection/check/test, which if not accomplished, would result in a possible hardness degradation or allow an unknown condition to exist [12:3-4].

A Category III error is any error that lacks the seriousness to meet the criteria for a critical or major error. A minor error does not necessarily result in a failure of the evaluation (12:3-4).

Performance grades. At the completion of the evaluation the technician is given a grade for his performance. Grades are:

1. Highly qualified (H). Performance of the overall task exceeded the acceptable level.
2. Qualified (Q). Performance of functions was acceptable.
3. Unqualified (UQ). Performance of one or more functions was unacceptable [12:3-5].

The procedures for determining the grades are:

1. List all errors noted during the task performance.
2. Determine the category and type of each error.
3. Compare the overall task performance with the grade criteria in Table [2] to assign the grade [12:3-5].

3901 Strategic Missile Evaluation Squadron

SAC delegated to the 3901 Strategic Missile Evaluation Squadron (SMES) the primary function of evaluating and rating a wing's ICBM maintenance personnel and equipment. SMES conducts these evaluations on a scheduled basis every nine months. SMES personnel evaluate a random sample of the various workcenter's technicians as they perform maintenance actions. SMES also conducts evaluations of QC personnel and training instructors. In the area of personnel evaluations, the entire maintenance complex must achieve a 90 percent pass rate in order to attain a satisfactory rating. Accordingly, each workcenter must also achieve a 90 percent pass rate in order to be rated satisfactory. The evaluations are conducted in exactly the same manner that

Table 2

Personnel Evaluation Grading Criteria (12:3-21)

RULE	A	B	C	D
	If the individual committed	and	and	Award a grade of
1	No error	NA	Performance of the overall task exceeded the acceptable level	Highly Qualified (with comments)
2	No Category I errors	No Category II errors	The Category III errors did not detract from overall outstanding job performance	
3		One Category II error	No Category III errors, or the accumulation of Category III errors did not result in unacceptable performance	Qualified (Q)
4		No Category II errors		

Table 2 (Continued)

RULE	A	B	C	D
	If the individual committed	and	and	Award a grade of
5	One or more Category I errors	NA	NA	Unqualified (U)
6	No Category I errors	Two Category II errors	NA	
7		One Category II error	The accumulation of Category III errors caused unacceptable performance	
8		No Category II errors		

NOTE: The table provides the evaluator a guide that minimizes the need for him to exercise evaluator judgment. Nevertheless, evaluator judgment will often be the determining element. This happens when the evaluator must determine the effect that the Category III errors had on the task performance.

wing QC personnel conduct their evaluations and technicians are graded according to the same criteria. In the area of hardware and equipment inspection, SMES inspectors will evaluate missile maintenance support equipment, tools, and vehicles to verify operability. The evaluators will also randomly pick a number of missile sites to conduct extensive inspections of site condition and ability of the site to function correctly in time of war (12:6-7).

Problem Statement

Statistical quality control techniques have been developed to control and improve quality through the application of statistical techniques and probability laws. Statistical techniques can be applied in order to achieve maximum conformance to established maintenance inspection standards. Through the use of statistical sampling methods it can be determined whether or not the maintenance conducted meets acceptable quality requirements. Statistical techniques can be used to determine an appropriate sample size to be inspected. The problem for research was to determine if a Maintenance Standardization and Evaluation Program inspection sample size can be more efficiently and effectively determined at the wing level in order to control the quality of maintenance performed at the missile sites.

Scope

This research was limited to the analysis of the MSEP at SAC's 321 Strategic Missile Wing at Grand Forks Air Force Base, North Dakota. The analysis was restricted to maintenance actions and MSEP evaluations conducted in 1978. The evaluation was concerned with maintenance actions and associated MSEP evaluations conducted on the LFs and LCFs and was not concerned with in-shop maintenance.

Research Objectives

The objectives of this research were to:

1. Develop a procedure by which a maintenance sample size could be determined at the wing level to control maintenance quality.

2. Ascertain the ramifications of this procedure in terms of increasing the efficiency and effectiveness of maintenance quality control.

Research Question

The question to be answered in this research was: Can the ICBM MSEP inspection sample size, at a selected base, be more efficiently and effectively determined at the wing level?

Justification

SAC's primary mission is to maintain the ability to deter potential enemies from attacking the United

States (U.S.) and, in the event the U.S. is attacked, to provide a second strike capability (15:1-2). The ability of SAC to carry out its mission relies heavily upon the reliability of SAC's hardware and consequently its maintenance quality. It is incumbent upon SAC to continually review its ICBM management procedures to insure that all activities are performing effectively.

SAC's management must be innovative and flexible. It should be innovative in order to find better, more economical ways of doing the job. It should be flexible to successfully cope with new situations. Both of these qualities are in ever increasing demand as fewer dollars become available to support the mission (13:1-2).

The increasing scarcity of resources impacts Air Force operations at every level. The rising costs of resources is a major concern to the Air Force since it affects its ability to perform its mission. The Air Force mission has not diminished in recent years while its budget in real dollars has been shrinking. Undersecretary of Defense for Research and Engineering, William J. Perry, testified before the House Appropriations Committee that the cost of military fighter aircraft has been increasing 10 fold every 20 years since World War 2. If this trend continues, Perry said, and the Defense Department budget increases only 3 percent per year, by the year 2110 the Pentagon will need to spend its entire budget to buy a single aircraft (16:11).

Because of the increased cost of resources, today's Air Force managers must take necessary actions to insure maximum utilization of time, men, and material. The effective and efficient management of the Air Force's maintenance quality control is of ever increasing importance. A sound quality control program can make significant savings in both direct and indirect costs. For example, effective control of the quality of maintenance performed on equipment can prevent unnecessary equipment down time. High quality assurance of maintenance will also increase equipment reliability.

Literature Review

The guidance and concepts of MSEP as contained in the various Air Force directives have already been discussed and no further review of them is necessary. Further, a complete history of MSEP development was beyond the scope of this research. There are a number of statistical approaches to sample size determination that are in use in the military and civilian sector that do warrant consideration, however. The literature review was devoted to those applicable publications pertaining to the development of sample sizes, their application in the military, and previous research conducted in the area of sample size determination in an Air Force maintenance environment.

Acceptance sampling overview. Acceptance sampling is used to determine what percentage of products conform to established specifications. In the maintenance function, this equates to determining what percentage of maintenance actions performed conform to technical order specifications. Acceptance sampling is based on the statistical concept that a random sample of appropriate size will have within it a proportional representation of all the items in the parent population. An estimation of product quality is obtained through sampling to determine if 100 percent inspection should be part of the production process. There are two general ways of describing the degree of conformance to quality specifications in acceptance sampling. One measures attributes and the other measures variables. Attribute measurements involve a simple determination of whether or not the product is "good" or "bad"; while the measurement of variables involves the determination of how much the product varies from other units or from design specifications. The use of attributes in acceptance sampling is generally based on the binomial statistical distribution. Acceptance sampling is executed through the development of a sampling plan (1:195).

A literature review of the various types of sampling plans would not have been relevant to the problem posed in this thesis. The purpose of this research was to show that a more effective and efficient method of determining an

appropriate sample size for maintenance quality verification could be found than what is currently being done in ICBM maintenance. The literature review focused on the various approaches used for only one type of sampling plan: the single sampling plan. This type of plan was deemed to be the most appropriate.

Single sampling plan. Chase and Acquilano state that a single sampling plan is defined by (n) and (c), where (n) is the number of units in the sample, and (c) is the acceptance number. The size of (n) may vary from 1 up to the entire population of the parent group or lot from which it is drawn. The acceptance number (c) denotes the maximum number of defective items that can be discovered in the sample before the entire lot is rejected (1:197).

Values for (n) and (c) are determined from the interaction of four factors that quantify the objectives of the producer and the consumer of the product. The four factors are producer's risk, consumer's risk, acceptable quality level, and lot tolerance percent defective. The objective of the producer is to assure that the sampling plan has a low probability of rejecting good lots. Lots are defined as acceptable if they contain no more than a specified level of defectives, called the acceptable quality level (AQL). The objective of the consumer is to assure that a sampling plan has a low probability of accepting bad

lots. Lots are defined as not acceptable if the percentage of defectives is greater than a specified amount, termed lot tolerance percent defective (LTPD). The probability associated with rejecting a bad lot is denoted by the Greek letter beta, β, and is called the consumer's risk. The probability associated with rejecting a good lot is denoted by the Greek letter alpha, α, and is termed the producer's risk. The selection of particular values for AQL, β, LTPD, and α is an economic decision based on cost tradeoffs. The more protection a consumer or producer desires, the more it will cost. A determination of (n) and (c) is made from these values as based on various tables and graphs located in quality control handbooks. An operating characteristic (OC) curve can then be constructed which will describe how well the sampling plan discriminates between good and bad lots (1:197).

Another approach to constructing a single sampling plan is presented by Dodge and Romig. They provide a complete series of tables for single sampling plans. Their approach is to provide tables for various values of LTPD. Appropriate sample sizes (n), and acceptance numbers (c), can be determined from the appropriate table through a determination of the lot size and process average. Dodge and Romig also provide OC-curves for use in discriminating between good and bad lots (2:4). A further analysis of this approach is covered in Chapter 2.

Duncan's approach to a single sampling plan is very similar to both Chase and Acquilano and Dodge and Romig, but with differentiation between types of OC-curves. Duncan draws a comparison between type A OC-curves and type B OC-curves. A type A OC-curve provides the probability of accepting an isolated lot. The type A OC-curve describes how a consumer is likely to view the operating characteristics of a sampling plan when he obtains isolated lots of material or thinks about the quality of individual lots rather than the average quality of a stream of lots. The type B OC-curve describes how a consumer is likely to view the operating characteristics of a sampling plan when he is buying a steady supply of material from a given supplier. The type B OC-curve gives the probability of accepting a lot from a randomly operating process turning out a product of average quality (3:149).

Military applications of single sampling plan. Military application of the single sampling plan is governed by the specifications of MIL-STD-105D. The sampling plans in MIL-STD-105D are applicable to the inspection of end items, components and raw materials, operations, materials in process, supplies in storage, maintenance operations, data or records, and administrative procedures. Sample sizes are determined using a combination of average quality level (AQL), the maximum percent defective that for purposes of

sampling inspection, can be considered satisfactory as a process average, and lot size. Tables and appropriate OC-curves are provided in MIL-STD-105D for different types of sampling plans. MIL-STD-105D is followed specifically by military contract representatives who are charged with the responsibility of insuring that contractors are selling quality products to the military. MIL-STD-105D is also used as a basis for quality control at the various Air Logistics Centers when they are conducting their day-to-day maintenance operations. Of particular interest was the fact that MIL-STD-105D is used to determine sample sizes at Ogden Air Logistic Center where depot level maintenance is performed on the Minuteman missile components (8).

Previous research to determine MSEP sample size. William A. Mitchell conducted a study to show that local determination of MSEP sample size leads to a more efficient and effective use of QC resources than if sample sizes are dictated by MAJCOMS. The study dealt with an aircraft wing in United States Air Forces Europe (USAFE). Mitchell asked whether the sample totals directed by USAFE accurately reflect what they are supposed to. He proposed that local managers should be allowed to determine those areas where quality control emphasis should be placed and schedule inspections accordingly. The number of inspections should be based on the confidence level desired by local management. Mitchell

showed that the higher the confidence level desired, the more inspections were required. He provided a methodology for sample size determination for MSEP evaluations based on the desired confidence level. He drew a comparison between what USAFE guidance would have dictated a sample size to be in a hypothetical situation and what his methodology would dictate the sample size to be. He showed that command guidance would have led to a lower confidence level in his example than what his methodology would have provided (9:54).

CHAPTER 2

METHODOLOGY

Overview

This chapter outlines the approach used in the analysis of the problem posed in this research. The chapter is divided into four sections. The first section provides the sources of data and information used in the report. The second section contains the procedure for the determination of a statistical sample size that could be used by maintenance QC personnel. The third section explains the procedure for comparing the calculated sample size for each workcenter with what was actually evaluated by the QC section of the 321 SMW and with what SAC requirements were, in accordance with SACR 66-6. The chapter concludes with a listing of the assumptions and limitations associated with the methodology.

Data

The number of maintenance actions performed by each dispatching workcenter constituted the population size (N) and was obtained from the 1978 Maintenance Summary Report for the 321 SMW at GFAFB. A dispatching workcenter is a maintenance workcenter whose primary tasks are performed at

a missile site. The workcenters involved were the Periodic Inspection Teams (PIT), Electro-mechanical Teams (EMT), Combat Targeting Teams (CTT), Missile Handling Teams (MHT), Facility Maintenance Teams (FMT), Site Security Maintenance Teams (SSMT), and the Missile Maintenance Teams (MMT). The number of MSEP evaluations performed by QC in each dispatching workcenter for 1978 were retrieved from the Maintenance Personnel Evaluation Reporting System (MPERS) at GFAFB. MPERS was also used to obtain the evaluation pass rate per dispatching workcenter. The number of personnel subject to MSEP evaluation per dispatching workcenter was obtained from the 1978 Maintenance Summary.

Sample Size Determination

The Dodge-Romig system for determination of sample size in quality control activities was used with the data obtained from the test base (2:4). The series of steps applied to this study were:

1. Decide what characteristics to include in the inspection. SACR 66-6 states that QC inspections will constitute a representative sample of maintenance actions that the technician is authorized to perform (12:3-1). In this research the characteristics included were all the completed maintenance actions by each workcenter regardless of priority. The total number of maintenance actions completed by each dispatching workcenter constituted the lot size from which the sample size was determined.

2. Decide on the type of protection required for the sample size determination. The protection required depends upon the amount of allowable defects or failures allowed before the whole lot is considered to be below standards. Two types of protection plans are Average Outgoing Quality Level (AOQL) and Lot Tolerance Percent Defective (LTPD). AOQL plans set a limit to the average quality of the lots inspected. As the percent defective of the lots increases, the samples will be rejected at an increasing rate. Rejected lots must be 100 percent inspected. As the rejection level increases, the number of items inspected increases. The level of outgoing quality, therefore, increases after a certain level of defectives is reached. Thus, average quality of the lots reaches an average outgoing quality limit.

Sampling plans utilizing LTPD limit the number of defectives in each lot sampled. The emphasis of LTPD sampling plans concentrates on quality levels of every individual lot, not the average quality of numerous lots. Each lot is sampled to insure the quality of the lot is acceptable. For this study the lot consisted of all the maintenance actions conducted by a maintenance workcenter during a one year period. Therefore, the LTPD sampling plan was chosen over the AOQL plan. The value used for the LTPD plan was 10 percent. This figure was based on the MSEP grading criteria in SACR 66-6 which states that at least a 90 percent

pass rate must be achieved by each workcenter in the personnel proficiency program for that workcenter to be judged as satisfactory (12:6-7).

Whenever a sampling plan is used in lieu of 100 percent inspection of all items, the consumer (SAC) and the producer (a maintenance workcenter) are taking risks. For the sake of economy the consumer must accept that some defectives will go undiscovered in each lot. The consumer must also accept the fact that some lots which exceed the acceptable defective rate will be accepted as good lots (2:12). A consumer's risk (β) of .10, a risk common in industrial practice, was used (1:196). For example, if a lot size of 60 maintenance actions contained more than 6 defectives, the lot size would be identified as bad 90 percent of the time, on the average.

The producer (a maintenance workcenter) like the consumer takes risks when a sampling plan is used in lieu of 100 percent inspection. The producer's risk (α) is the probability that a lot which actually meets the acceptable quality level will be rejected as bad on the basis of the inspected sample. A producer's risk of .05 was used as it is one commonly used for industrial practice (1:196). The producer's risk is directly related to the average rate of defectives produced (the process average). The sampling plans were constructed based on given process averages. If

the actual process average changes, the producer's risk and consumer's risk vary.

For a given lot size, numerous combinations of sample size (n) and acceptable number of defectives (c) could be selected to achieve the desired consumer's risk (.10) and producer's risk (.05). The objective of a sampling plan is to provide the most efficient adjustment between consumer's risk and producer's risk from the standpoint of minimizing inspection effort.

3. Decide whether to use a single, double, or multiple sampling plan. In a quality program, QC personnel have the option of single, double, or multiple sampling. Single sampling requires the quality inspector to examine a specified number of randomly selected items from the lot size in question. If the number of "bad items" in the sample exceeds the allowable number determined by the sampling plan, the entire lot is rejected as unacceptable without further sampling. If the number of "bad items" in the sample size does not exceed the allowable number determined by the sampling plan the lot size is accepted as good without further sampling.

Double and multiple sampling, unlike single sampling, may require examination of additional items from the lot size in question. This is because the acceptable number of "bads" for acceptance of the lot size may be less than the required number of "bads" for rejection of the lot size.

If the number of "bads" detected in the first sample exceeds the acceptance number and is less than the rejection number, one or more additional samples must be taken before the lot size can be rejected or accepted (2:9-15).

This thesis used single sampling because it most closely correlated to the evaluation method used by the 3901 SMES team. A single sampling plan is congruent with the 3901 SMES's "acceptance-rejection" policy. If the number of failures detected through MSEP is greater than 10 percent, the workcenter's maintenance production quality is judged to be below standards (12:6-8). SAC's policy is consistent with the single "acceptance-rejection" number of bad items provided by the single sampling plan. If the percentage of bad maintenance is greater than 10 percent, the quality is not being controlled for that workcenter. An increased emphasis on quality verification from then on would be required until maintenance quality was again within tolerance.

4. Select an appropriate sampling table for the parameters selected. Table 3 was used for sample size determination. The table is for a single sampling plan with an LTPD of 10 percent, a consumer's risk (β) of 10 percent, and a producer's risk (α) of .05.

5. Determine an estimate of the appropriate process average (PA). PA is the process average percent defective. It is the average percent of defectives produced by

Table 3

Single Sampling Table for Lot Tolerance
Percent Defective (LTPD) = 10% (2:185)

Lot Size	Proc. Avg. 0-0.10%			Proc. Avg. 0.11-1.00%			Proc. Avg. 1.01-2.00%			Proc. Avg. 2.01-3.00%			Proc. Avg. 3.01-4.00%			Proc. Avg. 4.01-5.00%		
	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %
1-20	All	0	0	All	0	0	All	0	0	All	0	0	All	0	0	All	0	0
21-50	17	0	1.3	17	0	1.3	17	0	1.3	17	0	1.3	17	0	1.3	17	0	1.3
51-100	20	0	1.5	20	0	1.5	20	0	1.5	33	1	1.7	33	1	1.7	33	1	1.7
101-200	22	0	1.5	22	0	1.5	35	1	2.0	48	2	2.2	48	2	2.2	60	3	2.4
201-300	23	0	1.5	38	1	1.9	50	2	2.3	65	3	2.4	75	4	2.6	85	5	2.7
301-400	23	0	1.5	38	1	2.0	50	2	2.4	65	3	2.5	90	5	2.7	100	6	2.9
401-500	23	0	1.5	38	1	2.0	50	2	2.5	75	4	2.8	90	5	2.9	110	7	3.2
501-600	23	0	1.5	38	1	2.1	65	3	2.7	80	4	3.0	100	6	3.2	125	8	3.3
601-800	23	0	1.6	38	1	2.1	65	3	2.8	90	5	3.1	100	6	3.3	140	9	3.4
801-1000	39	1	2.1	50	2	2.6	65	3	2.8	90	5	3.2	115	7	3.4	150	10	3.7
1001-2000	39	1	2.1	50	2	2.6	80	4	3.1	105	6	3.4	140	9	3.9	195	14	4.4
2001-3000	39	1	2.1	50	2	2.6	80	4	3.1	115	7	3.7	165	11	4.1	230	17	4.7
3001-4000	39	1	2.1	50	2	2.6	90	5	3.4	130	8	3.8	190	13	4.4	255	19	4.8
4001-5000	39	1	2.1	50	2	2.6	90	5	3.5	130	8	3.9	200	14	4.5	270	20	4.9
5001-7000	39	1	2.1	65	3	3.0	105	6	3.6	140	9	4.1	200	14	4.6	295	22	5.0
7001-10,000	39	1	2.2	65	3	3.0	105	6	3.6	150	10	4.2	210	15	4.7	315	24	5.2

Table 3 (Continued)

Lot Size	Proc. Avg. 0-0.10%			Proc. Avg. 0.11-1.00%			Proc. Avg. 1.01-2.00%			Proc. Avg. 2.01-3.00%			Proc. Avg. 3.01-4.00%			Proc. Avg. 4.01-5.00%		
	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %	n	c	AOQL %
10,001-20,000	39	1	2.2	65	3	3.0	120	7	3.7	150	10	4.3	240	17	4.8	340	26	5.4
20,001-50,000	39	1	2.2	80	4	3.2	120	7	3.7	165	11	4.4	260	19	5.0	380	30	5.7
50,001-100,000	39	1	2.2	95	5	3.3	130	8	4.0	180	12	4.4	270	20	5.1	380	30	5.7

n = sample size; c = acceptance number
"All" indicates that each piece in the lot is to be inspected
AOQL = Average Outgoing Quality Limit

the process in a given period of time. PA is determined by dividing the number of failures by the number in the sample size. PA for a dispatching workcenter, then, was the total number of evaluation failures divided by the total number of evaluations conducted by QC. PA equaled the overall pass rate for a particular workcenter subtracted from 1.00.

6. Select the appropriate sample size from Table 3. The sample size for a workcenter was determined by locating the column with its computed process average and going down that column until it intersected with the row containing the appropriate lot size. The number that resulted from this intersection was the determined sample size. For those cases where the process average was greater than 5 percent, a process average of 5 percent was used. Dodge and Romig state that when

> . . . the PA . . . is estimated to be larger than the largest PA value given in the table choose the sampling plan corresponding to the largest PA in the table (the last column) and to the given lot size [2:7].

7. Find the operating characteristic (OC) curve of the inspection sample and the overall maintenance task population. The problem of choosing an acceptance sampling plan centered on how it would perform in action. This was best explained graphically by the OC-curve. As previously stated, there are two distinct types of OC-curves: Type A and Type B.

Type A OC-curves are associated with single lot sizes with finite populations. This was the case with the maintenance workcenters under study. The lot sizes were finite in size and the study pertained to the probability of accepting specific lots.

Type B OC-curves are associated with sampling from an infinite universe and are compatible with AOQL sampling plans.

As the lot size gets large, the Type A OC-curve rapidly approaches the OC-curve for infinite lots. The Type A OC-curve for an infinite lot, however, is mathematically identical to a Type B OC-curve. A Type B OC-curve, therefore, can be used as a good approximation to a Type A OC-curve when lots are large; for example, lots 10 times the sample size (3:150-151).

For this study Type B OC-curves were used to approximate the Type A OC-curves in accordance with the following steps outlined by Dodge and Romig (2:55).[2] If the acceptance number (c) is greater than 3 or the sample size (n) is greater than 500 choose a Type B curve with the same (c) value and closest value of (n) from Appendices 1 and 2 of Sampling Inspection Tables by Dodge and Romig. The lot size (N) was disregarded as immaterial (2:55).

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[2]Type A OC-curve was available for MHT and an approximation using Type B curves was not required. The curve was copied from p. 174 of Inspection Sampling Tables for n=35 and c=1.

The OC-curve for a specific sampling plan graphically depicts the probability of accepting a lot size with a range of actual percent defectives. This is illustrated in Figure 2. The lot size under inspection had an actual percent defective of 5 percent. The corresponding probability of acceptance was .96. In other words, if the lot size in question with a 5 percent defective rate was inspected with the corresponding sampling plan, the lot size would be accepted 96 percent of the time based on the sample.

Procedure for Comparing Statistical Sample Size and MSEP Sample Size

The sampling plan (sample size and acceptance number) calculated by the preceding procedure will be displayed in tabular form. Also included in the table will be the total maintenance actions performed and the average number of technicians per workcenter. Additionally, evaluations performed by QC, broken out by the number of technicians evaluated and the number of maintenance actions evaluated, and the pass rate for each workcenter will be shown. The number of evaluations that QC was required to administer in accordance with SACR 66-6 will also be included. This will be a range of values because an individual technician from a workcenter could have been evaluated on a single task while a team of technicians from the same workcenter could have been evaluated on a single

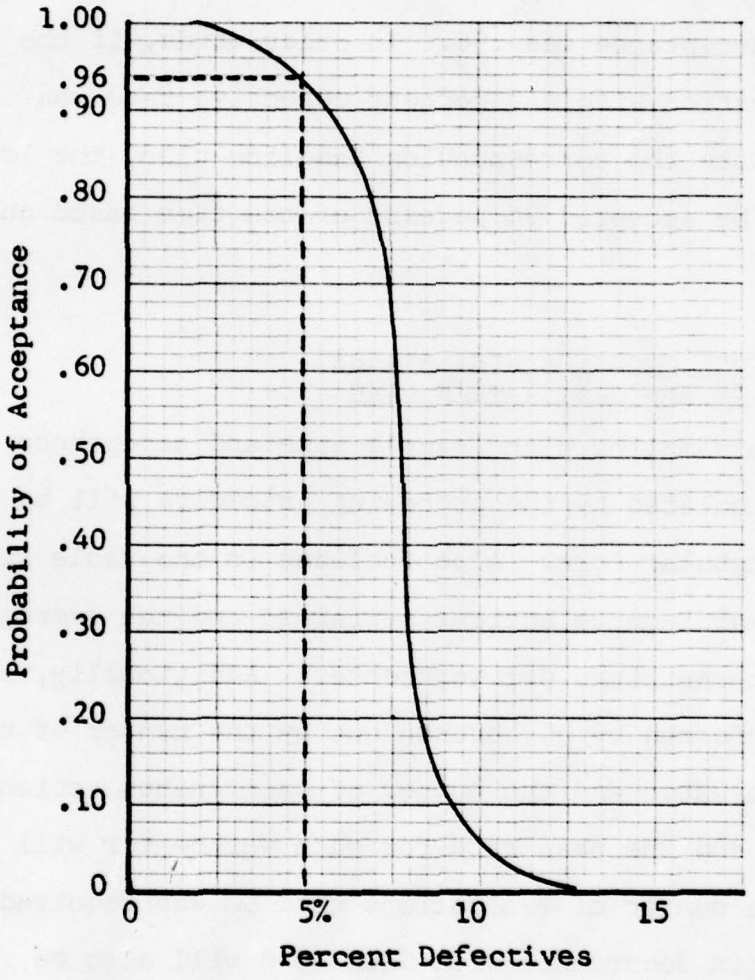

Figure 2. Operating Characteristic Curve--Single Sampling Plan Average Outgoing Quality Limit (AOQL) = 2.0% (2,83)

task with each technician given credit for an evaluation. This can be illustrated through the following example. If a workcenter had 20 personnel assigned and they were divided into four 5-man teams, the range of evaluation requirements would be from 28 to 140. It is possible that each member of the team could be given an evaluation as the team as a whole was working on one maintenance task. If this was continually carried out throughout the year for each team and technician, the total maintenance actions evaluated for the year would be 28, or 7 tasks multiplied by four teams. Conversely, it is possible that each member of a team would be evaluated on completely different maintenance actions, thus giving an annual total for the team of 35 and hence 140 maintenance actions evaluated for the year. The actual number of maintenance actions evaluated for the year will probably fall somewhere between the extremes.

The sample size required by MSEP will be compared with the calculated statistical sample size. The comparison will be to determine if the MSEP sample size resulted in a larger or smaller inspection size than computed statistically.

Assumptions and Limitations

1. All maintenance actions and evaluations at GFAFB were assumed to have been documented correctly.

2. Each maintenance action within a workcenter, regardless of priority, was assumed to have had an equal chance of being selected for evaluation.

3. No distinction was made between critical, major, and minor errors. Data simply showed a percentage of failed evaluations and the number of evaluations. No distinction was made to the types of tasks which were evaluated or why evaluations were rated unsatisfactory.

4. While a failed task may have been the result of something other than actual task workmanship, other causes of failures were ignored.

CHAPTER 3

DATA ANALYSIS AND RESULTS

Overview

A comprehensive analysis of the data obtained from the 321 SMW was used to discover possible shortcomings in MSEP. This chapter discusses the analysis performed on the data and the results obtained. The chapter is divided into three sections. The first section presents, in tabular form, a summary of the data and the calculated sample size derived using the procedure presented in Chapter 2. A complete explanation of the table is included. The second section is a more detailed approach to the information presented in the first section. The data and sample size are discussed as they pertain to each workcenter. The chapter concludes with a summary of all analysis results.

Data Presentation

Table 4 provides a summary of the data and calculations obtained from the procedures outlined in Chapter 2. An explanation of the table follows:

1. Column 1 lists the dispatching workcenters.

2. Column 2 is the number of maintenance tasks completed. These were the maintenance actions, scheduled

Table 4

Summary of Data and Sample Size Calculations (6; 7)

Workctr.	Maint. Tasks Completed	Tech. Eval.	Maint. Actions Eval.	Pass Rate	Personnel Assigned	SACR 66-6 Min. Req.	Calculated Size	Accept. Number
MHT	162	68	69	98.8	12 (three 4-man teams)	21-84	35	1
MMT	2,438	313	428	88.7	45 (nine 5-man teams)	63-315	230	17
CTT	2,395	118	353	95.9	18 (nine 2-man teams)	63-126	230	17
EMT	6,601	232	259	89.2	36 (eighteen 2-man teams)	126-252	295	22
PIT	3,392	90	156	92.2	18 (three 6-man teams)	42-126	255	19
SSMT	1,636	120	236	86.8	21 (seven 3-man teams)	49-147	195	14
FMT	3,473	115	163	95.0	18 (six 3-man teams)	42-126	255	19

or unscheduled, actually completed so that the maintenance discrepancy was eliminated from the Maintenance Management Information and Control System. The numbers only represent actual maintenance and do not represent training activity unless the training involved the elimination of an existing maintenance discrepancy. The differences between the number of task completions by the different workcenters are explained by the differences in the variety of the primary tasks that each is responsible for.

3. Column 3 is the number of evaluations that were conducted by QC under MSEP on the technicians in that particular workcenter.

4. Column 4 is the number of maintenance actions that the evaluations in Column 3 represent. A specific evaluation may have involved only one maintenance task or several different ones.

5. Column 5 is the pass rate. This figure represented the percentage of tasks that QC rated technicians at least qualified during the various evaluations conducted.

6. Column 6 contains the number of personnel assigned to a particular workcenter who were subject to evaluation under MSEP during 1978. They represented the average number of technicians for each workcenter that were subject to evaluation during the year. An average was used because personnel were continually being transferred in or

out of the workcenter, separated from the service, or otherwise removed from MSEP evaluation throughout the year.

7. Column 7 contains the SACR 66-6 directed minimum evaluation requirements. These represent the number of actual maintenance actions that could have been evaluated if all the required personnel evaluations were conducted in a workcenter in accordance with the MSEP requirements. These figures represent a range because of the following reasons: (a) each technician on a team could have received credit for an evaluation even though the whole team worked on the same maintenance action; or (b) each technician on a team might be evaluated on completely separate tasks. This can be illustrated by using MHT's SACR 66-6 minimum requirements as an example. If all 12 personnel in MHT had been evaluated on 7 completely different maintenance actions, the total number of maintenance actions evaluated for MHT would have been 84. However, if each member of a 4-man MHT team was given a task evaluation while the entire team was working on one maintenance action, the total number of maintenance actions evaluated would have been only one. The total number of maintenance actions evaluated for the entire MHT workcenter could have been as low as 21 if each member of the team was evaluated separately on the same maintenance action.

8. Column 8 lists the calculated sample size. These represented the sample sizes that should have been

evaluated if maintenance quality was to be adequately verified, according to the methodology developed in Chapter 2.

9. Column 9 lists the acceptance number. These are the number of failures that would have been allowed in the sample size before the entire lot was declared to be unsatisfactory.

Results by Workcenter

Missile Handling Teams. MHT performed 162 maintenance actions in 1978. QC evaluators conducted 68 evaluations on 69 maintenance actions. Of the 69 maintenance actions evaluated, failures occurred 1.2 percent of the time. There were 12 personnel assigned to MHT, on the average, who were subject to evaluation under MSEP. Calculations for the MHT workcenter show that a minimum sample size of 35 different maintenance actions needed to be taken on the 162 completed tasks performed. SACR 66-6 required minimum MSEP evaluations would have resulted in from 21 to 84 actual maintenance actions being evaluated. If QC had conducted evaluations on only 21 maintenance actions, a shortfall of 14 evaluations would have occurred, even though they would have been within SAC guidance. Likewise, if QC had conducted evaluations individually on technicians on different maintenance actions, an overage of 49 evaluations would have occurred. GFAFB evaluators evaluated 34 more maintenance actions than calculations indicate they needed to.

Missile Maintenance Teams. The data for MMT shows that 2,438 maintenance actions were completed in 1978. QC conducted 313 evaluations on 428 maintenance actions. MMT experienced an 88.8 percent pass rate which indicated a failure rate of 11.2 percent. There was an average of 45 personnel assigned to MMT at GFAFB, who were subject to MSEP evaluations. Calculations showed that a total of 230 maintenance actions should have been evaluated. SACR 66-6 minimum requirements indicate that from 63 to 315 maintenance actions could have been evaluated as required by MSEP. A shortfall or overage could have resulted from QC's evaluation efforts. GFAFB evaluators actually evaluated 198 more maintenance actions than were necessary according to calculations.

Combat Targeting Teams. The results for CTT showed that 2,395 maintenance actions were completed in 1978. QC conducted 118 evaluations on 353 maintenance actions. CTT's pass rate was 95.5 percent for 1978 which indicated a failure rate, and hence process average, of 4.5 percent. There was an average of 18 personnel subject to MSEP evaluation. Calculations showed that 130 maintenance actions should have been evaluated. SACR 66-6 minimum evaluation requirements led to a range of 63 to 126 maintenance actions that should have been evaluated. This entire range was far below calculated requirements. The evaluators at GFAFB

evaluated 123 more maintenance actions than what calculations called for.

Electro-Mechanical Teams. EMT completed 6,601 tasks in 1978. QC conducted 232 evaluations on 259 total maintenance actions. The pass rate for EMT was 89.2 percent and, consequently, a failure rate of 10.8 percent. There were 18 two-man teams assigned to the EMT workcenter, on the average, for a total of 36 personnel subject to MSEP evaluation in 1978. Calculations showed that the sample size for EMT completed work should have been a total of 295 maintenance actions. The SACR 66-6 minimum requirements indicated that a range of 126 to 252 maintenance actions could have been evaluated. The calculated sample size fell within this range which indicated that a shortfall or overage of evaluations could have occurred while still allowing the base to remain within SAC guidance.

Periodic Inspection Teams. The data for PIT showed that 3,392 maintenance actions were completed by that workcenter in 1978 and that QC conducted 90 evaluations on 156 of those actions. PIT obtained a 92.2 percent pass rate which denoted a failure rate, and hence process average, of 7.8 percent. There were 18 personnel in the workcenter, on the average, subject to evaluation under MSEP. Calculations showed that 255 maintenance actions should have been evaluated out of the 3,392 completed tasks. SACR 66-6 minimum

MSEP evaluation requirements indicated that a range of from 42 to 126 actual maintenance actions could have been evaluated. This entire range fell below the sample size calculated to insure that adequate quality was maintained.

Site Security Maintenance Teams. The data for SSMT shows that 1,636 maintenance actions were completed by this workcenter in 1978. QC conducted 120 evaluations on 236 completed tasks. The pass rate for SSMT was 86.6 percent for a failure rate and process average of 13.2 percent. There was an average of 21 personnel in the workcenter who were subject to MSEP evaluation. Calculations for sample size determination showed that 195 maintenance actions should have been evaluated out of the 1,636 total. If MSEP evaluation requirements were met a range of from 49 to 147 actual maintenance actions could have been evaluated. This range was below the calculated sample size. The evaluators conducted 41 more evaluations on maintenance actions than sample size calculations indicated that they should have.

Facilities Maintenance Teams. The data for FMT shows that a total of 3,473 maintenance actions were completed in 1978. QC conducted a total of 115 evaluations on 163 maintenance actions. The pass rate for FMT was 95 percent for a failure rate and process average of 5 percent. There was an average of 18 personnel subject to MSEP evaluation in 1978.

The calculated sample size was 255, which means that the evaluators had a shortfall of 92 evaluations in order to insure that quality maintenance was being accomplished. The range of evaluations that could have occurred when QC had followed SACR 66-6 guidance was 42 to 126. QC exceeded the highest figure in this range. The entire range, however, was below the calculated sample size.

Summary of Analysis Results

The data showed that 6 of the 7 dispatching workcenters in the 321 SMW received QC evaluation in excess of the requirements of SACR 66-6 MSEP. Wing QC evaluation totals per workcenter show that in four instances the calculated sample size was exceeded and for the other three, a shortfall occurred. The shortfall for the PIT workcenter was the largest with a total of 99, followed by a 92 shortfall for FMT. There was a shortfall of 36 maintenance evaluations for the EMT workcenter. In five cases, the calculated sample size was larger than the range of values that would have occurred had the base complied strictly with SACR 66-6 requirements. In three of these cases, the sample size difference was noticeable. The calculated sample size was 129 evaluations higher than the highest value in the SACR 66-6 minimum range for FMT. It was also 129 evaluations higher for the PIT workcenter and 104 higher for the CTT workcenter. The calculated sample size fell

within the SACR 66-6 range for MHT and MMT. The conclusions are that there are some substantial differences between the calculated sample size and the sample sizes that would occur if the guidance in SACR 66-6 were followed. The ramifications and implications of this difference are covered in Chapter 4. Pictorial comparisons between calculated sample sizes, SACR 66-6 requirements, and what was actually evaluated at GFAFB are given in Figures 3 through 9. OC curves for the situation in each workcenter are provided in Appendix A.

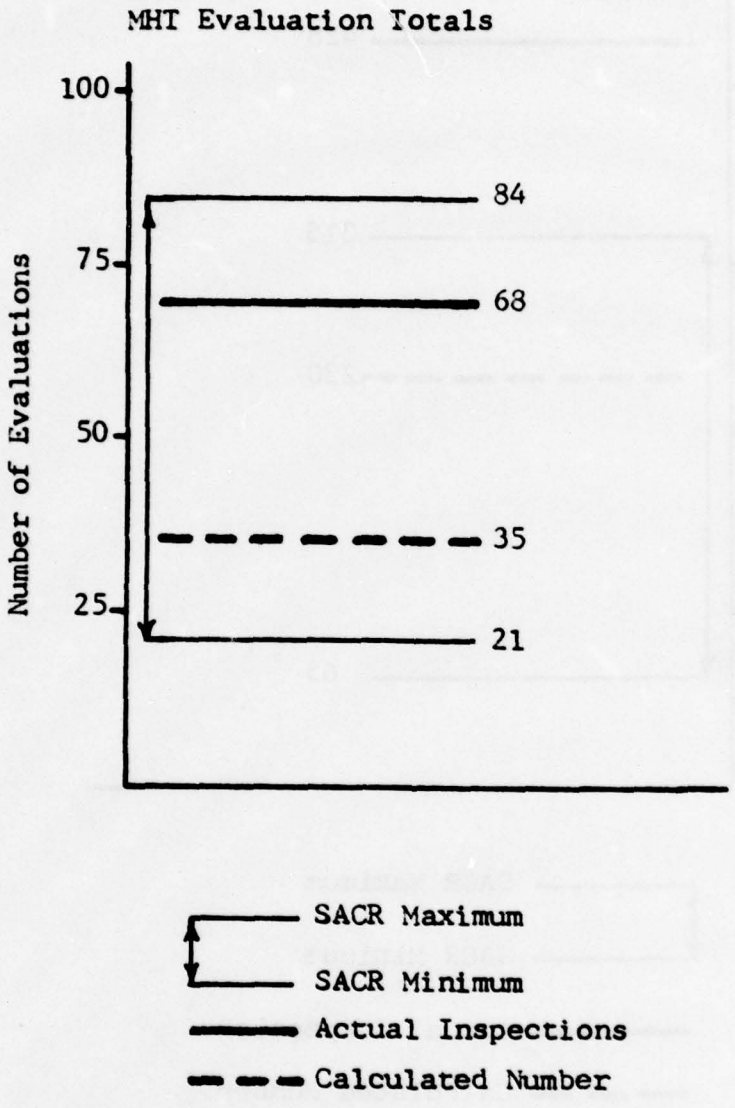

Figure 3. MHT Sample Size Comparisons

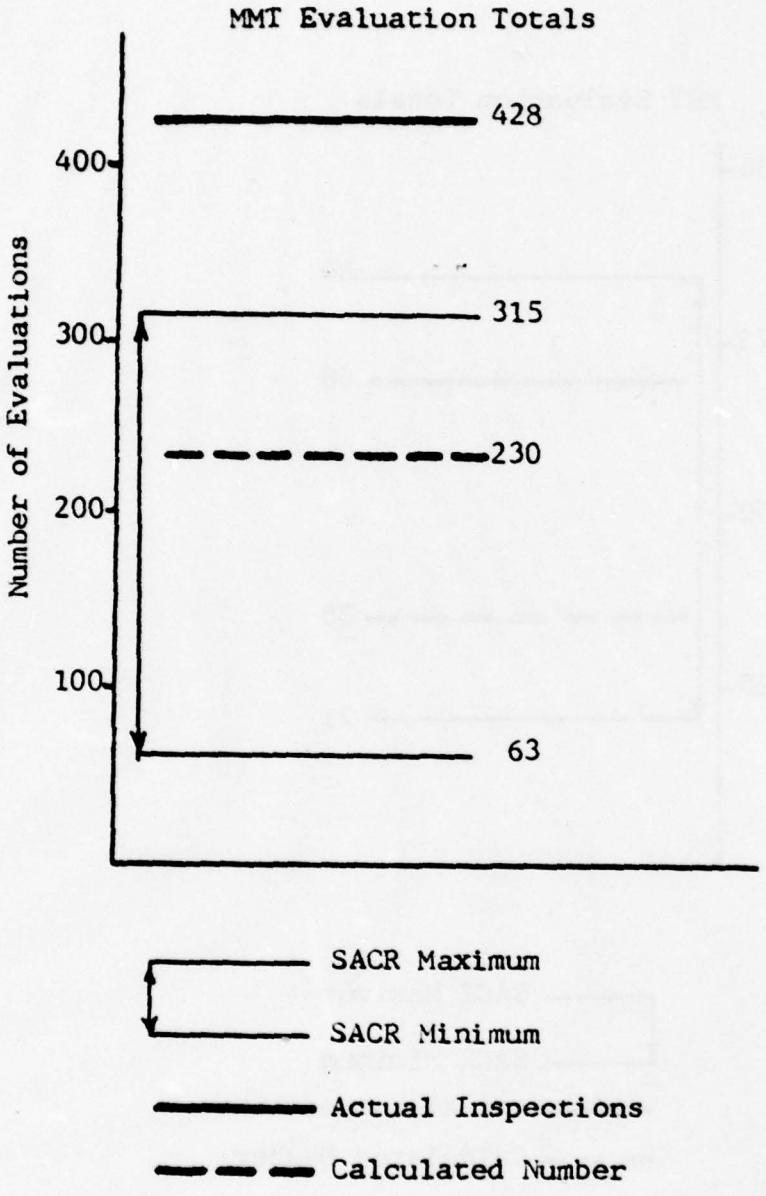

Figure 4. MMT Sample Size Comparisons

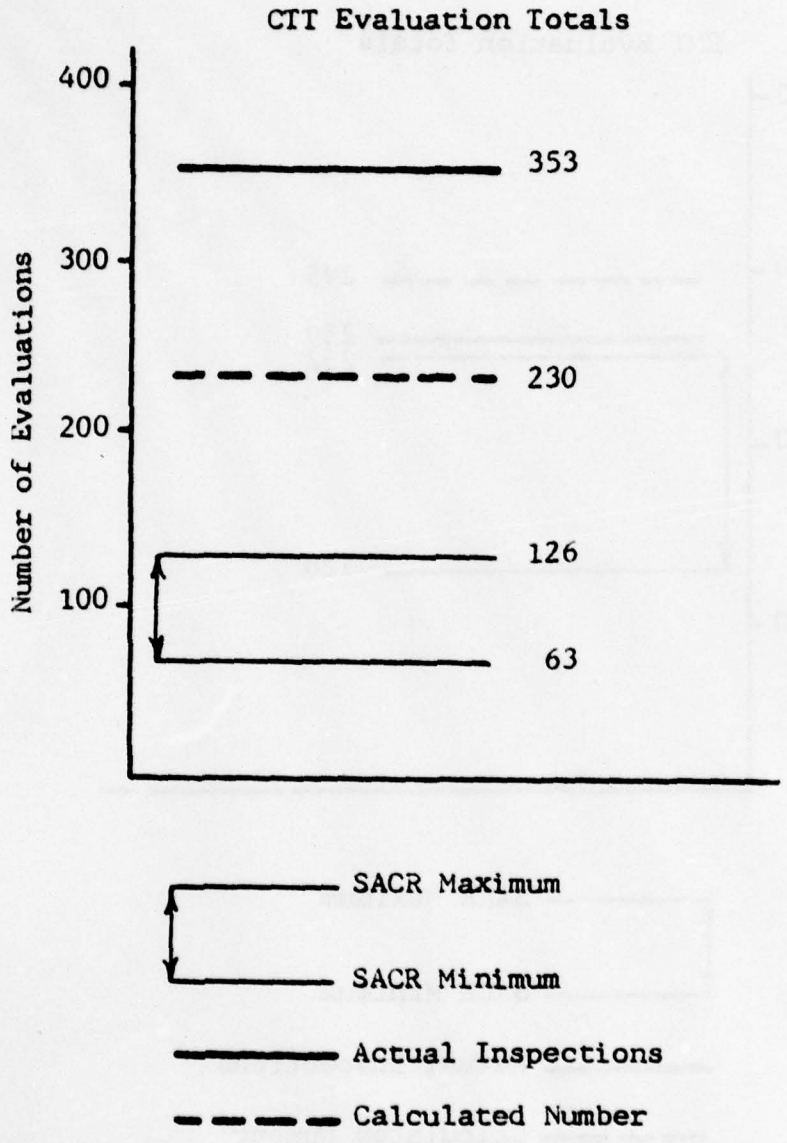

Figure 5. CTT Sample Size Comparisons

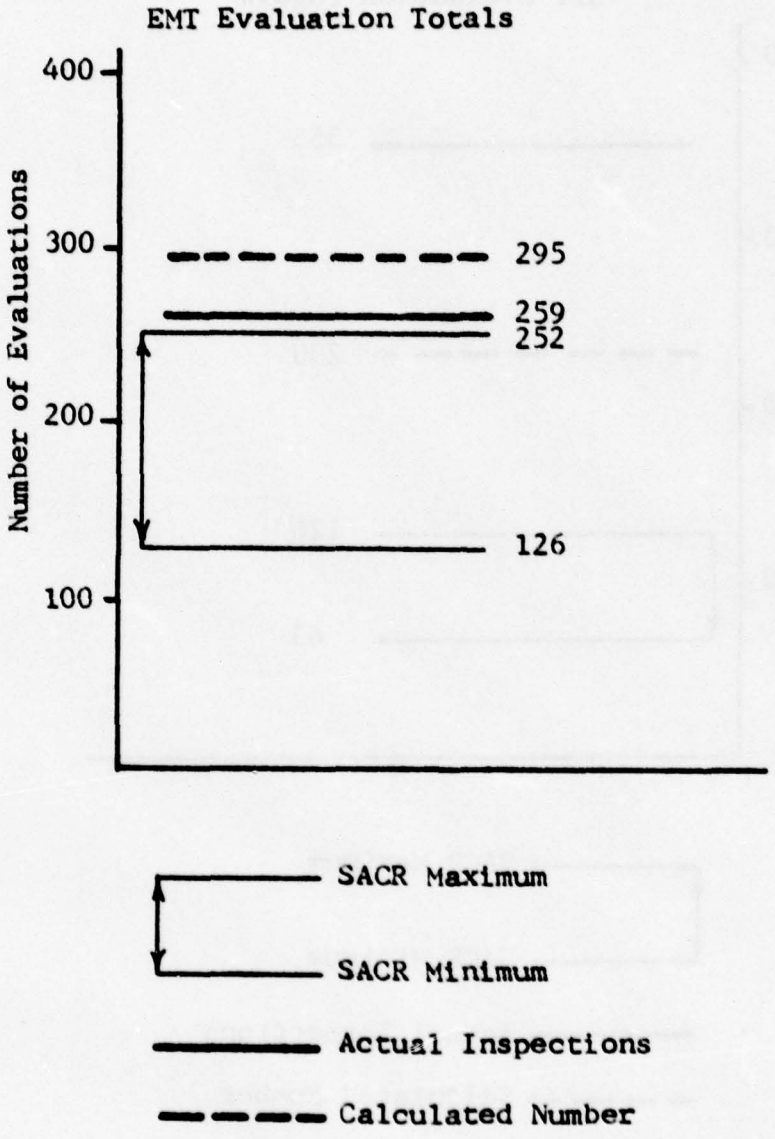

Figure 6. EMT Sample Size Comparisons

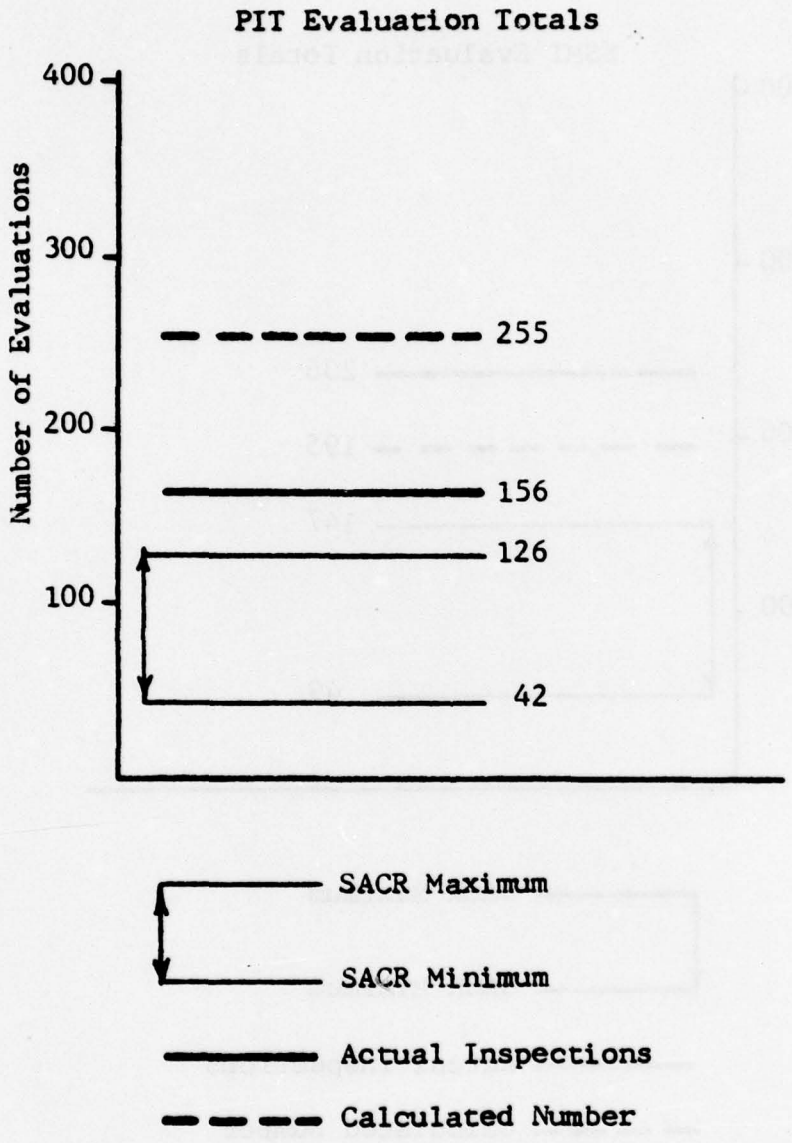

Figure 7. PIT Sample Size Comparisons

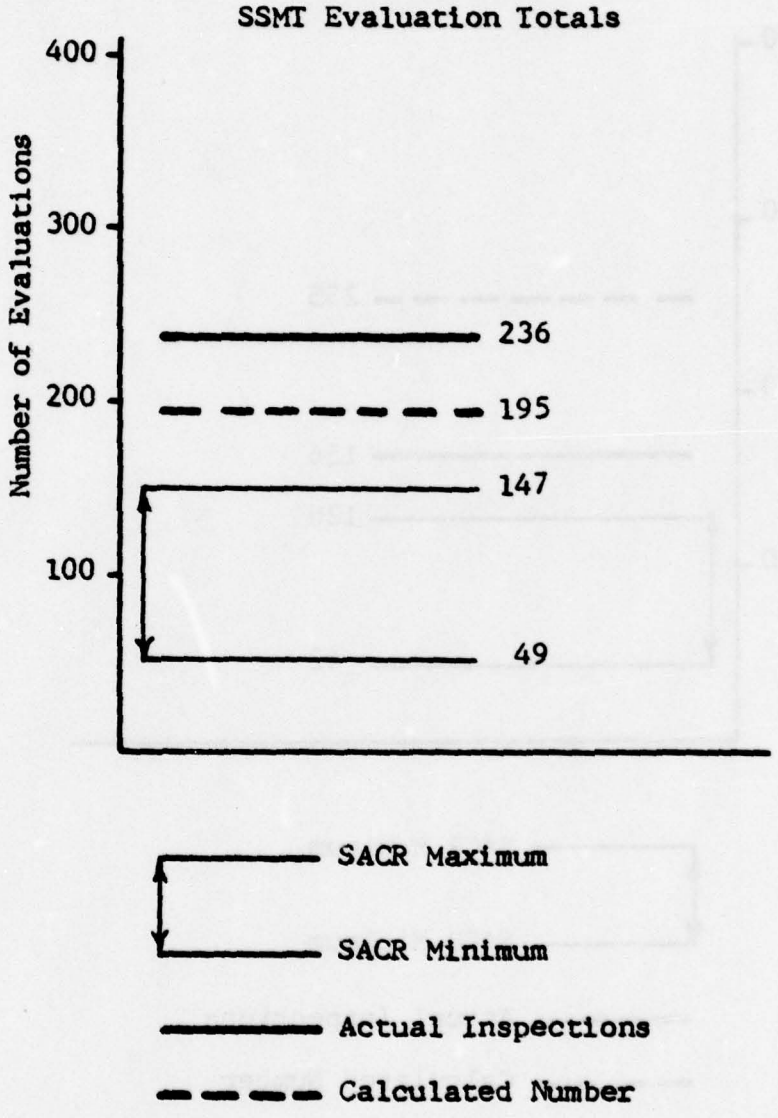

Figure 8. SSMT Sample Size Comparisons

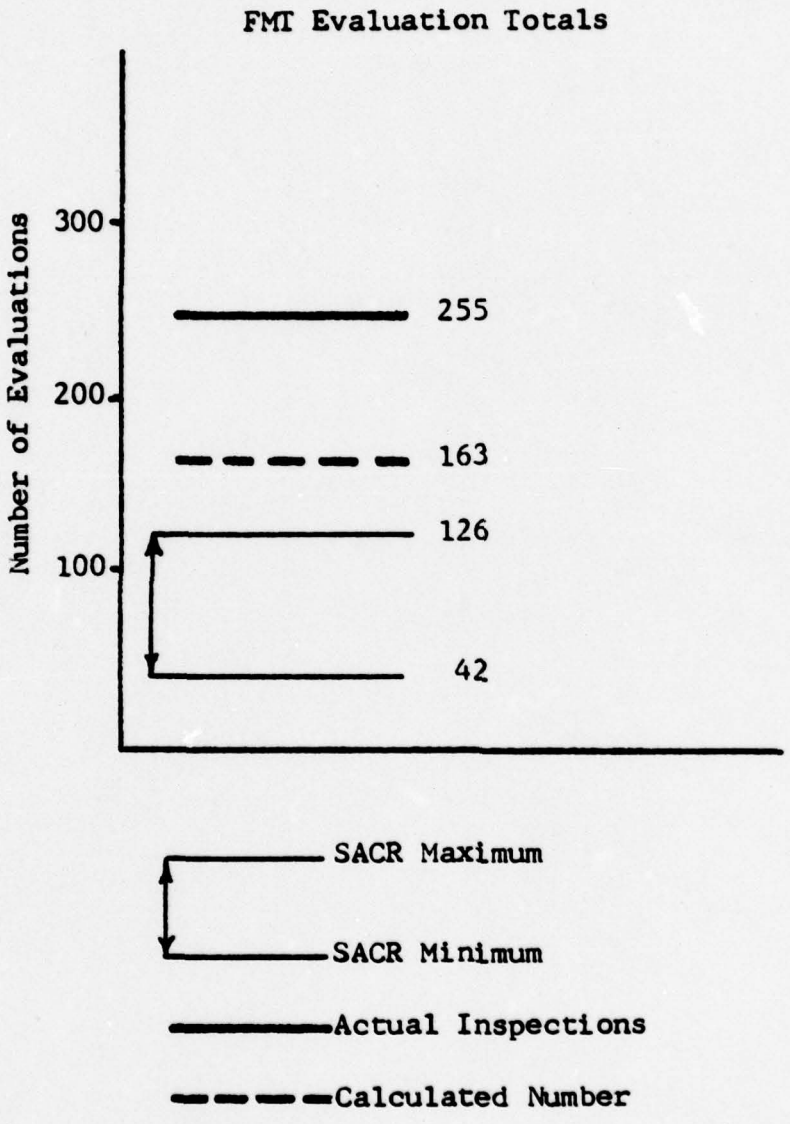

Figure 9. FMT Sample Size Comparisons

CHAPTER 4

DISCUSSION AND CONCLUSIONS

Overview

This chapter presents the discussion and conclusions of the analysis of the Minuteman ICBM Maintenance Standardization and Evaluation Program.

Discussion of Research Objectives

Objective 1. The first objective of this research was to develop a procedure by which a maintenance sample size could be determined at the wing level to control maintenance quality. Chapter 2 presented steps whereby such a sample size for each workcenter could be determined at the wing level. The analysis in Chapter 3 proved that a wing could determine maintenance sample sizes better than the current method directed by SACR 66-6. There are two considerations that would be necessary before the procedure could be used. First, a method would have to be developed to differentiate the various maintenance actions by priority. Management would most likely want to emphasize higher priority maintenance actions. Accordingly, QC could attempt to insure that higher priority maintenance actions were evaluated more

often than lower priority actions. Second, the procedure would have to be used in conjunction with a forecasting methodology. Maintenance managers need to know how many evaluations would be required next month or next quarter, not how many were required last month or last quarter. A forecasting method would be necessary to determine how many maintenance actions would be scheduled and how many could be expected to be completed. Quality Control could plan their evaluation schedule and calculate an appropriate sample size based on the forecasted maintenance plan.

Current methods for scheduling QC evaluations do not consider the number of maintenance actions completed for a given period of time. SAC guidance states that a specific number of evaluations is required to insure technician proficiency regardless of the amount of maintenance actions completed by the workcenter. There is no firm guidance as to the approach to use for verification inspections (after-the-fact inspections) of work completed other than when deemed appropriate by local maintenance managers. There is a requirement for QC to inspect 50 percent of the LFs and LCFs to verify site condition; however, this is not necessarily used as a quality control mechanism. A more scientific method is needed to insure that an appropriate number of maintenance actions are evaluated for quality assurance. This would lead to a much more effective and efficient use of available QC resources (10).

It is not suggested that the approach presented in this research would be a panacea for the problem of quality verification within Minuteman maintenance. It is realized that there are many other factors that enter into the concept of quality assurance. Because of the critical nature of the hardware involved, more emphasis may be placed on insuring that maintenance is done correctly than might be placed on other types of maintenance throughout the Air Force. A chronic shortfall of replacement parts, severe weather conditions of northern tier missile bases, and the distances many of the LFs and LCFs are from the support base, all play an important part in the determination of quality verification requirements at a missile wing. Also, many of the maintenance actions are so critical and the results so adverse if a mistake is made, that local management might want as many experienced personnel at the applicable missile site as can reasonably be spared, regardless of the proficiency of the maintenance team. Because of these factors, suggested sample sizes would probably not be strictly adhered to (11).

The procedure developed in this thesis is a more rigorous method for determining sample sizes than the MSEP requirements established in SACR 66-6. Because of the pressure on today's managers to make the most out of an austere budget and the trend toward personnel cutbacks, it is necessary for Minuteman maintenance managers to thoroughly

review current procedures of quality verification. The results presented in Chapter 3 substantiated this point.

Objective 2. The second objective of this research was to ascertain the ramifications of the procedure developed, in terms of increasing maintenance quality control efficiency and effectiveness. An analysis of the ramifications was made using the information for the workcenters presented in Chapter 2. In general, the ramifications of adhering to the prescribed procedure would lead to significant manhour savings in some cases and more effective quality verification in others. The approach was to compare the calculated sample size with the sample size used by QC evaluators at GFAFB. Conclusions were based on the results of this comparison:

1. Missile Handling Teams. If GFAFB QC evaluators had used the methodology outlined in this research to determine a sample size, they would have been able to save a significant amount of evaluator time. The data from Table 4 show that 69 maintenance actions were evaluated by QC in 1978 but the calculated sample size indicated that only 35 maintenance actions needed to be evaluated. Thus, QC evaluated 34 more maintenance actions than were necessary. Referring to Appendix B, the average number of hours spent on the evaluation of one maintenance action was 10 (5). An MHT QC evaluation team is generally composed of 2 or 3

personnel; so the total number of manhours spent evaluating one maintenance action by an evaluation team varies from 20 to 30 (11). Since QC evaluators conducted 34 inspections too many, 680 (34 x 20) to 1020 (34 x 30) total manhours could have been channeled toward other endeavors.

Because the primary tasks of MHT (missile removal and emplacement) are so critical, local managers would probably be uncomfortable with a total maintenance evaluation figure of only 34. Managers would probably want QC experts present during these maintenance operations even though an evaluation was not planned.

2. Missile Maintenance Teams. The results for MMT showed that QC conducted 198 more evaluations than the calculated figures indicated they needed. An MMT evaluation team is composed of 2 or 3 evaluators. Referring to Appendix B, the average number of hours spent evaluating 1 MMT maintenance action was 10. This meant that 20 to 30 manhours were spent in the evaluation of 1 maintenance action. Since 198 evaluations were excessive, 3,960 (198 x 20) to 5,940 (198 x 30) total manhours could have been used in other QC activities. The large number of evaluations conducted at the test base reflected management's concern over the successful outcome of the highly critical primary tasks of MMT (warhead removal and replacement, and missile guidance set removal and replacement). Additionally, the high failure rate of 11.3 percent probably influenced

managers to increase the amount of QC evaluations in order to improve maintenance quality. Retraining of MMT technicians would also be a consideration.

3. Combat Targeting Teams. The data for CTT showed that QC conducted 123 more evaluations than were necessary according to the calculated sample size. Since a QC team for this workcenter consists of 1 or 2 evaluators, the manhour savings based on the average maintenance action evaluation time in Appendix B would be between 1,230 (10 x 123) and 2,460 (20 x 123) manhours.

4. Electro-Mechanical Teams. The results for EMT showed that QC conducted 36 fewer evaluations than the calculations indicated would be necessary. The conclusions, based on these figures, were that not enough maintenance verification of this workcenter's performance was conducted. Although QC was within Command guidance, they were not assuring maintenance quality as effectively as the method presented in this thesis.

5. Periodic Inspection Teams. Based on calculations, QC conducted about 100 fewer evaluations than required. The conclusion was that maintenance quality was not being verified at an acceptable level for this workcenter. It should be noted that base maintenance managers probably did not feel pressure to exceed SACR 66-6 requirements because PIT maintenance actions were generally low priority, routine, or deferred type work. This research ignored priorities and

therefore concluded the calculated requirement was much higher than what was accomplished.

6. Site Security Maintenance Teams. The data for SSMT showed that QC exceeded the calculated requirement by evaluating 41 more maintenance actions than necessary. The total number of manhours required by QC to conduct these extra evaluations total 820 (41 x 20). This was based on an SSMT evaluation team being composed of 2 individuals and, as indicated by Appendix B, 10 hours required to evaluate 1 SSMT maintenance action. Because of SSMT's 13.2 percent failure rate, the extra QC evaluations were considered necessary and additional training was also a consideration.

7. Facilities Maintenance Teams. The results for FMT showed that the calculated sample size was larger than the sample used by QC. While QC evaluated commensurate with SAC guidance, not enough maintenance actions were evaluated to insure maintenance was being performed adequately by the workcenter, according to calculated sample size.

Conclusions

The Maintenance Standardization and Evaluation Program is a very viable and beneficial program. The intent of the program, insuring quality maintenance through enforcement of strict compliance to applicable technical orders, is satisfactory. Improvements can be made to the program to make it even more effective, however.

A more scientific approach should be used in determining the evaluation sample sizes. An approach should be used where sampling is based on the amount of maintenance performed rather than by performing a certain amount of inspections annually. A forecasting technique should be used to predict how much maintenance will be conducted in the next applicable time period and then an appropriate sample size, based on the procedure developed in this research, can be determined. QC could use this sample size to plan its corresponding evaluation schedule. The evaluations could be after-the-fact verification inspections, spot inspections, or personnel proficiency evaluations. The point is that a sample size can be more scientifically determined and that the number of evaluations, regardless of type, can be planned. Proficiency requirements could still be met in the process. The end result would be a more effective and efficient use of QC personnel, and SAC would be more assured of receiving a quality product.

It could be argued that there are already enough "built-in" quality verifiers in the system and that quality is presently being verified effectively and efficiently. There are a number of means now that are "de facto" quality verifiers. One of them is the on-going electronic interrogation between the LCF and LF mentioned previously. It is a quality verifier in that after a critical maintenance task has been performed and the system is brought back on alert,

a maintenance fault will be indicated if something improper had been done. However, many faults that could affect launch status still would not show up in the LCF in the form of a Maintenance Status Reply or fault indication.

A second "de facto" quality verifier is the maintenance team itself. Each team is required to follow a detailed checklist when it completes a maintenance activity and departs the LF or LCF. This checklist contains a number of critical items that must be visually checked. If improper maintenance had been done on these items, the maintenance team should catch the problem during "back out," assuming the "back out" was done correctly and the problem accurately reported.

A third "de facto" quality verifier is a result of supervisory field visits to the missile sites. Workcenter supervisors and other key supervisors and managers within the maintenance complex are required to periodically make field visits to an LF or LCF to keep current with conditions in the missile field. To the extent that they are proficient in the maintenance activity being conducted and/or with the way the equipment should be, they are a means of quality assurance.

A fourth "de facto" quality verifier is the requirement to verify the condition of 50 percent of the LFs and LCFs annually (13:10-8). While the inspectors are not specifically looking at particular past maintenance actions,

discrepancies and shoddy maintenance should certainly be noticed by this inspection.

One final "de facto" quality verifier is centered around the quality evaluation team itself. While on the missile site to evaluate a specific maintenance team or maintenance technician, it would not be oblivious to other maintenance activity going on or to any glaring discrepancies resulting from shoddy maintenance performed in the past. Most QC evaluators are proficient enough in the whole system to notice problems associated with the maintenance conducted by other types of maintenance teams. They are thus well qualified to verify maintenance quality.

The "de facto" maintenance quality verifiers, discussed above, do assist the maintenance effort. It does not matter how maintenance is verified for quality, only that an orderly, scientific approach be adopted to determine how much maintenance must be verified. One method has been proposed to fulfill this objective. This proposed method is not the only way that an efficient and effective sample size can be determined. The sample size should be determined at the wing level, however. It is only at the wing level that all the factors that go into maintenance scheduling can be objectively ascertained and a rational approach to the maintenance process developed. Once that approach has been developed, the methodology for a realistic sample size determination can be carried out.

Summary

This thesis explained SAC ICBM MSEP. A statistical procedure was developed to more effectively and efficiently use available QC resources. The procedure considered the number of maintenance actions performed instead of relying solely on a number of evaluations per technician. The data from a sample base was analyzed and the ramifications of using the derived statistical sample size discussed. It was shown that the methodology can result in a more effective and efficient use of QC personnel when evaluation samples are determined at the wing level. This approach would enable SAC to better verify and maintain the quality of its missile maintenance. This becomes more critical as the hardware ages and the concept of deterrence becomes more important. The world has to know that the Minuteman force is ready to do its job anytime. A more effective and efficient maintenance quality verification procedure can enhance this desire.

APPENDIX A

OPERATING CHARACTERISTIC CURVES

Operating Characteristic Curves

The Type A Operating Characteristic (OC) curves depicted in Appendix A (Figures 10 - 16) illustrate the probability of accepting maintenance actions of the Minuteman maintenance teams investigated by this thesis. The range of percent defectives was depicted on the abscissa (x-axis) and the probability of accepting the lot was depicted on the ordinate (y-axis). The curves were transposed from Sampling Inspection Tables by Dodge and Romig.

Table 5

Symbols for OC-Curves

α = .05
β = .10
n = Sample Size
c = Maximum Acceptable Number of Defectives

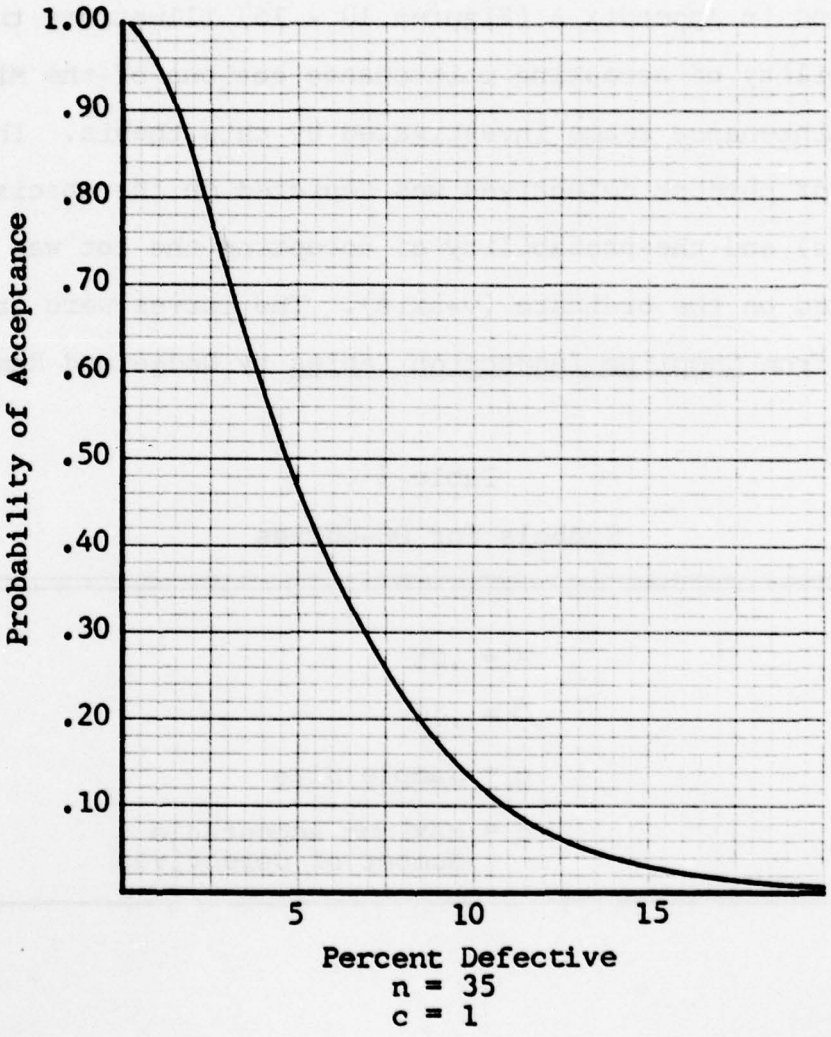

Figure 10. OC-Curve for MHT

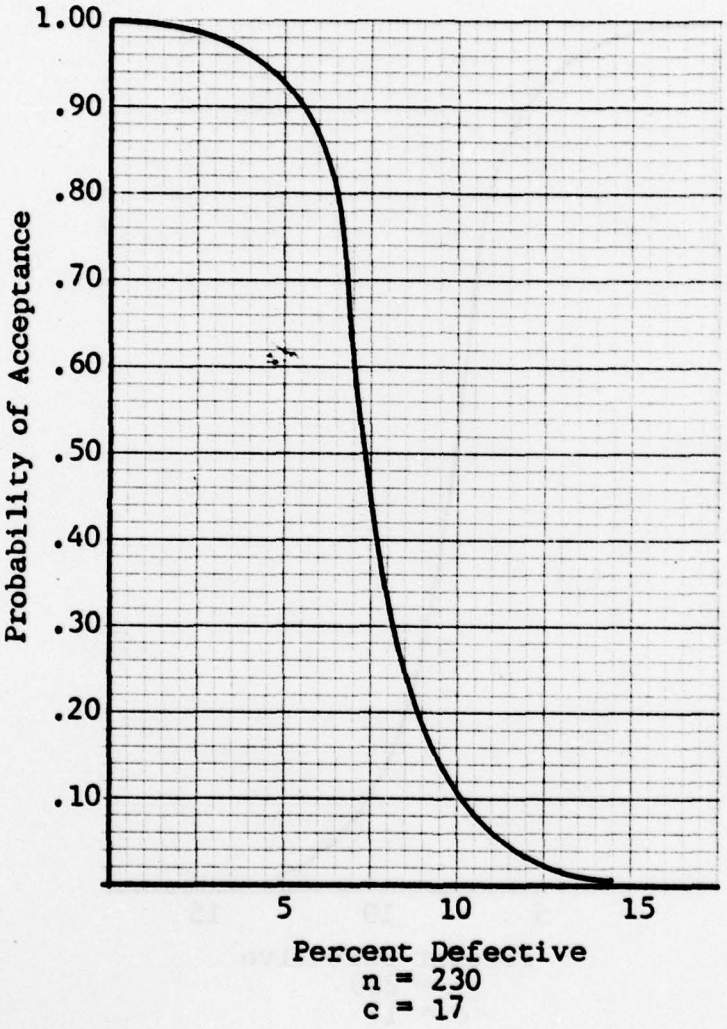

Figure 11. OC-Curve for MMT

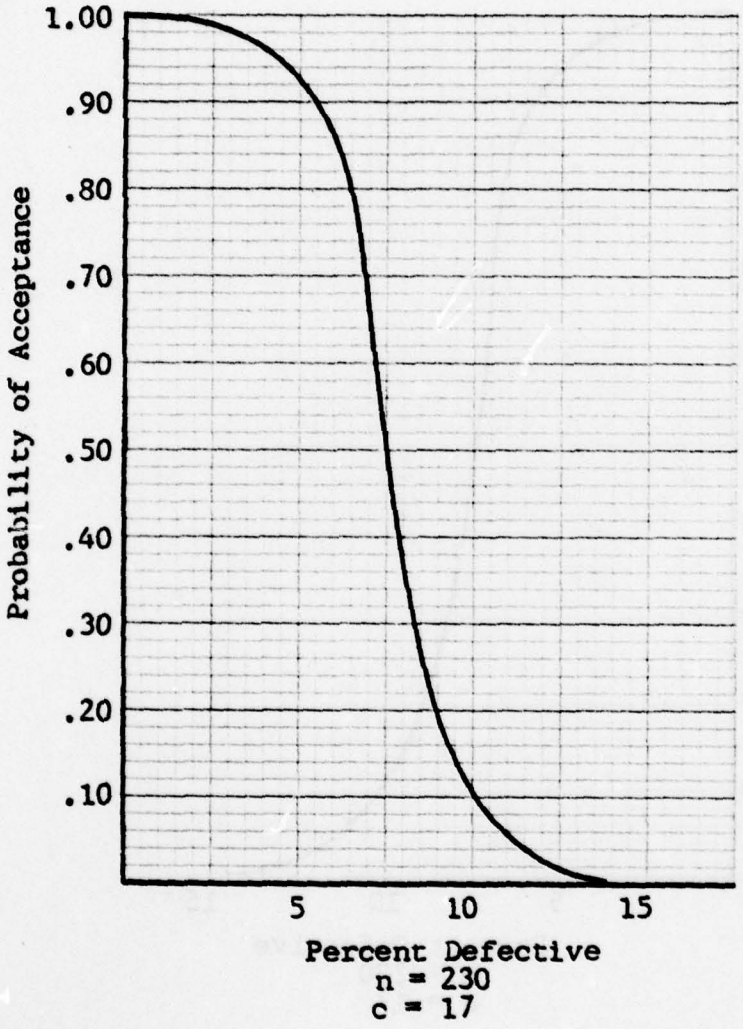

Figure 12. OC-Curve for CTT

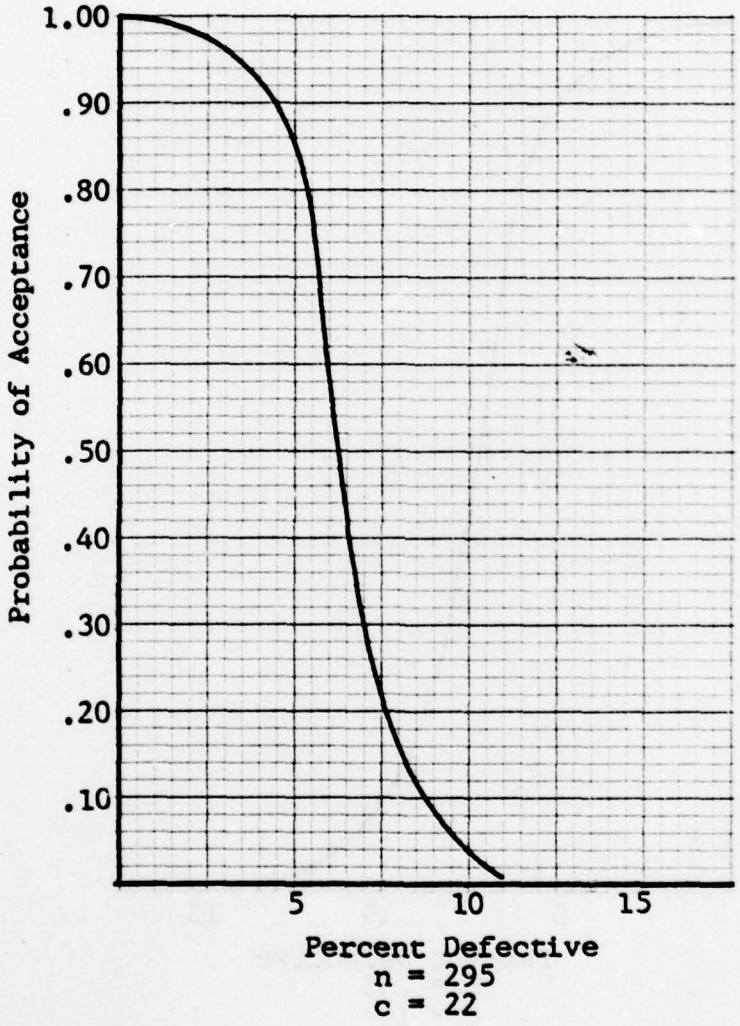

Figure 13. OC-Curve for EMT

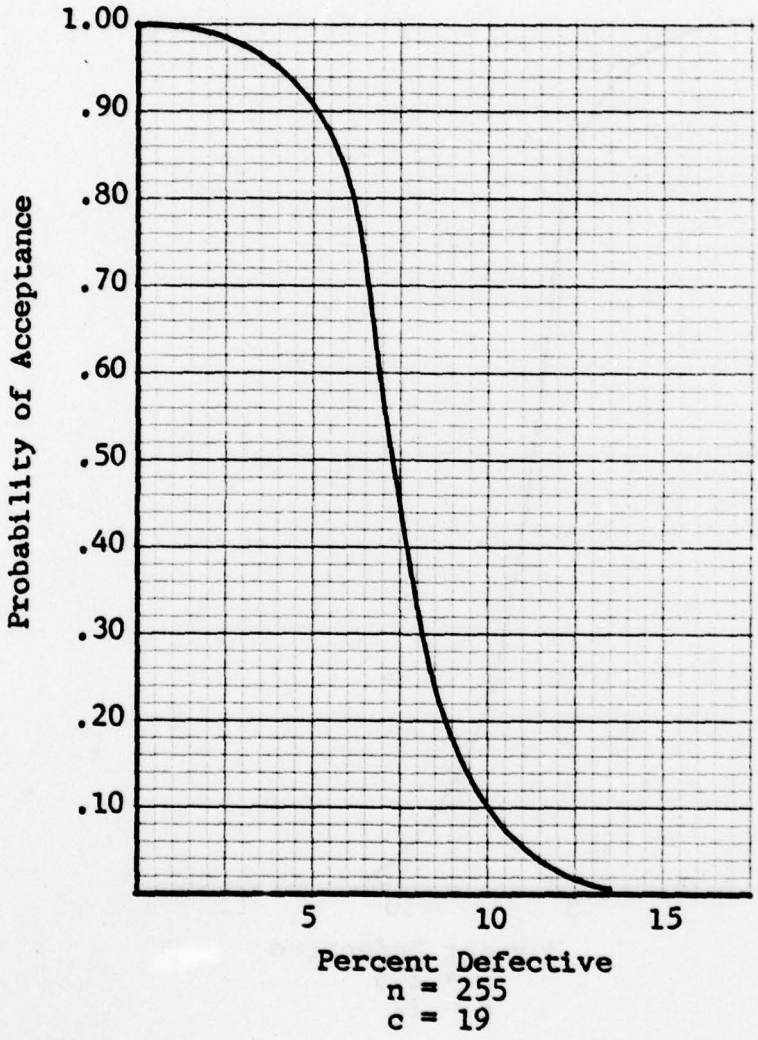

Figure 14. OC-Curve for PIT

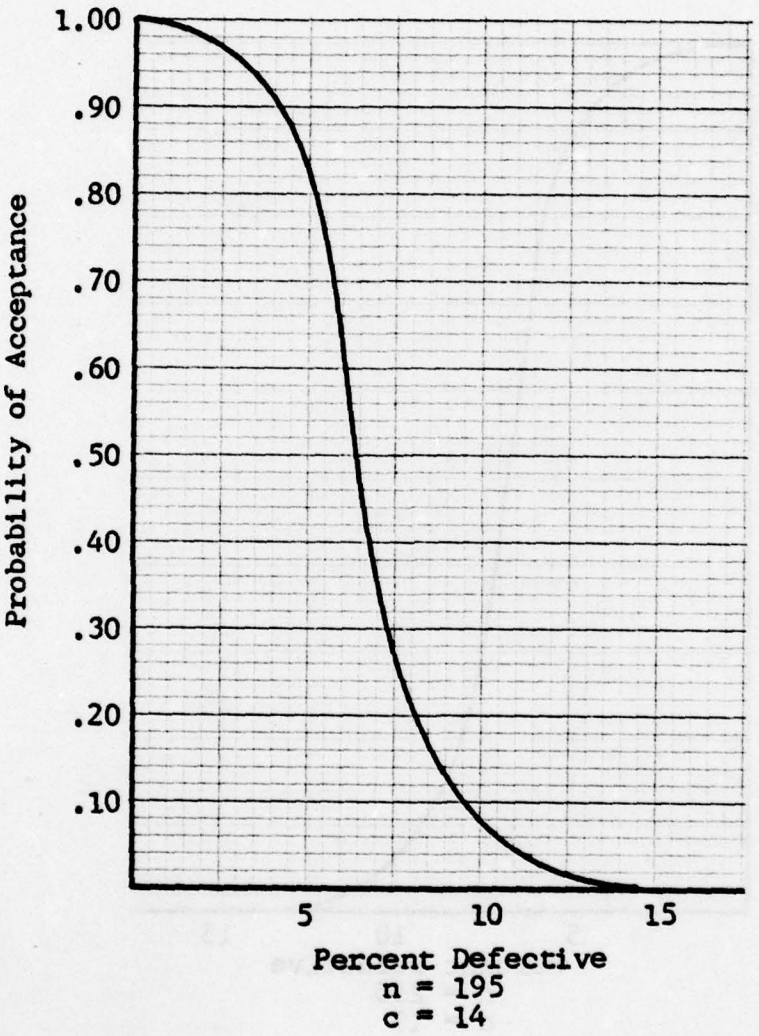

Figure 15. OC-Curve for SSMT

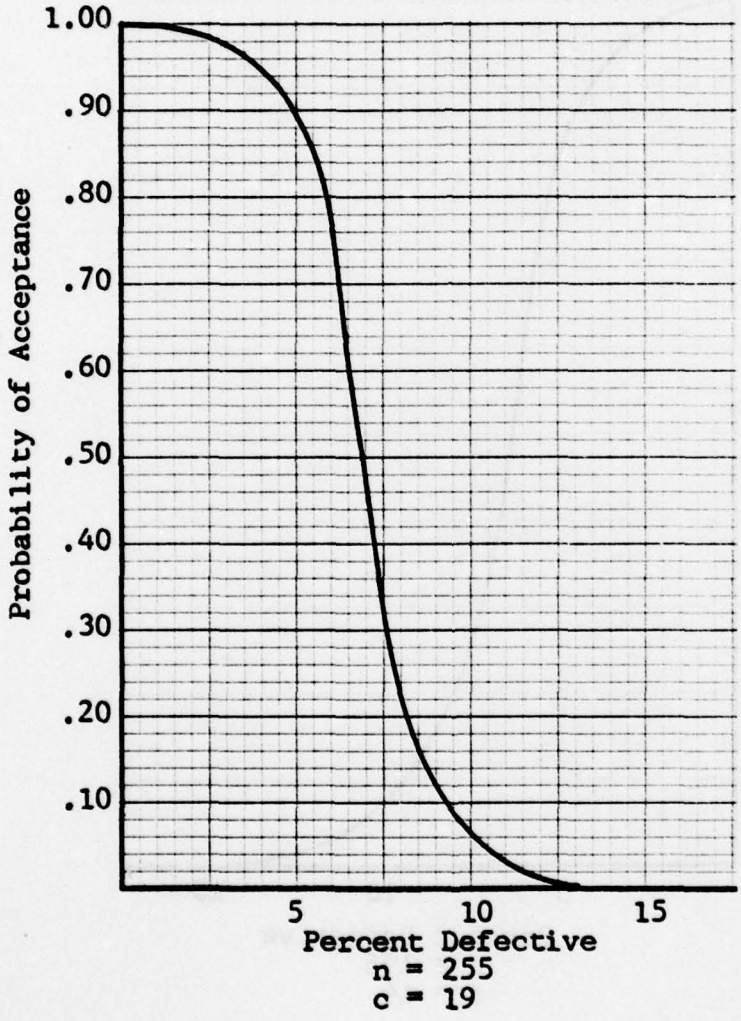

Figure 16. OC-Curve for FMT

APPENDIX B

NUMBER OF MANHOURS SPENT ON INSPECTION
BY QUALITY CONTROL PER SHOP IN 1978

Table 6

Number of Manhours Spent on Inspection
By Quality Control Per Shop in 1978 (5)

1.	Periodic Inspection Teams	
	a. Initial Evaluations	402.96
	b. Annual Evaluations	345.72
	c. Portal to Portal Evaluations	120.12
	d. Special Inspections	576.12
	e. Number of hours spent for evaluation of one maintenance action	10.00
2.	Missile Maintenance Teams	
	a. Initial Evaluations	1151.88
	b. Annual Evaluations	2083.92
	c. Portal to Portal Evaluations	840.00
	d. Special Inspections	705.72
	e. Number of hours spent for evaluation of one maintenance action	10.00
3.	Combat Targeting Teams	
	a. Initial Evaluations	878.64
	b. Annual Evaluations	307.32
	c. Portal to Portal Evaluations	60.00
	d. Special Inspections	417.60
	e. Number of hours spent for evaluation of one maintenance action	10.00
4.	Missile Handling Teams	
	a. Initial Evaluations	360.00
	b. Annual Evaluations	1036.80
	c. Portal to Portal Evaluations	672.36
	d. Special Inspections	244.80
	e. Number of hours spent for evaluation of one maintenance action	10.00

Table 6 (Continued)

5.	Electro-Mechanical Teams	
	a. Initial Evaluations	461.42
	b. Annual Evaluations	1650.48
	c. Portal to Portal Evaluations	300.12
	d. Special Inspections	288.00
	e. Number of hours spent for evaluation of one maintenance action	10.00
6.	Facilities Maintenance Teams	
	a. Initial Evaluations	720.12
	b. Annual Evaluations	249.72
	c. Portal to Portal Evaluations	444.96
	d. Special Inspections	230.40
	e. Number of hours spent for evaluation of one maintenance action	10.00
7.	Site Security Maintenance Teams	
	a. Initial Evaluations	86.40
	b. Annual Evaluations	1219.08
	c. Portal to Portal Evaluations	360.12
	d. Special Inspections	446.40
	e. Number of hours spent for evaluation of one maintenance action	10.00

NOTE: The ten hour figure for number of hours spent evaluating one maintenance action was an average based on the following: (a) one hour to prepare for the evaluation; (b) two hours en route to the missile site; (c) three hours of evaluations; (d) one hour to debrief the team; (e) two hours en route back to the base; and (f) one hour to write up the report. The travel time was an average based on average distance to the various missile sites at GFAFB.

The figure was for maintenance action verification and not for specific technician evaluations. More than one technician evaluation may have occurred during the ten hour period even though only one maintenance action was being accomplished.

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AN ANALYSIS OF THE MINUTEMAN INTERCONTINENTAL BALLISTIC MISSILE--ETC(U)
SEP 79 J M BIERIE , R W COOK , A H LANE

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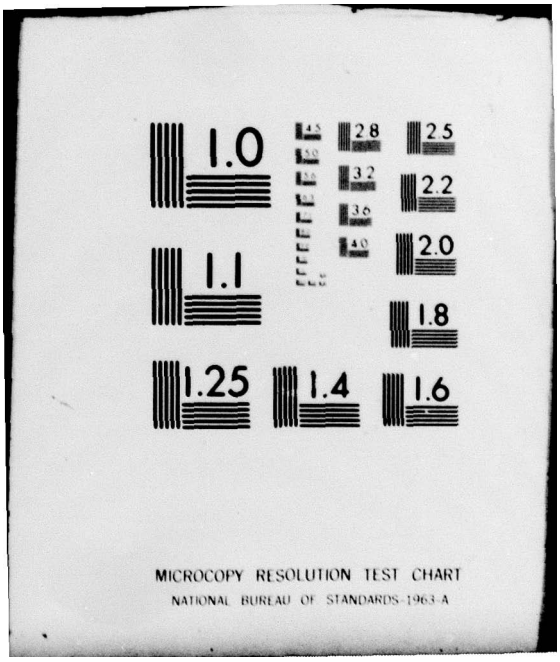
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Chase, Richard B., and Nicholas J. Aquilano. Production and Operations Management. Homewood IL: Richard D. Irwin, Inc., 1977.

2. Dodge, H. F., and H. G. Romig. Sampling Inspection Tables--Single and Double Sampling. 2d ed. New York: John Wiley and Sons, Inc., 1959.

3. Duncan, Acheson J. Quality Control and Industrial Statistics. Homewood IL: Richard D. Irwin, Inc., 1965.

4. Kast, Fremont E., and James E. Rosenzweig. Organization and Management: A Systems Approach. 2d ed. New York: McGraw-Hill Book Company, 1970.

5. Lawhorn, Master Sergeant Samual, USAF. Resource Manager, Det. 18, 3904 Management Engineering Squadron, Grand Forks AFB ND. Personal interview. 14 March 1979.

6. Maintenance Personnel Evaluation System, 321 Strategic Missile Wing, Grand Forks AFB ND. Information retrieved from this system in March 1979.

7. Maintenance Summary, 321 Strategic Missile Wing, Grand Forks AFB ND, December 1978.

8. MIL-STD-105D, "Sampling Procedures and Tables for Inspection by Attributes," 29 April 1963.

9. Mitchell, Major William B., USAF. "Quality Control: A Unit Level Analysis of the Maintenance Standardization and Evaluation Program." Unpublished research report, unnumbered, Air Command and Staff College, Maxwell AFB AL, March 1976.

10. Morehead, Lieutenant Colonel Gail L., USAF. Commander, 321 Organizational Missile Maintenance Squadron, Grand Forks AFB ND. Telephone interview. 12 January 1979.

11. Spivey, Staff Sergeant Kevin L., USAF. Data Analysis Specialist, 321 Strategic Missile Wing, Grand Forks AFB ND. Personal interview. 14 March 1979.

12. U.S. Department of the Air Force. Equipment Maintenance Standardization and Evaluation--ICBM. Strategic Air Command Regulation 66-6, Volume I. Offutt AFB NE, 1977.

13. U.S. Department of the Air Force. Maintenance Management, Intercontinental Ballistic Missile Maintenance. Strategic Air Command Regulation 66-12. Offutt AFB NE, 1977.

14. U.S. Department of the Air Force. Maintenance Management Policy. AFM 66-1. Wash DC: Government Printing Office, August 1978.

15. U.S. Department of the Air Force. United States Air Force Basic Doctrine. AFM 1-1. Wash DC: Government Printing Office, 1977.

16. "Washington Roundup," Aviation Week and Space Technology, July 30, 1979, p. 11.

B. RELATED SOURCES

Anderson, Major Gerald W., USAF. "An Analysis of the Aircraft Maintenance Standardization and Evaluation Program Within the Strategic Air Command." Unpublished research report, unnumbered, Air Command and Staff College, Maxwell AFB AL, 1966.

Cowan, George M. Chief, Quality Assurance Branch, OO-ALC/MAQS, Hill AFB UT. Telephone interview. 15 January 1979.

Daschback, Major Thomas M., USAF. "The Aircraft Maintenance Standardization and Evaluation Program--A Viable Program?" Unpublished research report, unnumbered, Air Command and Staff College, Maxwell AFB AL, March 1977.

Felgenbaum, A. U. Total Quality Control. New York: McGraw-Hill Book Company, 1961.

Flischel, Don C. Chief of Management Quality Systems, General Electric Evendale. Personal interview. 8 February 1979.

Grant, E. L. Statistical Quality Control. 3d ed. New York: McGraw-Hill Book Company, 1964.

Halpin, James F. Zero Defects. New York: McGraw-Hill Book Company, 1966.

Juran, J. R. Quality Control Handbook. New York: McGraw-Hill Book Company, 1962.

Kennedy, Clifford W. Q. C. Methods. Englewood Cliffs NJ: Prentice-Hall, 1948.

Loughridge, Major Charles D., USAF. "A Study of the Strategic Air Command's Aircraft Maintenance Standardization and Evaluation Program." Unpublished research report, unnumbered, Air Command and Staff College, Maxwell AFB AL, May 1975.

McLaughlin, Major Clyde W., USAF. "Lessons Learned from Minuteman Production." Unpublished research report, Defense Systems Management School, Ft. Belvoir VA, November 1974.

MIL-Q-9858A, Quality Program Requirements, 16 December 1963.

Turban, Efrain, and Jack R. Meredith. Fundamentals of Management Science. Dallas TX: Business Publications, Inc., 1977.

U.S. Department of the Air Force. Quality Assurance Plan, Missile Electronics Components. QAP 00-MAK 20-8. Ogden ALC, Hill AFB UT, April 1977.

U.S. Department of Defense. Statistical Quality Control I. Rock Island IL: U.S. Army Management Engineering Training Agency, 1973.