AN ANALYSIS OF MEASURES USED TO EVALUATE THE AIR FORCE CRITICAL ITEM PROGRAM

THESIS

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

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Preface

The purpose of this study was to evaluate the potential of two measures, percent defects and cycle time, to measure overall performance of the Air Force Critical Item Program (CIP). The need for such study was generated from the current absence of any measurement system available to evaluate the CIP. This research used these two measures with actual data, evaluated the correlation between aircraft availability and percent defects and cycle time, and analyzed management perceptions addressing the usefulness of these measures for field use. Performance of this analysis resulted in support for these measures by over two thirds of the critical item managers interviewed. As a result, this study concluded that both of these measures, percent defects and cycle time, could be useful to the Air Force in managing the CIP effectively.

Several individuals were instrumental in the successful completion of this study. First and foremost in this effort were the contributions of my thesis advisor and reader, Lt Col Larry W. Emmelhainz and Capt John Sullivan. These two individuals were of invaluable assistance in guiding the proper direction of this research. I am also deeply indebted to all others who provided insight and direction of the problem at hand. In this respect, I would especially like to thank the assistance of Mr. Luis Correa, Mr. Ed

Kroutsdorfer, and Mr. Cristopher Lynch. I would also like to thank the efforts of Capt Jill Page and Ms. Helen Hartness who were instrumental in providing actual data, without which this study would not have been successful. Finally, I extend my deep gratitude to all critical item managers who were involved in the interview process. Their input and opinions were the cornerstone upon which the conclusions of this study lay.

Robert R. Lee

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AN ANALYSIS OF MEASURES USED TO EVALUATE THE AIR FORCE CRITICAL ITEM PROGRAM

I. Introduction

General Issue

The Air Force critical item program is a dynamic management process crucial to the effective and efficient support of Air Force weapon systems. It is a program that has been gradually developing from 1967 to present. During this time the program has suffered difficulties preventing it from achieving its full potential. One of the current shortfalls of the program is the nonexistence of measures to evaluate its performance. Recognizing this shortfall, this study evaluates two quality control measures for use in evaluating the performance of the Air Force Critical Item Program.

Background

> Even more than before, the progress of any war that involves something more than a walkover will be in part determined by the speed with which material can be moved from the rear to the front and allocated to the units most in need. (20:69)

The rapid build-up of American forces during Operation Desert Shield resulted in the re-identification of shortfalls associated with current Air Force Information Systems. The C-141 System Program Manager identified these shortfalls during surge of Air Logistic Center (ALC) activities while supporting Operation Desert Shield (21)

The basic cause identified was the inability of Air Force Information Systems to provide accurate asset reporting information vital to the management of surge efforts (21). Without such information, the System Program Manager's ability to make crucial surge management decisions markedly decreases. The existing systems generated information that, according to SAFE reports, dated back as much as a year. Other reports produced data which required extensive manual manipulation to provide up-to-date asset levels and specific support problem areas (21). Based on these shortfalls, the C-141 System Program Manager (SPM) requested a study be conducted to determine what information systems, if any, were capable of supporting surge management requirements.

Further investigation of the surge process and available supporting information systems uncovered several Air Force management and development efforts in this problem area. These discoveries helped focus this study specifically on problems surrounding the heart of the surge operation -- the critical item selection process.

Critical Item Management

As stated earlier, the C-141 SPM identified a problem in extracting accurate information to make time-sensitive surge decisions. To understand the impact of this shortfall a review of the surge management process is beneficial.

At the start of the surge process, the SPM must establish a prioritized critical item list prior to fully coordinating and implementing other activities. Foremost in this process is the identification of those items in critical support status most contributing to a weapons system's inability to perform its primary mission (21). A critical item is determined by applying certain criteria measuring the unavailability of that item on its respective weapon system. A critical item is officially defined by AFM 67-1, Volume 1, Part One, Chapter 26 as "those items having the most detrimental impact on mission performance" (15:26-9).

Upon attainment of a prioritized critical item list, activities such as realignment of personnel, expansion of the work week, expedition of contracts, and expedition of repair can be focussed to those items with highest priority on the critical item list (29:4). Items crucial to mission performance, such as aircraft landing gear, qualify as critical items if they meet specific major command (MAJCOM) criteria for degraded support. Items identified as critical receive increased management and resource support with the goal of maximizing weapon system availability.

History of Critical Item Management

In some form, the Air Force Critical Item Program has existed since 1967. The first critical item program was called the "High NORS (Not Operationally Ready Supply) Critical Item Program" (43:1). Like the current program, the goal of the High NORS Critical Item Program was to increase weapon system availability by improving critical item asset support (43:1).

Through the years several studies and audits have identified flaws in this program. Starting in 1967, these studies addressed subjects such as problem forecasting, development of mathematical formulae, criteria bias and evaluation, appropriate management action, and model development (40; 48; 11; 43; 2; 4). A 1986 study by the Air Force Logistics Management Center (AFLMC), served to redefine the critical item management process (7). This study, conducted through MAJCOM and AFLC request, analyzed the criteria and procedures used to identify critical items (7:iii). Conclusions from this study recognized that the CIP was reactive, did not consider sustainability shortages, was one dimensional (considered only one criterion), was manually work load intensive, lacked communication between item managers and the MAJCOMs, and had corrective actions which indirectly reduced supportability by reducing worldwide demand rates (7:29). As a result of this study, the Air Force implemented a regulation attempting to formalize the AFLMC recommendation to require the use of multidimensional criteria (7:29). The structure of the current CIP is based on the conclusions and supporting recommendations of this report.

Current Status of Critical Item Management

Application of the AFLMC recommendations and the introduction of improved management information system capabilities have provided today's managers with potentially powerful management tools. In efforts to improve the program, AFLMC recommendations brought about the institution of a three tiered categorization for degraded support items. These three tiers cited from least to most important are "Problem," "Potential Critical," and "Critical," (15:26-9). Under the new guidance, items subject to critical item management should meet the third hurdle (critical), while items in the first two hurdles were to be watched carefully (7:20-23).

Current guidance requires that CIP selections be based on one or more of these criteria (15:26-8). These criteria (discussed in detail in Chapter II) have nine categories including weapon system factor, monthly mission capable (MICAP) hours, monthly MICAP incidents, yearly MICAP incidents, yearly awaiting parts (AWP) incidents, single point failures, MAJCOM developed parameters, and supply assistance follow-up procedures (15:26-8). Individual MAJCOMs are responsible for tailoring specific guidelines within these criteria to establish critical item selection

(15:26-5). Based on current guidance, MAJCOMs have final approval authority for all items included and excluded from the CIP (15:26-10).

Relatively new management information systems are also available to aid managers in the critical item selection process. The Weapon System Management Information System (WSMIS)/Get-Well Assessment Module (GWAM) (22) is specifically designed for this purpose. WSMIS/GWAM, based on input from numerous other Air Force information systems, generates a critical item candidate list (22:2-4). This list is individually tailored to each MAJCOM by using specific criteria to analyze items recommended to the critical item candidate list. In turn, each MAJCOM and SPM then accomplish a review of the critical item candidate list to identify those few exceptions not identified by WSMIS/GWAM that they judge should be elevated to critical item status. Ideally, the WSMIS/GWAM list should identify 60-80 percent of the those items approved as critical by the MAJCOMs (36). A list with this accuracy would enable the MAJCOMs to rely on WSMIS/GWAM for primary critical item selection rather than the manpower intensive manual method currently used. Because a cap exists on the maximum number of items in the CIP, the MAJCOM and SPM are required to negotiate the contents of the final list (15:26-7). Items have to be eliminated if more critical items are identified than officially authorized. As stated earlier, the MAJCOM has final authority on all items included or excluded in the CIP.

Problems Associated With the Current Critical Item Program

In spite of the changes made in the late 1980's, a recent audit by the Air Force Audit Agency, AFAA/QLS, has identified numerous problems with the CIP. Audit Agency findings include inconsistencies in CIP guidance, low utilization of WSMIS/GWAM management products, inconsistent use of MAJCOM criteria, and misuse of the CIP for less than critical items (12).

The Audit maintains that CIP official guidance contradicts itself (12). According to AFM 67-1, Volume I, Part One, Chapter 26, Section 7, Paragraph a, critical item selection will be based on multidimensional criteria. Shortly following in this same paragraph, it states a requirement that only one criterion is necessary to justify critical item selection (15:26-8). In addition to being confusing, this guidance defeats the purpose of multidimensional criteria by allowing selection of critical items based on only one criterion (12). The guidance also contradicts conclusions stated in the AFLMC report which identified the inadequacy of one dimensional criterion for critical item selection (7:29).

The Audit Agency conducted random sampling of information systems associated with the critical item management process. These samples were taken from Strategic Air Command (SAC) and Tactical Air Command (TAC) programs from 14 June 1990 to 1 August 1990 (12). Results of the sampling are as follows:

> SAC/14 June 1990. Of 206 items on the WSMIS/GWAM Critical Item Candidate list for SAC, 30 items were randomly selected. Of these 30 items, 16 items (53%) were not identified in the MAJCOM approved CIP list.
>
> SAC/1 July 1990. Of 202 items in the SAC CIP, 30 items were randomly selected. Of these 30 items, 16 items (53%) had not been identified as critical by WSMIS/GWAM.
>
> TAC/1 August 1990. Of 318 items in the TAC CIP, 30 items were randomly selected. Of these 30 items, 11 items (36%) were not on the WSMIS/GWAM Critical Item Candidate list.
>
> TAC/1 August 1990. Of 403 items coded critical on the WSMIS/GWAM Critical Item Candidate list for TAC, 30 items were randomly selected. Of these 30 items, 16 items (53%) were not identified in the MAJCOM approved CIP. (12)

These samples strongly indicate that MAJCOM selected critical items and those selected by WSMIS/GWAM are inconsistent.

Other Air Force Audit Agency reviews identified numerous items in the CIP which did not meet any of the MAJCOM specified criteria (12). Many of these items had been in the program for several months (up to nine months in some instances) while never meeting critical status criteria, including the time of their initial entry to the CIP (12). Current guidance (15:26-12) requires deletion of CIP items from the program if they meet standard thresholds for the previous three months. Items attaining these thresholds are referred to as "well." Audit findings that "well" items remain in the CIP in upwards of nine months suggests a lack of proper management attention to the program. It is appropriate to reiterate that for every item in the CIP, another critical item not in the CIP is prevented entry due to the established cap. Thus when "well" items remain unchecked, limited funding and resources are needlessly wasted. This finding suggests that management must be more attentive to ensure items remain in the CIP only as long as necessary.

Telephone interviews with critical item managers in the field indicated a low confidence level in items identified by the WSMIS/GWAM critical item candidate list (52; 54). These managers indicated that because of the low correlation of the WSMIS/GWAM critical item candidate list to the MAJCOM approved critical item list, the WSMIS/GWAM list was currently of little value. This last observation is very disturbing to managers due to the enormous sum of money invested in WSMIS/GWAM to automate the critical item selection process (36).

In summary, the critical item management process has been in existence for over two and a half decades. It was originally designed to be a proactive management tool with the goal of improving weapon system availability. Over the past two and half decades, numerous Air Force studies and audits have identified significant and recurring defects in the program. Implementation of study and audit recommendations have been very slow. As a result, these defects continue to limit the achievement of the program's true potential. Though management has addressed deficiencies on an individual basis, there are currently no measures to evaluate the performance of the program as a whole (36). Thus, inherent defects within the program are retained and continue to impair its performance. To address this situation, the quality literature suggests measures could be instituted which might provide management with an overall perspective of the CIPs performance. With measurement/control devices in place, the Air Force could incrementally identify and correct individual problems affecting the success of the CIP.

Quality Control Applications

> The ideal unit of measure provides an agreed basis for decision making...is understandable...applies broadly...is susceptible of uniform interpretation...is economic to apply...and is compatible with existing designs of sensors. (32:76-78)

Review of quality control literature indicates that the use of statistical quality control (SQC) techniques are applicable to the problems encountered by the CIP (8; 10; 23; 24; 32; 39; 55; 50). Specifically of interest are two measures, percent defects and cycle time, which have been used by several top quality management performers. These measures have aided corporations in attaining substantial quality improvements that would not have otherwise been achieved (50; 37:108).

The first measure of interest is percent defects. Unlike the common meaning of defective, in the context of SQC it means a failure to "conform to specifications in some respect" (24:17-18). Therefore, a defect is a single failure to conform to one specification (24:18). Using these definitions of defective and defect, the measure of percent defects can be applied to a service or production application. According to Juran, percent defects falls under his third species for units of measure associated with errors and failures (32:72). Looking specifically at the CIP, several conditions can be defined as a defect. Even though each MAJCOM establishes tailored critical item selection criteria, standard defect conditions can be globally applied to the program as a whole. Examples of these defect conditions include:

1. Items in the CIP which do not meet established critical item selection criteria. For example, items achieving a "well" status that continue to be carried in the CIP.

2. Items that do meet critical item selection criteria that are not in the CIP.

3. Items that enter and leave the CIP on a recurring basis.

Using percent defects as a measure, the Air Force could establish a tool that identifies changes in CIP performance. This should encourage CIP managers to decrease the number of defects and create an environment for continual improvement.

As indicated earlier, recent application of this quality control measure has resulted in substantial quality improvements for private industrial firms such as Motorola and Xerox (37:104,108; 50). The improvements made by these two firms clearly demonstrate the considerable benefits of using SQC methods.

The measure of percent defects by itself, however, is not enough. A measure is needed that addresses the problem of items remaining in the CIP longer than necessary. This type of measurement device must be established to provide incentive for managers to improve the status of critical items and to ensure the overall program continues to improve (17). Without such a measure, managers might be tempted to manipulate the program to give the perception of better performance when in reality there is no improvement. Cycle time provides such a measure. This measure falls under Juran's first classification of measure at the technological level (32:72). In the context of this study, cycle time is defined as the time spanning from when an item enters the CIP to the time an item leaves. Like percent defects, cycle time is also used by Motorola in its SQC program. Benefits derived from this measure have decreased delivery rates for Motorola by over 27% (37:108). Cycle time also appears potentially applicable to all MAJCOMs.

Problem Statement

While the CIP is known not to work well, no specific measures of the program exist. The quality literature suggests that two measures, percent defects and cycle time, might work; however, no one has evaluated these measures with respect to managing the CIP.

Overall Objective

Together, measurement of percent defects and cycle time could identify trends in the performance of the CIP with respect to meeting its goal of increasing aircraft availability. Identification of these trends would enable the Air Force to react proactively in resolving problems and institute continuous improvement. Therefore, the overall objective of this thesis is to test the proposition that the measures of percent defects and cycle time can provide the Air Force with a useful tool for evaluating the performance of the CIP.

Investigative and Measurement Questions. To answer the question posed in the problem statement, two investigative questions are addressed. In turn, to satisfy each investigative question, several measurement questions are identified. Methodology for the determination of problem statement conclusions are discussed in detail in Chapter III. The two investigative questions to be applied and their associated measurement questions are as follows:

Investigative Question #1. Does measurement of percent defects aid the Air Force in managing the CIP effectively?

Associated Measurement Questions:

1. Do items in the CIP meet MAJCOM criteria IAW AFM 67-1?

2. Do items in the CIP correspond to items identified by WSMIS/GWAM?

3. Do items enter and leave the program on a recurring basis?

4. How does this measure correlate to aircraft availability in terms of total not mission capable (MICAP) period hours?

5. Do CIP managers find this measure useful?

Investigative Question #2. Does measurement of cycle time aid the Air Force in managing the CIP effectively?

Associated Measurement Questions:

6. What is the variation in time for items managed in the CIP?

7. How does this measure correlate to aircraft availability in terms of total MICAP period hours?

8. Do CIP managers find this measure useful?

Scope

The scope of this study is directed at validating measurements for performance evaluation of the Air Force

CIP. Due to availability of historical critical item program data and the currency of criteria programmed in WSMIS/GWAM, only Strategic Air Command (SAC) data were collected. Specific weapon systems analyzed within SAC include the B-52, B-1, F-111, C-135, and E-4 aircraft. Critical item data were collected and analyzed beginning June 1990, commensurate with the latest update of the SAC WSMIS/GWAM critical item candidate selection criteria.

Assumptions and Limitations

Though data collection is limited to SAC, findings should be applicable to other Air Force Major Commands. This assumption is based on the similarities existing between MAJCOM programs and the problems experienced by each. However, due to limitations of access to comprehensive longitudinal data, conclusions of this study are subject to some uncontrollable bias. Therefore, this study establishes a baseline for the value of these measures, but does not provide significant statistical proof.

Chapter I Summary

The purpose of the Air Force CIP is to provide a proactive management tool to identify and improve the status of assets that are most degrading to weapon system availability. Numerous and recurring problems have prevented this program from accomplishing that goal for the last two and a half decades. The apparent reason for these shortfalls is the lack of CIP overall management controls.

The overall objective of this study is to test two measures that might provide a means of evaluation for the CIP. These measures, if validated, should provide an evaluation of the current status of the program and a means to promote continuous improvement.

Chapters II and III provide detailed insight into the background of this issue and the methodology by which it is approached by this study. Chapter II reviews current literature concerning the status and history of the critical item program and applicable quality control measurement techniques available. Chapter III establishes the applied methodology to determine conclusions addressing the problem statement. Chapter IV identifies the findings discovered through implementation of the stated methodology. Finally, Chapter V provides the conclusions and recommendations based on the findings from Chapter IV.

II. Literature Review

Introduction

As identified in Chapter I, numerous studies and audits have been accomplished addressing the critical item program (CIP). These studies began appearing almost at the same time the first critical item management program was developed. Though numerous, publication of these studies have not followed a continuous time-line. Instead, Air Force concern for this program appears to come in strides of great interest followed by periods of relaxed attention. This may explain why the CIP still contains many of the problems initially identified two and a half decades ago.

To further establish the basis of this research, this chapter discusses the literature available on all aspects of the critical item program. It begins with a review of early program development, including initially discovered problems. A chronological development details the important aspects of the program and provides the reader with a logical progression resulting in its current status. The history of the critical item program is followed by review of the integration and improvement of new automated information system capabilities which have greatly added to its performance. Problems identified in Chapter I are discussed in much more detail in this chapter to ensure full understanding of the topic.

Also important to this research is a review of available quality control literature. The selection of measurement instruments is of key importance to any scientific research. As such, a review of quality control measures provides the reader with a better understanding of the methodology used by this study. Therefore, applicable statistical quality control measures are also reviewed.

Critical Item Program Development

> Placing the right resources at the right place when they are needed has been the logistic objective since the cave man started throwing rocks. (44:1)

1967 to 1971. The Air Force Critical Item Program (CIP) was originated in September 1967 with the establishment of Headquarters Air Force Logistics Command Regulation (AFLCR) 67-21 (43:1). Originally this program was called the High Not Operationally Ready Supply (NORS) Critical Item Program (43:1). The time frame of this program's development fell around the midpoint of the Vietnam War. As it still is now, the goal of the critical item program was to increase weapon system availability by improving the asset status of those items most contributing to a weapon system's inability to perform its mission. With weapon system availability being of significant concern during a war, it is understandable why this program received so much attention at the time.

Just prior to the implementation of AFR 67-21, several master's theses were accomplished in this management area. In 1967, Captains Philip Norton and Arthur Tennyson attempted to establish two objectives concerning critical item forecasting. They were successful in demonstrating their first objective, that causes of criticality, directly related to changes in consumption rates, contributed to a significant portion of items in a critical supply status (40:86). However, their second objective, to develop a mathematical formula to identify critical items by comparing a support capability to the actual consumption rate, was unsuccessful (40:87).

Also at this time Mr. Kenneth Seifert and Captain Martin Nakunz addressed a similar issue. Their objectives were three fold. Their first objective confirmed that Air Force methodology for computing demand levels of repair cycle assets at base level still inflated the total demand levels for Interchangeability & Substitute (I&S) Groups (48:58). Their second objective established that there was a lack of compatibility in reporting systems used by Air Materiel Areas (now called Air Logistic Centers) and the base level (48:59). These authors maintained that "lack of compatibility casts serious doubt upon the reliability and integrity of NORS requisitions for critical items within the Air Force supply network" (48:59). Their third objective determined that Air Materiel Areas used differing approaches for critical item management (48:60). Approaches were found significantly different for the management of reconciliation procedures. Seifert and Nakunz recommended that further study be accomplished addressing the interface of requirement determination and materiel distribution systems (48:61).

A 1968 study by Captains Stanley Condojani and Warren Welsh accomplished an analysis of critical items of cargo aircraft. Their two objectives were first, to determine the distribution of critical items with respect to Federal Supply Groups (FSG); and second, to determine if there was a valid technique for predicting their occurrence (11:7). For their first objective, they concluded that FSGs 16 (aircraft components and accessories) and 66 (aircraft instruments) comprise 68.3% to 87.4% of all cargo aircraft critical items (11:78). From their second objective they determined that a correlation between critical items and flying hours existed (11:78). They also determined that the higher the flying hours the better this correlation becomes (11:78). Based on their conclusions, they recommended a mathematical factor be developed for requirements computation. The factor would be a function of expected average monthly increase in flying hours with the purpose of preventing critical item development (11:79).

In 1969 Ms Florence Phillips and Captain Floyd Hooks evaluated the NORS selection criteria for the selection of High NORS critical items (43). Their study was based on concerns raised by both audit and field conclusions that critical item selection criteria were biased in their selection of critical items. The criteria of specific concern were of weapon system items having over 1000 identified NORS hours and requiring longer than 60 days to fill back orders for Uniform Materiel Movement and Issue Priority System (UMMIPS) priority codes 01 - 08 (43:41,52; 4). According to audit and field conclusions, the criteria identified items for critical management that did not impact high flying hour mission aircraft, while simultaneously preventing low flying hour mission aircraft from much needed management resources (43:51). Data collected by Phillips and Hooks were inconclusive in proving their hypotheses; however, data were significant enough to encourage future studies in this area.

In 1971, Captains Raymond Agnor and Douglas Topping further addressed the subject of criteria bias based on weapon system fleet size (2:39). From their study they established three conclusions. First, by comparing fleet sizes, they determined that fleets with a larger population of aircraft had a lower average number of NORS hours per aircraft than did smaller population fleets (2:39). Second, they established that due to current criteria, items with a higher average number of NORS hours per aircraft were not selected as critical over items with lower averages (2:45). Their final conclusion found "that applying a weighted average number of NORS hours per aircraft better identifies those items most adversely affecting mission capability of operational aircraft fleets" (2:60). As a result of these conclusions, Agnor and Topping recommended further refinement of critical item selection criteria (2:70).

1982 to 1986. As mentioned at the beginning of this chapter, the Vietnam War most likely influenced the degree of interest placed on the critical item program during the late 1960s and early 1970s. During this time frame at least five masters theses, one audit, and an unknown number of field studies were accomplished addressing this subject area (40; 48; 11; 43; 2; 4). However, after the early 1970s, a definite lull in the literature for critical item management took place. This lull can presumably be attributed to a decrease in management attention to the subject. It is not until the mid 1980s, more than ten years after the above literature, that renewed interest in this area is found.

In 1982, an Air Force Audit Agency report identified more deficiencies in critical item management (5). The audit found "numerous instances of critical items not being intensively managed, while erroneously designated critical items were being afforded special attention" (5:executive summary). The audit also revealed that items in the critical item program took times ranging from four to twenty months before leaving the program (5:4). The auditor concluded that quarterly review of critical items by Air Logistic Centers (ALC) was inadequate to improve the readiness posture of aircraft (5:4). The report recommended a more frequent review be conducted of the program. Other conclusions found that "uniform procedures were not established to monitor the addition and deletion of items to the critical item program" (5:6).

In 1985, yet another masters thesis was accomplished addressing critical item performance. Mr. David Thomson analyzed the critical item performance of the Gardner-Dannenbring Aggregate Inventory Model. His objective was:

> to determine if the aggregate model's critical item performance can be improved by modifying the model to discriminate between critical and non-critical items and compute stockage policies which will concentrate on reducing the number of back orders for critical items. (53:4)

Based on Mr. Thomson's conclusions, he recommended that:

> minimal critical item back orders is a more operationally oriented supply objective than variable costs or maximum fill rates because the importance of the items is recognized and priority is given to those items which can cause an aircraft grounding. (53:40)

Mr. Thomson's study was the first to examine the application of a specific inventory model to nuances surrounding the critical item program.

A 1986 follow-up audit of the 1982 audit found that, though addressed, 1982 audit recommendations had not been adequately resolved by management (3:4). The findings of this audit highlight the slow improvement process that the critical item program has demonstrated from its inception.

This same year (1986), the Air Force Logistics Management Center (AFLMC) performed a complete study of the Air Force critical item management program (7). The conclusions and recommendations from this study served to revamp the entire program resulting in significant improvements. Because this study had such a large impact on management of the current critical item program, its findings and conclusions are addressed in detail.

This study, AFLMC Project LS841129, was conducted based on Major Command (MAJCOM) and ALC requests from the Fourth Critical Item Conference (7:iii). Concerns of these organizations, reflected the same problems identified by the 1982 and 1986 audits referenced above. To satisfy these concerns, AFLMC identified the following objectives (7:1):

1. Review and evaluate the current critical item system.

2. Evaluate possible alternative criteria from identifying critical items.

3. Determine who should identify a critical item.

4. Recommend standard critical item criteria.

5. Recommend changes to the critical item system.

In addressing the objectives, AFLMC first reviewed the current critical item program criteria. These criteria, as stated above, are mainly based on MICAP hours (hours attributed to a weapon system not operational due to supply or maintenance actions, originally referred to as NORS). In this review, AFLMC found that the definition of a MICAP incident had changed several times from 1970 to 1982 (7:2). These definitions were as follows:

1970 - If more than one item was grounding a weapon system, only one item was a MICAP.

1974 - All items grounding a weapon system could be called a MICAP.

1976 - Any item keeping an engine unserviceable could be MICAP.

1977 - Various types of support and communications equipment could be MICAP reportable.

1978 - Any item with a MICAP reportable standard reporting designator (SRD) could experience MICAP conditions.

1982 - The Air Logistics Center's Program Depot Maintenance lines could use the Force Activity Designator (FAD) of the owning command for aircraft and an item preventing a functional flight test could be MICAP if the flight test was scheduled within eight days.

These changes in MICAP definition, though not affecting the CIP directly, do reflect the Air Force's increased ability to analyze data (7:2).

In their analysis of the system, AFLMC found two problems in addition to those identified by the 1982 audit (7:4). The first problem identified the current system as reactive. This was due to the absence of a system to detect potential problems. The second problem identified the current system as manually workload intensive. Item managers were required to manually accomplish AFLC Form 74, Critical Item/Warstopper Data for each item attaining the MICAP hour criteria. This form required extensive research and data to complete properly, creating an enormous workload (7:4).

AFLMC also collected AFLC and Strategic Air Command (SAC) MICAP data in order to analyze the critical item program (7:4). From analysis of AFLC data they discovered that approximately 33% of managed items remained critical for over one year (7:4). In addition they found that two to three percent of the critical items managed returned to the program within one year after having initially left (7:4). From analysis of SAC data they discovered that 83% of the items meeting critical item criteria had not been included in the critical item program (7:5). Failure of the MAJCOMs to include such items in the critical item program had been a point of contention with AFLC for some time (7:6).

In search for new criteria, AFLMC tested weapon systems impact ratio as a possible alternative to monthly MICAP hours. Weapon systems impact ratio (WSF) i' calculated as follows:

$$\text{WSF} = \frac{\text{Total MICAP Hours for a Stock Number}}{\text{Total Possessed Hours for the Weapon System}}$$

In their analysis, AFLMC found both criteria appropriate predictors of future problem items (7:11). However, they also found that the MICAP hour criteria was biased towards larger population aircraft systems while the WSF criteria was biased towards lower population aircraft systems (7:12).

Based on a review of the past literature and from their first hand analysis, AFLMC determined that certain selection and management criteria must be attained by the CIP for it to be successful (7:17). AFLMC's selection and management criteria were as follows:

Selection Criteria. The CIP must be able to:

1. Rank items according to weapon system impact.

2. Identify pre-critical categories.

3. Include items that affect sustainability as well as readiness and awaiting parts.

4. Use more than one dimension to select items.

5. Identify the overall weapon systems impact.

Management Criteria. The CIP must:

1. Reduce the manual workload associated with evaluating and monitoring critical items.

2. Be proactive; it must be able to identify and prevent items from becoming critical.

3. Identify different categories of critical items, so that items that cannot get well in the near term are not excessively monitored.

4. Communicate to all MAJCOMs and bases what items are in (or not in) the program, "get well" actions, and the "get well" date.

5. Review all actions to improve the supportability of the item, including increasing the worldwide requirement.

6. Ensure expediting action does not decrease the capability to support the item by reducing the worldwide requirement.

7. Intensively manage all items that severely impact mission support, including War Readiness Materiel shortages, and component parts generating awaiting parts (AWP) conditions. (7:17)

Aware that modules developed for the Weapon System Management Information System (WSMIS) would improve mass quantification of data, AFLMC recommended a three tiered categorization for degraded support items be instituted to address the above requirements. The three tiers recommended from least to most critical respectively were: potential problem, problem, and critical (7:20). AFLMC maintained that early identification of potential problem and problem items would provide a proactive capability within the program. AFLMC also proposed multidimensional criteria for distinguishing items among the three tiers (7:21). AFLMC emphasized the importance of multidimensional criteria versus critical item selection based on only one data point (7:22).

Final conclusions and recommendations from this study include (7:29):

Conclusions.

> 1. In the past, the Air Force Critical Item Program has been reactive and relatively ineffective.
>
> 2. The current Critical Item Program does not consider war reserve materiel (sustainability) shortages nor does it consider component parts that severely impact the repair of end items for weapon systems.
>
> 3. The Critical Item Program Selection Criteria is one-dimensional, and does not adequately consider the impact on a weapon system.
>
> 4. The Automated Critical Item Network (ACIN) and the Weapon Systems Management Information System (WSMIS) will reduce the manual work load and should significantly improve the Critical Item Program.
>
> 5. Our proposed item selection criteria is proactive, multi-dimensional, and considers an item's impact on both weapon systems readiness and sustainability.
>
> 6. A coding scheme to identify and communicate item manager actions to the MAJCOMs should improve the management of critical items.
>
> 7. Actions taken once an item is added to the Critical Item Program may reduce pipeline times, thereby reducing the worldwide demand level and decreasing the supportability of that item.

Recommendations.

> 1. Continue to support the implementation of the Automated Critical Item Network (ACIN) and the Weapon System Management Information System (WSMIS).

2. Service test AFLMC proposed critical item selection criteria for SAC in March 1987 as part of WSMIS.

3. Approve AFLMC proposed critical item selection criteria.

4. Develop a coding scheme to identify and communicate item manager actions to the MAJCOMs.

5. Modify the Standard Base Supply System and the Air Force Logistics Command requirements system to ensure base and depot repair times and order ship times are not reduced for critical items.

Based on application of the AFLMC recommendations and the introduction of improved automated management information system capabilities, today's managers possess potentially powerful management tools. Before further describing the process and policy of the current critical item program, it is appropriate to describe the structure and development of the automated critical item information systems available today.

Automated Information Systems

> The core logistics functions of Requirements, Acquisition, Distribution, and Maintenance are so dependent upon information systems that only a fraction of the normal peacetime business could be conducted without them. (6)

As indicated earlier, the most significant automated information system used in critical item management is WSMIS. WSMIS was created to support wartime objectives and functions of Air Force Logistics Command (22:2-2). Currently, WSMIS is composed of four operational modules. These modules are the Readiness Assessment Module (RAM), Sustainability Assessment Module (SAM), Requirements

Execution Availability Logistics Module (REALM), and the Get Well Assessment Module (GWAM) (22:2-2). The three modules used in critical item management are SAM, RAM, and GWAM.

> SAM projects the number of sorties that can be flown and the number of available mission-capable aircraft, based on wartime tasking and logistics resources. SAM uses operational plans, logistics performance factors and logistics resource data, and other Air Force data systems to assess how well current logistics resources will meet combat objectives. SAM identifies those items that are projected to prevent weapon systems from achieving their wartime objective of generating sorties and passes this information to GWAM. (22:2-4)
>
> RAM determines the readiness of the weapon system and materiel resources required, including aircraft, engines, and support equipment to conduct wartime missions. RAM's objectives are to provide quantitative measures of readiness as close to real-time as possible. RAM must also identify the readiness-limiting items so that they may be passed to GWAM for Get-Well Plan development. (22:2-4)
>
> GWAM accepts the problem parts data identified in RAM and SAM, along with information from other data systems, and provides the IMS with the information to develop solutions for these problem items. GWAM must provide the necessary information and tools, so that the SPM, SCO, and IMS may make educated decisions about how to manage AFLC's resources and provide the required wartime support. (22:2-4)

The current WSMIS operational architecture is displayed in Figure 1 (22:2-7).

The WSMIS module that pulls all critical item program information together is GWAM. Using SAM, RAM, and various other data bases, GWAM is responsible for tracking all approved critical items. The overall objectives of GWAM are to provide all levels of management the status of efforts to solve inadequate logistics support of items (22:2-6). This is achieved by ensuring the specific objectives of GWAM

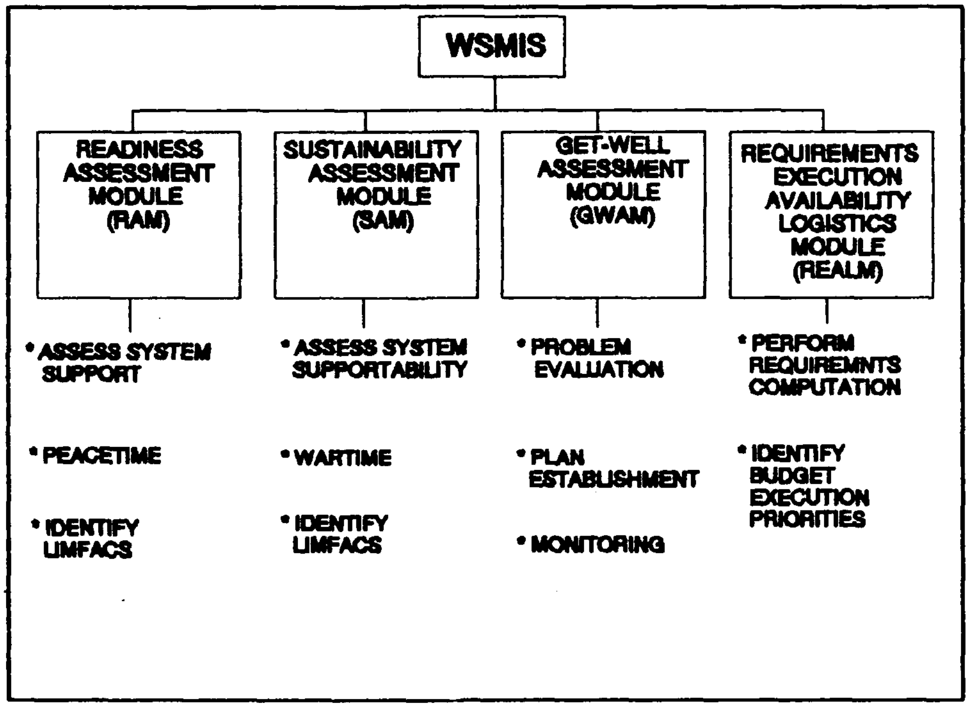


Figure 1. WSMIS Operational Modules

(Figure 2) are accomplished. These specific objectives are:

1. To provide an automated tool to support the CIP

2. Provide on-line access to Limiting Factor (LIMFAC) data and identify those that are most critical

3. Identify the problems that created the LIMFAC

4. Aid in the development of get-well plans

5. Track get-well plan implementation. (22:2-6)

GWAM outputs are generated from all four sub-modules identified in Figure 2 (22:4-10). These outputs include: the Problem Item Summary, the Critical Item Summary, the SAFETRACK report, the Potential Critical Item Listing, the SAM 30 Day Problem Item Listing, the Get-Well Status Listing, the Location of Assets Report, the Problem Indicators Report, and the Central Leveling Item System

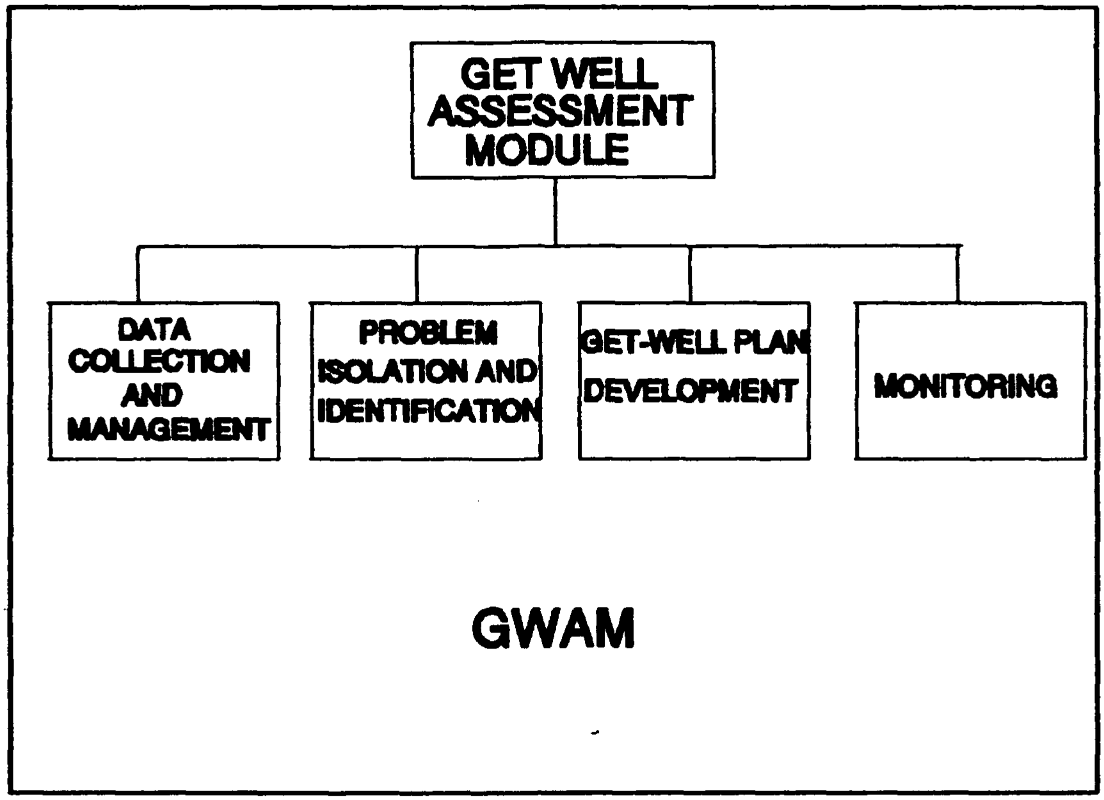


Figure 2. GWAM Overview Diagram

Report (22:4-10,4-12). A short summary of each of these reports is provided below.

Problem Item Summary. Displays the current problem items from the four file sources: Critical Item, Potential Critical Item, SAM Wartime Sustainability Problem Items, and SAFETRACK items (22:4-10).

Critical Item Summary. Used by critical item management to review critical item workloads and to monitor status of the assigned critical items (22:4-12).

SAFETRACK. Shows the Peacetime Operating Stock (POS) levels and on-hand quantities (22:4-12).

Potential Critical Item Listing. Lists ranking national stock numbers (NSN) by high population and low population engine hours (22:4-12).

SAM Day 30 Problem Item Listing. Lists the current wartime problem items by reporting organization (22:4-12).

Get-Well Status Listing. Lists the get-well plan status and dates for MICAP, priority and routine Get-Well dates (22:4-12).

Location of Assets Report. Incorporated from the Ogden ALC SAFE Report, it generates peacetime asset status (22:4-12).

Problem Indicators Report. Is a composite of status and requirement information about a requested NSN (22:4-12).

Central Leveling Item System Report. Is the on-line version of the CLIS report available in hard copy from the D028 system (22:4-12).

These reports provide managers with substantial information about individual item status and indicate potential and existing problem areas.

In addition to the above reports, GWAM provides the user with on-line access to automated Air Force Form 74, Critical Item/Warstopper Data (22:2-21). This capability allows the user to view the status of any critical item with an approved get-well plan. As MAJCOMs play a key role in critical item identification (described in detail later in this chapter), the capability to remotely view this information in real-time is invaluable.

Current Criteria

> An ever-increasing reliance upon machines, self-propelled weapons, and highly sophisticated weapon systems places increasing importance upon effective supply support. An aircraft that won't fly, a nuclear field weapon that won't fire, or a missile on a launch pad that is not capable of performing its intended mission is valuable only to the enemy. (1:3)

AFLMC recommendations brought about the institution of a three tiered categorization for degraded support items. Though the labels and specific criteria of the current system are slightly different from AFLMC's recommendations, their basic concepts have been put into operation. According to AFM 67-1, Vol 1, Part One, Chapter 26, Air Force Critical Item Program, the lowest tier, "Problem," identifies items causing minor limitations to weapon system operations (15:26-9). The second tier, "Potential Critical," identifies those items that restrict weapon system operations, but not to the extent critical items do (15:26-9). The final tier, "Critical," identifies those items having the most detrimental impact on mission performance (15:26-9). Use of these three hurdles is the basis for the critical item selection process.

Critical Item Selection Process. To better understand the critical item selection process, this section will describe the individual functional areas and their role/responsibility in the critical item management process.

Air Logistic Centers (ALC). The ALCs are responsible for identifying major causes of support problems, taking required corrective action, and ensuring all associated administrative responsibilities are completed (15:26-5). In addition, they are to establish a Critical Item Review Committee and appoint an ALC Critical Item Monitor to regularly review and administer the local critical item program (15:26-5).

Major Commands (MAJCOM). Each MAJCOM establishes its own unique criteria using the guidelines identified above. Having done this, MAJCOMs are responsible for reviewing the CIP items to ensure their legitimacy within their own criteria (15:26-5). Along with the ALC System Program Manager (SPM), the MAJCOMs then complete a review and negotiation of the items they have submitted for final inclusion in the CIP (15:26-5).

System Program Manager (SPM). The SPM acts as the point of contact for all critical hurdle items affecting the weapon system (15:26-6). In doing this, the SPM reviews automated Forms 74 (Get Well Plans) and the MAJCOM identified critical items to recommend changes where appropriate (15:26-6). The SPM must also coordinate with other SPMs and the MAJCOMs concerning funding strategies for corrective actions. Important in this process is the SPMs participation in the MAJCOM negotiation for addition and deletion of items to the CIP (15:26-7).

ALC Critical Item Manager (CIM). The CIM acts as the point of contact between the ALC and Air Force Logistics Command (AFLC) (15:26-5). The CIM is a permanent member of the ALC Critical Item Review Committee with the responsibility of monitoring CIP corrective actions, and ensuring automated Form 74 (GET Well Plans) are managed properly (15:26-5).

Item Management Specialist (IMS). The IMS is responsible for core logistics functions including requirements budgeting, distribution, and transportation (15:26-7). To accomplish this, the IMS coordinates expedited repair actions with the production management specialist, tracks worldwide spare assets, develops automated Forms 74 (Get Well Plans), and initiates emergency procurement requests (15:26-7).

Equipment Specialist (ES). The ES is responsible for identifying needed reliability and maintainability improvements (15:26-7). The ES accomplishes this by reviewing automated Forms 74 no later than the 15th day of each month (15:26-7).

Production Management Specialist (PMS). The PMS identifies all cases where negotiated repair actions are less than required repair actions (15:26-7). This highlights those items that may be additionally detained due to maintenance capability. Like the ES, the PMS accomplishes this task by a review of the automated Form 74 (15:26-7).

ALC Critical Item Review Committee. This committee is chaired by the Materiel Manager (MM) and composed of two letter directorate level representatives (15:26-8). This committee is required to meet monthly to review and determine appropriate corrective actions for all newly assigned critical items and those recurring for four consecutive months (15:26-8). In accomplishing this review, SPM, IMS, PMS, and ES personnel will attend these meetings as needed to provide required information.

Critical Item Selection. Current guidance requires critical item program selections be based on one or more of the multidimensional criteria identified below (15:26-8).

As stated earlier, individual MAJCOMs are responsible for tailoring specific guidelines within these criteria to establish critical item selection (15:26-5).

1. Weapon System Availability: Items that limit weapon system performance are identified based upon their limitation to predetermined aircraft goals established for each MDS by each MAJCOM. This determination is accomplished analytically in the Weapon System Management Information System (WSMIS)/Sustainability Assessment Module (SAM).

2. Weapon System Factors: Is the total number of non mission capable (MICAP) hours generated by an individual line item divided by the total possessed hours of the weapon system that the item supports for the most current month available.

3. Monthly MICAP Hours: An established total of MICAP hours for the previous month.

4. Monthly MICAP Incidents: An established number of MICAP incidents for the previous month.

5. Yearly MICAP Incidents: An established number of MICAP incidents for the previous twelve months.

6. Yearly Awaiting Parts (AWP) Incidents: An established number of AWP incidents for the previous twelve months.

7. Single Point Failure: Items which have zero MICAP tolerance due to mission impact.

8. Other Parameters Developed by MAJCOMs.

9. Ensure supply assistance follow-up procedures comply with prescribed directives AFM 67-1, Vol 1, Part One, Chapter 1, Section E and Vol 2, Part Two, Chapter 9, Paragraph 110. (15:26-8)

All criteria provide a quanitfiable means to evaluate critical items with the exception of number eight. The eighth criterion allows the MAJCOMs to apply any unique hurdle criteria they deem appropriate in determining critical items. Currently, there is no requirement for the

MAJCOMs to justify these unique criteria (36). This ability, along with their ultimate authority to determine what is included and excluded from the program, gives MAJCOMs enormous control over CIP management.

Important in the critical item management process is the determination of when an item should leave the program. When an item's asset status has been sufficiently corrected, the item is termed "well" (15:26-10). AFM 67-1, Vol 1, Part One, Chapter 26, defines well as follows:

> Economic Order Quantity (EOQ) Items. Items not having met one of the standard thresholds for the previous three months and no priority 01-08 back orders at the time of the review. Items must be supportable through on-hand stock and or firm due-ins from procurement. (15:26-10)
>
> Recoverable Items. Items not having met one of the standard thresholds for the previous three months or no priority 01-08 back orders exist at the time of the review. Items must be supportable through redistribution of assets, repair or firm due-ins from procurement with delivery within the next 30 days. (15:26-10)

Upon achievement of the above two criteria, critical items are to be deleted from the CIP. In addition, critical items may also be deleted upon negotiation between the MAJCOM and SPM (15:26-10).

Aircraft Availability

Aircraft availability is a concept which attempts to link supply purchase actions to operational capability (41:36). From a supply perspective, aircraft availability is based on the number of aircraft awaiting and not awaiting a resupply action, independent of maintenance or crew requirements (41:36). To further demonstrate this concept, an aircraft is considered to be available if all parts have been provided, regardless of pending maintenance actions or crew shortfalls. Under this concept, spares are purchased to maximize aircraft availability measures verses maximization of commonly used aircraft spares fill rates (41:37). Benefits of using the aircraft availability model (AAM) is that it purchases only those items affecting aircraft availability, thus avoiding unnecessary inventory and waste of limited resources (41:37). Given the CIP is a key means by which resupply actions are undertaken, it is reasonable to conclude that problems affecting the CIP also impact the measure of aircraft availability.

Summary of the Critical Item Program

As has been presented, the critical item program is a dynamic management process crucial to the effective and efficient support of Air Force weapon systems. It is a program designed to enable proactive administration of problem support items in order to prevent management reactions. The primary goal of the CIP has been to increase weapon system availability. Having originated at the height of the Vietnam War, it is a process that has been in development for over two and a half decades. During this time, the program has undergone numerous changes and improvements culminating in the program used today. However, in this process, the program has suffered significant and recurring difficulties that have prevented it from achieving its full potential.

Close inspection of these difficulties have revealed several contributing factors. These factors include incorrect critical item selection criteria, conflicting regulatory guidance, insufficient management attention, and reactionary management practices (12; 36; 15; 7:29). However, more significant than these shortfalls is the clear lack of a process for measuring the performance of the overall program. Because of this shortfall, a means by which to satisfy the operational deficiencies of the program is unavailable. As a result, critical item managers at all levels must do the best they can to improve a program for which they have no measure for how well it is performing. Based on these circumstances, it becomes apparent that a process for measurement of the program is necessary to establish goals common to all critical item management activities. Without these common goals, differences of opinion and the resulting problems will continue to exist. Currently, AFLC and MAJCOM managers differ significantly in their individual concerns addressing CIP management actions. Because their respective approaches have little in common, actions necessary to improve the program have been difficult to negotiate between the two sides (36). As a result, the process of improvement has been further impaired. Sink and Tuttle clearly state the need for measurement as:

> Measure to improve. Measure to provide your management team with new insights into why the system performs the way it does, where it can be improved, and when the system is in control or out of control. (49:1)

According to Harrington, "Measurement is at the heart of any improvement process...If something cannot be measured, it cannot be improved" (28:19). Simply stated, without measurement of the total system, the quality of its product is unknown and therefore uncontrollable. To address the question of measurement and how best to approach it, a review of quality control techniques is necessary.

Quality Control

> Some processes in nature exhibit statistical control...But a state of statistical control is not a natural state for a process. It is instead an achievement, arrived at by elimination one by one, by determined effort, of special causes of excessive variation. (13:5)

Quality control is a concept that has been around many years. Some would argue that quality control has existed since the first craftsman. In the context that this study addresses quality control management, the first documented source dates back to the early 1920s. In 1924, Dr. Walter Shewart first introduced statistical quality control at the Bell laboratories (39:102). Dr. Shewart established the concept that quality could be tracked and controlled using statistical observation (39:102). He did this through defining the limits of random variation and setting acceptable upper and lower limits so that outliers could be easily detected and the causes studied (55:7).

A student of Dr. Shewart's, Dr. Edward Deming, put these concepts to work during World War II to aid the government in wartime procurement (55:8). Later in 1947, Dr Deming's skills were put to use in preparing the 1951 Japanese census (55:10). Through his activities in Japan, Dr. Deming's ideas and teachings of Shewart's techniques became very popular with Japanese businessmen (55:12). While America was not concerned with quality due to overwhelming world demand, Japan was very interested due to the need to rebuild its industrial base. Through the years Japan's central tenet in quality control had been to emphasize gradual process improvement (19:580). This Japanese commitment to quality and continuous improvement have placed them in the position they are today.

As a result of the unparalleled success of Japanese industry in the last several decades, quality control has become more than just a popular business buzz word. For American industry, the issue of quality has become a matter of survival. In today's business environment, a failure of a corporation to recognize this situation can have devastating results. The intense budgeting pressures on the Department of Defense (DOD) have also made quality a concern in the public sector.

In a 1989 article, General Hansen, then Commander of Air Force Logistics Command, stated "80% of the quality problems we have experienced are due to process deficiencies" (26:12). Thus, in review of quality issues government must ask itself two questions: "is government doing the right things...and is government doing it right?" (46:16). Questions such as these and the answers that have proceeded them have lead to the DOD's adoption and commitment to Total Quality Management (TQM) (42:18). The resulting dominant theme in the DOD's TQM program is commitment to quality and continuous improvement (42:18). To better understand what this means, a brief description on quality doctrine and some basic definitions are useful.

Statistical Quality Control. The purpose of statistical quality control (SQC) is to improve the product. SQC strives to prevent defects by gathering and analyzing data in order to identify problems (25:19). Though opponents to quality control argue that the process costs too much money, the opposite is usually the case. Gilmore notes that "improving product or service quality can lead to steep short run reductions in quality expenditures and to substantial long-run reductions in total operating costs" (23:21). It logically follows that continuous improvement will persist in reducing operating costs. Gilmore defines continuous improvement as "the integration of organizational philosophy, techniques, and structure to achieve sustained performance improvements in all activities on an uninterrupted basis" (23:21). This definition identifies that quality control is not only implementation of measures, but also the complete dedication to the concept by all involved.

As introduced above, SQC (also referred to as statistical process control) is the observation of random variation within acceptable limits in order to identify outliers (55:7). This variation can be broken down into two types, chance (common and numerous but which are not feasible to detect or identify) and assignable (a factor which contributes to variation and can be detected reasonably)(39:104). It is the latter, assignable variation, with which SQC is concerned.

To evaluate this variation there are two categories of measures, variables and attributes (24:3). A variable is present "when a record is made of an actual measured quality characteristic, such as a dimension expressed in thousandths of an inch" (24:3). An attribute is present "when a record shows only the number of articles conforming and the number of articles failing to conform to any specified requirements" (24:3). The presence of an attribute or a variable will determine the best SQC measurement device to use. For example, Shewart's "xR" chart (all charts are discussed later in this chapter) is best suited to variable measurement, while Shewart's "p" chart is best suited to attribute measurement (24:4).

To implement these concepts, a measure must exist upon which to base management controls. Juran defines the ideal unit of measure as one which:

> Provides an agreed basis for decision making...is understandable...applies broadly...is susceptible of uniform interpretation...is economic to apply...and is compatible with existing designs of sensors. (32:76-78)

Before further addressing the two specific measures contained in this study, a brief review of the types of data and purposes of data collection is appropriate.

Types and Purposes of Data Collection. In order to measure something, data must first be collected. How the data are collected will determine which measurement techniques are appropriate. Ishikawa classifies data collection into five categories (31:1-2) as follows:

> Data to assist in understanding the actual situation. These data are collected to check the extent of the dispersion in part sizes coming from a machining process, or to examine the percentage of defective parts contained in lots received.
>
> Data for analysis. Analytical data may be used, for example, in examining the relationship between a defect and its cause. Data are collected by examining past results and making new tests.
>
> Data for process control. After investigating product quality, this kind of data can be used to determine whether or not the manufacturing process is normal. Control chars are used in this evaluation and action is taken on the basis of these data.
>
> Regulating Data. This is the type of data used, for example, as the basis for raising or lowering the temperature of an electric furnace so that a standardized temperature level may be maintained. Actions can be prescribed for each datum and measures taken accordingly.
>
> Acceptance or rejection data. This form of data is used for approving or rejecting parts and products after inspection. There are two methods: total inspection and sampling.

Additionally, Ishikawa identifies two general kinds of data (31:3):

<u>Measurement data</u>: continuous data (length, width, time, etc.)

<u>Countable data</u>: enumerate data (number of defectives, number of defects, percentage defective, etc.)

<u>Percent Defects and Cycle Time</u>. The two measures considered in this study encompass both of Ishikawa's measurement types. Percent defects falls under countable data and cycle time under measurement data. In addition, these measures fall under Juran's third and first species of measures respectively (see Table 1). Juran's third species of measure is associated with errors and failures (percent defects), while his first and second species of measures addresses the technological level and product performance (cycle time)(32:72).

Recent applications of these measures have enabled two American corporations to achieve exemplary levels of quality. Specifically, these companies were Motorola and Xerox. Due to the successful application of these measures within private industry, Government interest has begun to develop surrounding their use (16).

William Smith, Vice President for Quality of Motorola, claims their company used these measures to instill the concept of quality into all workers versus those just in the quality department (16:35). Smith further claims these measures are generic in nature, in addition to being easily

Table 1. Juran's Six Species of Measures (32:72-73)

First Species, Technological Level:

QUALITY FEATURE	UNIT OF MEASURE
Distance	Kilometers, miles
Weight	Grams, ounces
Time	Hours, minutes
Electrical current	Amperes
Temperature	Degrees

Other technological units of measure are unfamiliar to most laymen but are well known to the technologists.

Second Species, Product Performance:

QUALITY FEATURE	UNIT OF MEASURE
Fuel efficiency	Miles per gallon Kilometers per/liter
Timeliness of service	Minutes, hours, days
Continuity of service	Percent "uptime"

Third Species, Errors and Failures:

QUALITY FEATURE	UNIT OF MEASURE
Defect content in goods	Percent defective demerits per unit
Field failures	Mean time between failures, maintenance hours per thousand, operating hours
Service interruption	Percent downtime
Error content of services	Percent error in billing

Fourth Species, Functional Department Performance:

FUNCTIONAL DEPARTMENT	EXAMPLE OF MEASURE
Product development	Months required to launch new products
Purchasing	Cost of poor quality per dollar of purchases
Manufacture	Cost of poor quality per dollar of manufacturing cost

Table 1 (continued).

Fifth Species, Upper Management Level:

QUALITY FEATURES	UNITS OF MEASURE
Competitiveness in the market place	Ratio of products performance to that of leading competitors
Cost of poor quality	Ratio of cost of poor quality to sales

Sixth Species, Evaluation of Managers Performance:
This species of measure is a combination of departmental quality performance and specific deeds done.

understood. This makes them very applicable throughout many quality control situations (50). Backing Smith's claims is the company's recent achievement of the Baldrige Award for quality excellence. Motorola has reduced percent defects to 300 failures per million units (.0003)(37:108). Motorola's goal is to continue to reduce this number to 3.4 failures per million by 1992 (37:108). Motorola has also shown vast improvements in cycle time, such as reduction of portable radio fill rates from 55 to 15 days (37:108). Again, striving for continuous improvement, Motorola hopes to reduce this to 7 days in the near future (37:108).

Xerox Corporation is another recent winner of the Baldrige Award, and they too have used the measure of percent defects to improve product performance. Xerox's goal for the 1990s is 125 defects per million with the future goal being zero defects (37:104). In short, these two American corporations have proven SQC can be used effectively in the United States.

Measurement Charts. Having described the basis and doctrine of SQC, in addition to establishing the past validity for the measures of percent defects and cycle time, one must now consider the measurement charts available upon which variation can be monitored. Looking at the quality literature, one finds that numerous measurement charts are available. To justify the measurement charts used in this study (further presented in Chapter III), several quality control charts are presented along with their individual contributions.

Pareto Analysis. Around the turn of the century (1897), V. Pareto, an Italian economist identified in a formula that the distribution of income is unevenly distributed with most of the income held by a very small population of people (35:18). Dr. J.M. Juran applied this concept in classifying quality control problems and named it Pareto Analysis (35:18). Visually, a pareto chart is very similar to a vertical bar graph (9:17). The purpose of the pareto chart is to identify priorities (55:105) or determine which problems are most significant (7:155). Figure 3 displays an example of a pareto chart. By graphing the errors or defects, managers can easily identify those areas causing the most problems and address them first (31:43). Pareto charts are often used as the first step in problem identification (31:46).

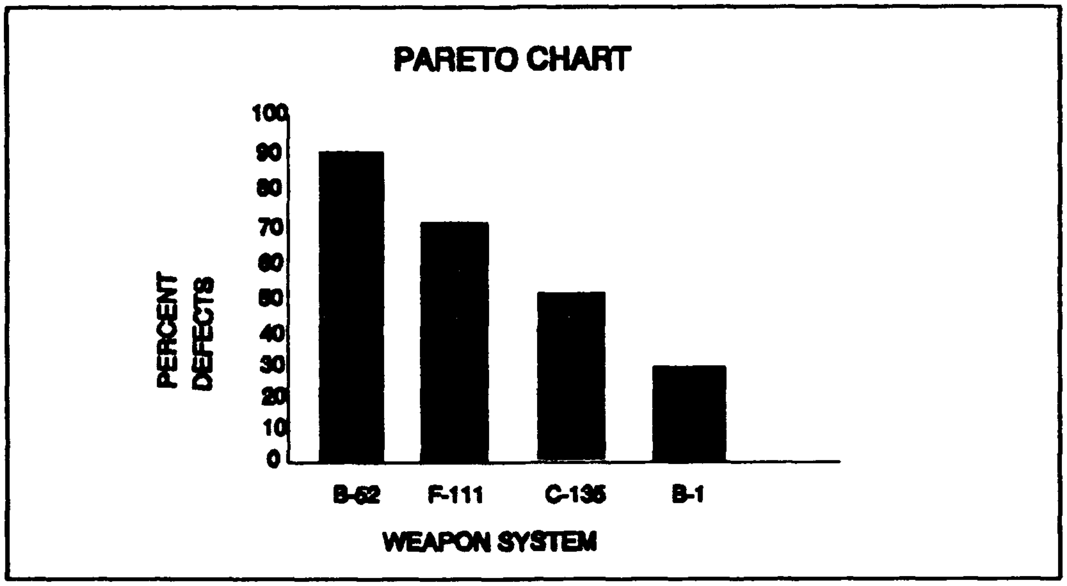


Figure 3. Pareto Chart

Histograms. According to Scherkenbach, histograms are one of the most misused statistical tools as they are only effective if measuring a process within statistical control (47:106). Basically, a histogram is useful in identifying how frequently something is observed or occurs (55:109). Harrington describes a histogram as "A type of bar graph, used to display distribution of whatever is being measured" (27:206). In short, "A histogram reveals the amount of variation that any process has within it" (9:36). Figure 4 provides an example of a histogram.

Cause & Effect Diagram. The cause and effect diagram was introduced in 1953 by Dr. Kaoru Ishikawa in summarizing the opinions of engineers towards quality (35:26). "Cause & Effect Diagrams (fishbone diagrams) are drawn to illustrate the various causes affecting a process

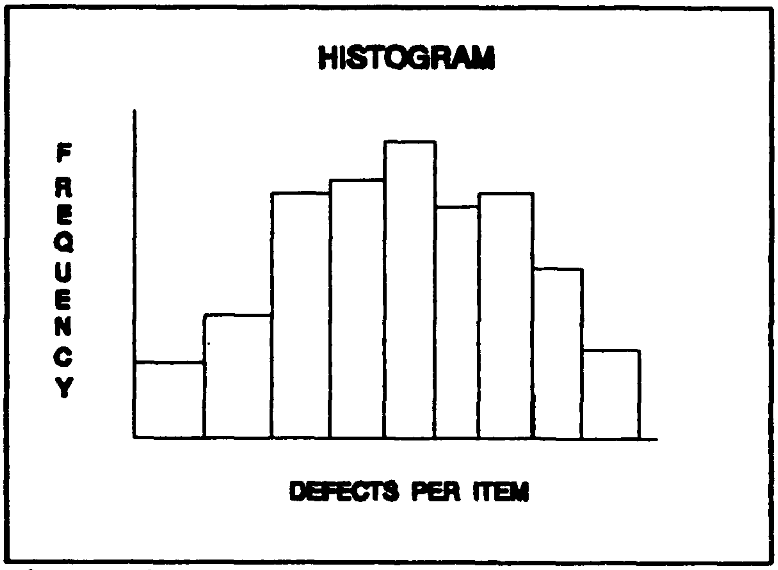


Figure 4. Histogram

by sorting out and relating the causes" (31:25; 9:24-25). The Japanese Industrial Standards define cause and effect diagrams as "a diagram which shows the relation between a quality characteristic and factors" (35:26). Use of cause and effect diagrams are usually an initial step by which management identifies the causal factors effecting a process (31:18). Figure 5 is an example of a cause and effect diagram.

Scattergram. A scattergram charts relationships between two variables (55:111). Brassard maintains it is most applicable:

> When you need to display what happens to one variable when another variable changes in order to test a theory that the two variables are related. (9:44)

This is useful in identifying cause and effect relationships among the two variables observed. In determining these

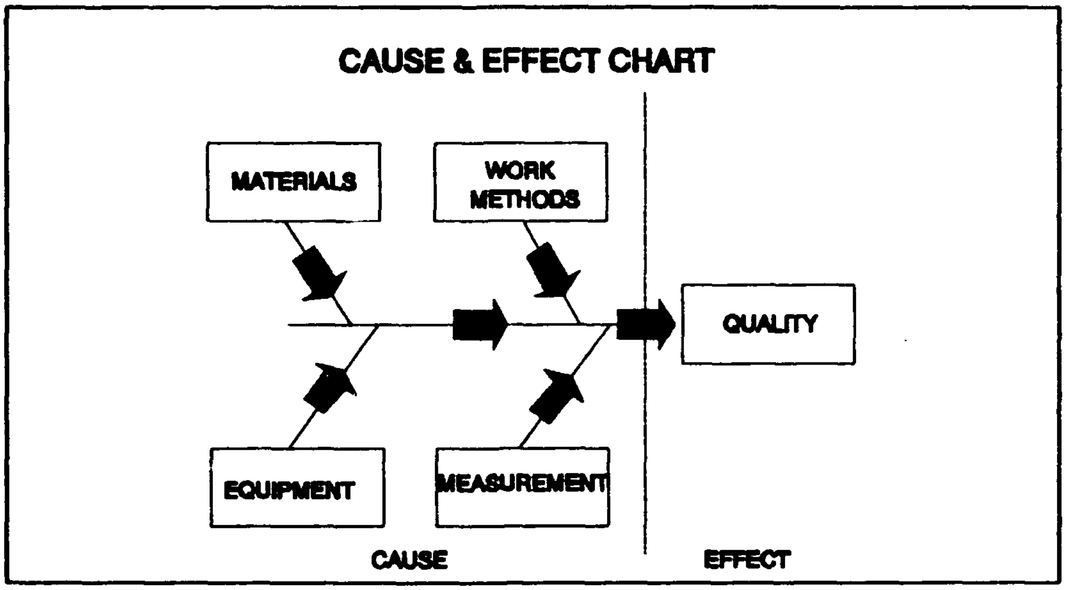


Figure 5. Cause and Effect Diagram

relationships, a correlation can be evaluated (31:92). If the trend of the observations is upward to the right, a positive correlation exists; if the trend is downward to the right, a negative correlation exists; if there is no trend visible there is no correlation (31:90-91). Figure 6 displays an example of a scattergram with positive correlation.

Control Charts. These charts, the most commonly used, were introduced by Dr. Shewart in 1924 (8:249; 35:92). According to Deming:

> The control chart sends statistical signals, which detect existence of a special cause, or tell us that the observed variation should be ascribed to common causes, chance variation attributable to the system. (14:319)

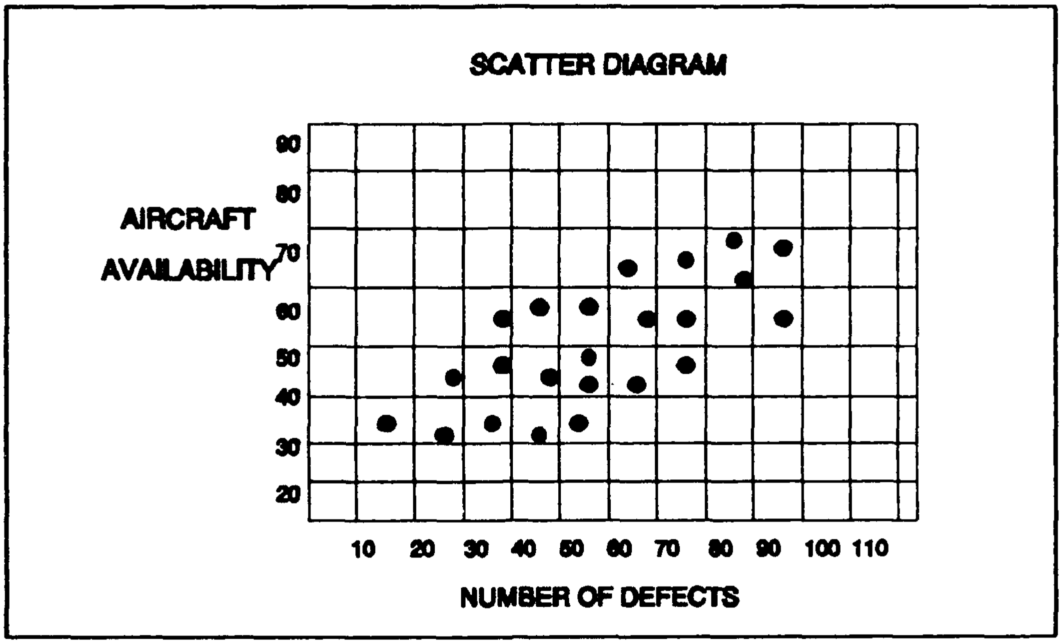


Figure 6. Scatter Diagram

Basically there are two kinds of control charts, continuous value and discrete value (35:94). Within these two kinds there are several variations which are described in Table 2. Variables, actual measured quality characteristics, are most appropriately evaluated using continuous value charts (24:3; 35:94). Attributes, the number of articles conforming or nonconforming to specified requirements, are most appropriately evaluated using discrete value charts (24:3; 35:94). To further illustrate the usefulness of these charts, the p and xR chart are described in more detail.

<u>p Chart</u>. This is an attribute chart (associated with discrete values) which measures the fraction of defective parts for a process of varying size

Table 2. Types of Control Charts

Characteristic	Name
Continuous value	xR chart (avg value and range)
	x chart (measured value)
Discrete value	pn chart (number of defective units)
	p chart (fraction defective)
	c chart (number of defects)
	u chart (number of defects per unit)

(8:74; 35:95; 31:77). It establishes upper and lower control limits for nonmeasurable characteristics of a product that require monitoring, such as number of typographical errors, mislabeled items and defects (8:75; 55:115). According to Juran and Gryna, "the inspection scheme is designed to serve both for product acceptance and for supplying operator control data" (33:343). Figure 7 displays an example of a p chart.

xR Chart. This is an average/range chart. Like the p chart it establishes upper and lower control limits for the items being measured. Unlike the p chart, the xR chart is used to evaluate variable items such as length, temperature, volume, and voltage (continuous values)(55:115; 35:95). In an xR chart there are two

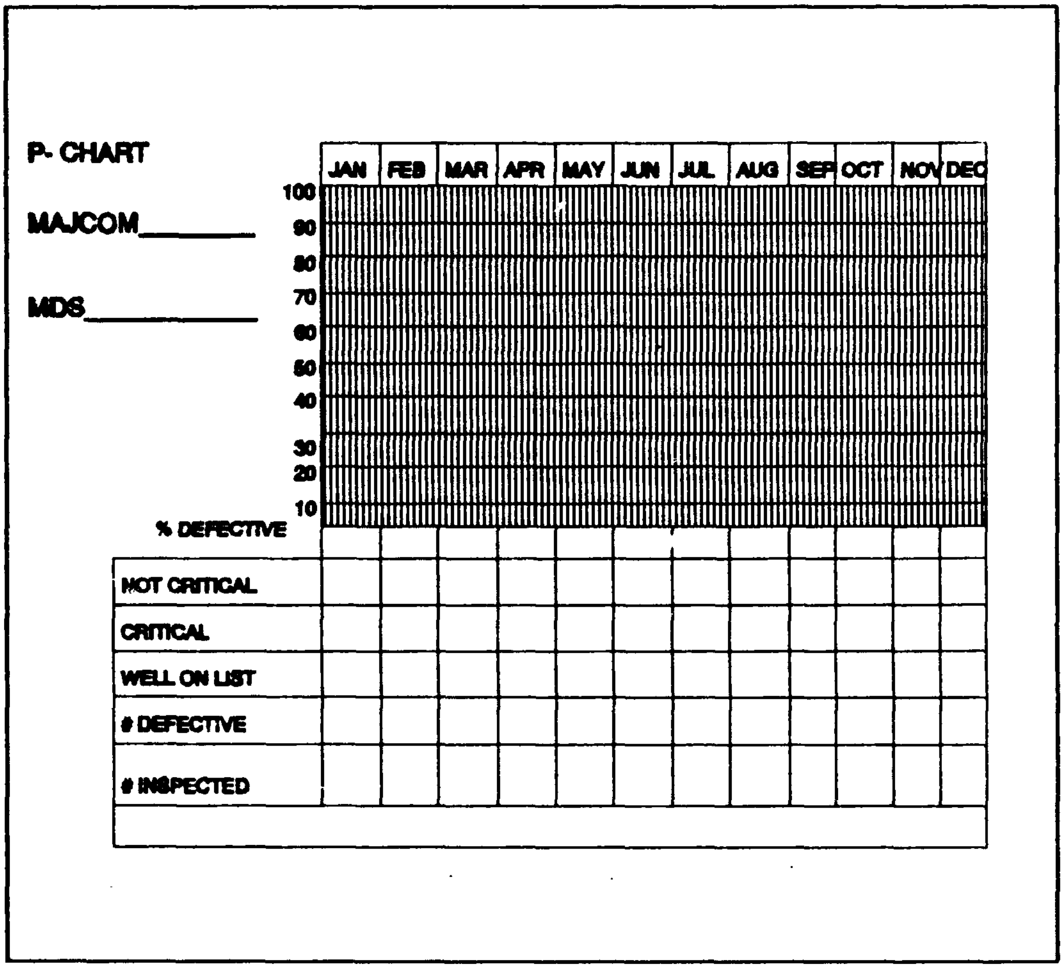


Figure 7. p Chart Example

distinct areas. The x portion of the chart "is a plot of the means of the samples taken from a process" (10:185). The R portion of the chart "is a plot of the range within each sample" (10:185). The R chart is used together with the x chart to control variation within subgroups (35:95). Figure 8 displays an example of an xR chart.

Summary of Quality Control

Quality control has become a useful and increasingly necessary management requirement. With today's increasing

Summary of Quality Control

Quality control has become a useful and increasingly necessary management requirement. With today's increasing costs, decreasing budgets, and customer demand for high level service, the question concerning quality is not if, but how. In order to implement quality control effectively,

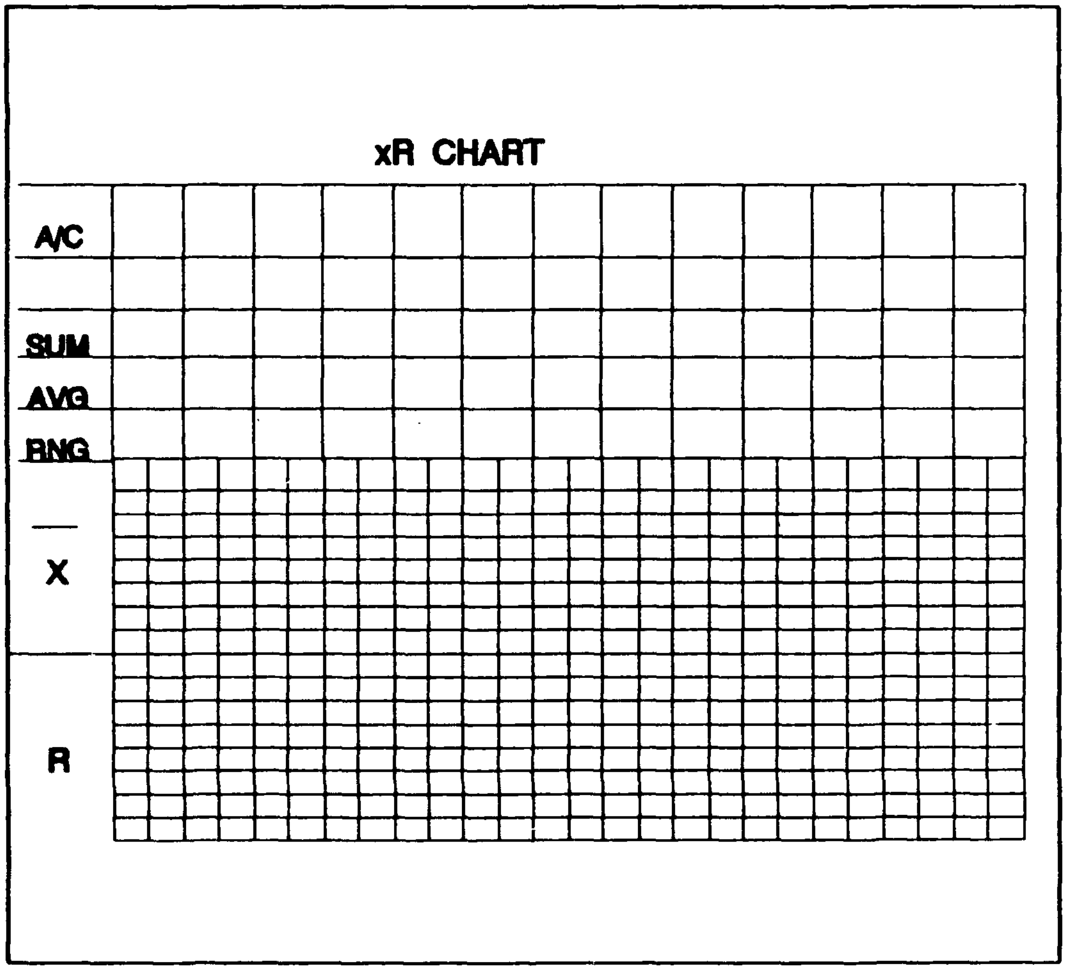


Figure 8. Average/Range Chart Example

managers must understand the basic principles upon which it is founded. Once this foundation is established, management can then turn to identifying the measures and tools necessary to implement quality products and to make continuous improvement a reality.

Chapter II Summary

In this chapter, a detailed review was presented addressing the history of the CIP, the automated enhancements of the CIP, and a background on quality control techniques. Through this discussion, the problems affecting the CIP were thoroughly presented along with the actions necessary to initiate the improvement process. A review of the literature further substantiates that the measures of percent defects and cycle time could apply to the CIP. Furthermore, the literature suggests these measures could provide an opportunity for establishing continuous process improvement. Based on these conclusions, a methodology was developed to investigate the potential of these measures. Chapter III details this methodology providing the reader with a step by step plan of how the primary research in this study was obtained. The findings and analysis of Chapter IV, were based on implementation of this methodology, and has subsequently established the conclusions and recommendations contained in Chapters V. Because the methodology and resulting conclusions were based heavily on the literature review, the reader is encouraged to be thoroughly familiar with the concepts contained in Chapter II before reviewing the remainder of this study.

III. Methodology

Introduction

This chapter outlines the process and procedures used in data collection and analysis for the purpose of answering the investigative questions posed in Chapter I. Several of these areas have already been introduced to the reader in the first two chapters to enhance the understanding of each area's importance and interaction within the study. Chapter III expands on those introductions and integrates all other pertinent characteristics or peculiarities surrounding their implementation. This chapter also identifies the limitations of this research based on measurement techniques and internal and external validity of the data.

Specific Problem Revisited

As identified in Chapters I and II, numerous problems currently affect the performance of the Air Force Critical Item Program. These problems include inaccurate critical item selection criteria, insufficient management attention, and reactionary management practices. More significant than these shortfalls is the clear lack of a means for evaluating the performance of the overall program. Because no evaluation capability of the critical item program exists, the quality of its performance and product is consequently uncontrollable. This management shortfall results in the specific problem statement addressed by this study. The problem statement identified in Chapter I, along with the applicable investigative and measurement questions, are presented again to refresh the reader's memory.

Problem Statement. While the Critical Item Program (CIP) is known not to work well, no specific measures of the program exist. The quality literature suggests that two measures, percent defects and cycle time, might work; however, no one has evaluated these measures with respect to managing the CIP.

Investigative and Measurement Questions. To answer the question posed in the problem statement, two investigative questions were addressed. In turn, to satisfy each investigative question, several measurement questions are asked. The two investigative questions and their associated measurement questions are as follows:

Investigative Question #1. Does measurement of percent defects aid the Air Force in managing the CIP effectively?

Associated Measurement Questions:

1. Do items in the CIP meet MAJCOM criteria IAW AFM 67-1?

2. Do items in the CIP correspond to items identified by WSMIS/GWAM?

3. Do items enter and leave the CIP on a recurring basis?

4. How does this measure correlate to aircraft availability in terms of total not mission capable (MICAP) period hours?

5. Do CIP managers find this measure useful?

Investigative Question #2. Does measurement of cycle time aid the Air Force in managing the CIP effectively?

Associated Measurement Questions:

6. What is the variation in time for items managed in the CIP?

7. How does this measure correlate to aircraft availability in terms of total MICAP period hours?

8. Do CIP managers find this measure useful?

Research Design

Before detailing the specific processes and procedures used in this study it is helpful for the reader to understand the research design. With this knowledge one better understands why certain methodologies are chosen over others. This discussion also enhances comprehension of the study limitations based on the methodologies used. Table 3 summarizes the overall research design of this thesis.

The problem focus of this study is formal. Since the Critical Item Program (CIP) has existed for many years, the problems associated with it have passed exploratory study and can now be described specifically and concretely.

Table 3. Research Design (18:58-61)

PROBLEM FOCUS	FORMAL
DATA COLLECTION	OBSERVATION & SURVEY
VARIABLES	EX POST FACTO
PURPOSE	DESCRIPTIVE
TIME	CROSS-SECTIONAL
SCOPE	CASE
ENVIRONMENT	FIELD STUDY

Because the program has been around for some time, limited access to existing data was available. Along with the availability of an existing data base, there were also numerous professionals charged with manipulating these data to manage the program. This study uses observational and survey data collection techniques based on the availability of the data and field experts. Data are collected after the fact, defining the variables as ex post facto. This study attempts to show relationships among variables of the critical item program by demonstrating how quality control measures can be useful in evaluating program performance. This relationship is specific in nature and therefore classifies as a descriptive versus causal purpose.

The limited availability of historical data prevents this study from having a pure statistical scope. Though statistical techniques were used, they were at a level which precluded achieving true statistical significance. Because of the limited availability of historical data and subsequent statistical application, the research was appropriately classified as a case study. Finally, as this study focuses on real world activities and actual data, the environment of the study specifically addresses a field application.

Primary Source Data Collection

As discussed earlier in this chapter, this study employs both observation and survey techniques in the process of primary data collection. Together, these two techniques provide a solid cross section of sources in validating the measures in question (18:183-184). This section separately describes specific data gathered by each technique due to the substantial differences in data collection methods.

Observation. The CIP is currently undergoing automated improvements. These ongoing improvements limit the size of the CIP's population which currently reflects newly automated changes. Based on this limitation, SAC is the only MAJCOM observed in this study. Specific weapon systems observed include the B-1, B-52, C-135, F-111, and E-4 aircraft. A 100% analysis of available data was accomplished for each of these aircraft systems in the observation phase. This 100% analysis limits the bias and error of the study's internal validity (18:277). The primary source of data comes from information contained in

WSMIS/GWAM. The reports used from WSMIS/GWAM include the approved critical item list, the critical item add/delete report, the critical item candidate list, and the automated Form 74. Observation of data occurs in a monthly and/or quarterly cycle depending on availability of reports. Through analysis of data observed and application of the two measures in question, these data were used to establish the current condition of the CIP for the SAC aircraft stated above.

Of special note was the collection of cycle time data. In order to determine true cycle time measures, current as well as completed items should be gathered to determine this measure. However, this was not possible for this study as no capability exists to aggregately gather cycle time data on items currently maintained in the program. The only ability to measure cycle time data was for items leaving the CIP through analysis of Add/Delete reports.

Archived Data. This study establishes a baseline through observation of archived data gathered from other sources such as Air Logistic Center (ALC) Critical Item Managers (CIM), System Program Managers (SPM), Major Command (MAJCOM) focal points and automated Forms 74. The format and report contents of this archived information, with the exception of automated Forms 74, were not comprehensive nor 100% consistent with measurement question requirements and therefore prevented the use of statistical significance testing. These data, however, do provide an acceptable baseline for comparison to data collected under controlled conditions.

Specifically, gathering of archived data for presence of percent defects and cycle time provided a baseline comparison for measurement questions 2, 3, 4, 6, and 7. For all SAC CIP items available through archived data, a comparison of the approved critical item list and WSMIS/GWAM critical item candidate list (or alternate source equivalent) was performed. As historical information (such as GWAM Candidate Lists) was not 100% available, some data were missing. These lists and their equivalents describe the items in the approved CIP and items nominated as candidates to the CIP. Included in these reports were the item specific criteria that were attained for candidate items to become nominated by WSMIS/GWAM. This comparison provides a baseline for measurement question 2. An analysis of archived automated Forms 74 provides information on how long items remain in the CIP and the historical monthly status of these items prior to their release from the program. This review provided a baseline for measurement question 6.

Upon collection of these data, separate comparisons were accomplished between trends in percent defects and cycle time to aircraft availability. For the purposes of this study, aircraft availability was based on the combination of not mission capable supply (NMCS) and not mission capable both (NMCB) data (45). Together, NMCS and NMCB establish nonavailability of aircraft due to supply actions. Because the CIP primarily effects supply and not maintenance, not mission capable due to maintenance (NMCM) is not considered in the comparison. NMCS and NMCB data are collected from the WSMIS/Readiness Assessment Module (RAM) using total MICAP period hours. Comparison of these trends identified whether a nonparametric correlation existed between the performance of the critical item program and the operational availability of aircraft. These data further provided a baseline for measurement questions 4 and 7.

Archived data do not exist to identify specific criteria attained for approved critical items not identified by WSMIS/GWAM. This condition results from MAJCOMs using unique criteria or judgment to select critical items. Currently, these unique critical item selections do not require justification or any form of reporting (15). Therefore, no historical data were available to provide a baseline for measurement question 1.

Current Data. Unlike archived data, current data (data collected beginning 1 April 1991) were collected in a format specifically designed to address applicable measurement questions. As consistency and format of current data collection were completely controlled, this study places more reliability and weight on these data.

Observation of current data solely uses WSMIS/GWAM reports. Subsets of data for MAJCOM and weapon system were created in WSMIS/GWAM for generation of approved critical item lists, critical item add/delete reports, critical item candidate lists, and automated Forms 74. Analysis of these data, like that achieved through archived data, provided inputs to answering measurement questions 2, 3, 4, 6, and 7. Through contacts made possible by the WSMIS/GWAM Program Manager, additional data were to be collected which detailed specific criteria attained for unique items selected by the MAJCOM (items not identified by WSMIS/GWAM as critical). These additional data were to provide the basis for answering measurement question 1.

This study again analyzes current data to NMCS and NMCB to determine if a nonparametric correlation existed between CIP performance and aircraft availability. Together with archived data, measurement questions 4 and 7 were answered.

Survey. The last method of primary source data collection was survey. A presentation of the above observations and conclusions were provided to critical item managers from all levels in the program (see Appendix C). Managers addressed include ALC CIMs, SPMs, SAC focal points, and Headquarters AFLC critical item focal points. Twenty three managers were addressed in the survey process (see Table 4). Of these twenty three managers, twenty two responded. The presentation of findings provided complete analysis and conclusions determined through observed data which addressed measurement questions 1, 2, 3, and 6. Also included in the presentation was a complete definition and description of how percent defects and cycle time were used

Table 4. Critical Item Experts Interviewed

Position	Number Interviewed
ALC Division Chiefs	5
SPM	5
MAJCOM POC	4
CIM	4
HQ AFLC	2
HQ USAF	1
AFAA	1

in this analysis. After presentation of the analysis, managers were asked (via telephone interview) to respond to several questions (see Appendix C). The questions were designed to be general and open ended to enable managers to respond freely and without bias. This questionnaire asked their opinion addressing the utility of percent defects and cycle time in evaluating the performance of the critical item program. Managers were asked to briefly support their answers. Due to the nature of the questions posed, validation of the interview instrument was difficult. To address this properly, a detailed review of the questions was accomplished through several phases. First, face validity of the instrument was obtained through review by a faculty advisor. Second, a review of the questions were accomplished through preliminary interview with local critical item management experts. From their comments, the questionnaire was modified for final application to the remaining field experts. Through this process ambiguous questions and bias were eliminated to the best extent possible given the limitations of the environment. Remaining experts were interviewed using the updated questionnaire upon completion of the validation effort. Conclusions for measurement question 5 and 8 were determined from this survey using content analysis (34:525). Through the methods of observation and survey all seven measurement questions were addressed. Once again, this combination of primary source data collection techniques was expected to provide a solid cross section of data and validity to the conclusions of this study.

Data Analysis

Having described how primary data were collected, this section describes the measurement tools employed to conduct the analysis. This section presents the statistical quality control (SQC) charts used, the mathematical manipulations required, and the limitations associated with each.

SQC Charts.

Based on analysis of the literature (Chapter II) the SQC charts chosen that best suit measurement of percent defects and cycle time were the p chart, and the average and range chart respectively. Both of these charts are applicable at both the MAJCOM and Air Force levels for measurement of the CIP's performance.

p Chart.

The p chart was chosen to measure percent defects over other control charts discussed in the literature due to its direct application to attribute measurement (9:54; 27:210; 33:337; 35:63). An example of a p chart is presented in Figure 9. To construct this chart, the following calculations were performed (9:54; 31:77-79; 33:334; 35:94):

$$p=\frac{\textit{number of defects}}{\textit{number inspected}} \tag{1}$$

$$\bar{p}=\frac{\textit{total number of defects}}{\textit{total number inspected}} \tag{2}$$

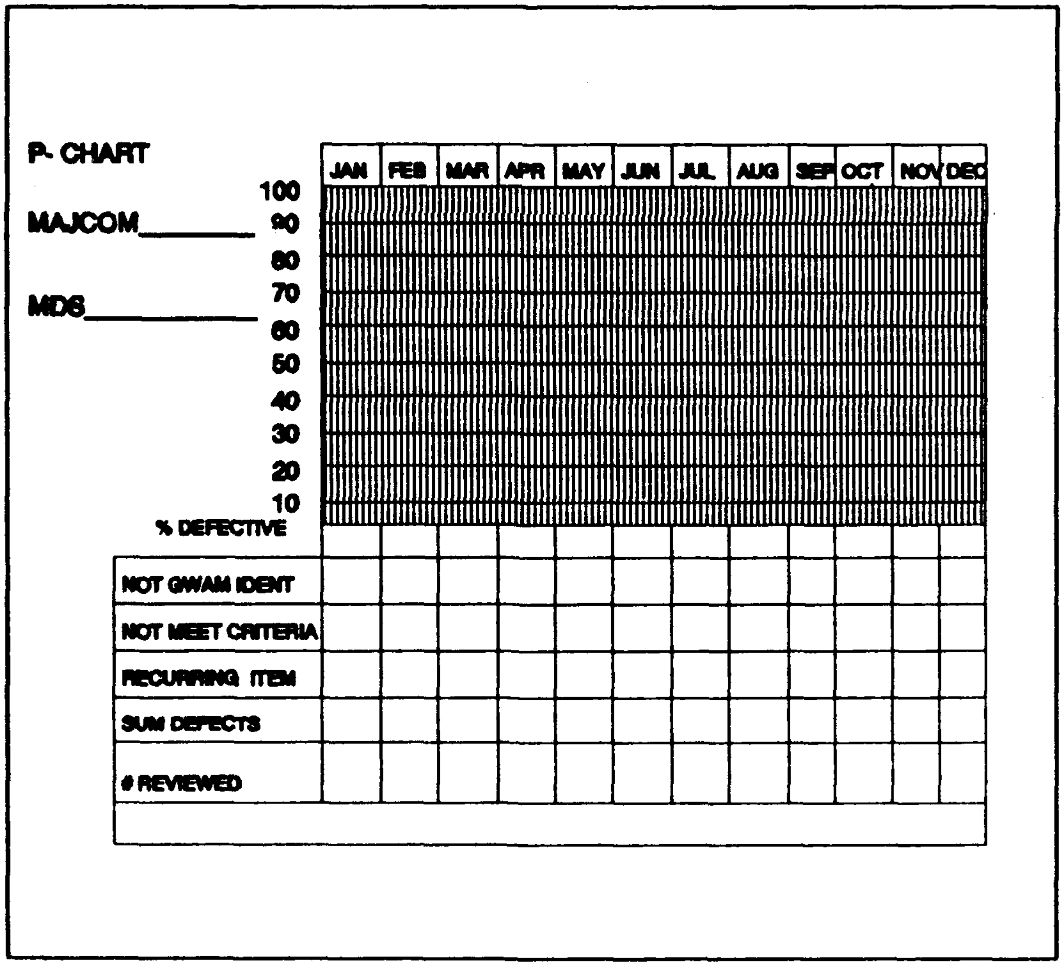


Figure 9. p Chart

Upper Control Limit

$$UCL=\bar{p}+3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \tag{3}$$

where:

UCL = upper control limit
p_{bar} = average number of defects
n = sample size

Lower Control Limit

$$LCL=\bar{p}-3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \tag{4}$$

where:

LCL = lower control limit
p_{bar} = average number of defects
n = sample size

The advantages associated with using this chart are that it is easily understood, it provides an overall picture of quality, and the data are usually readily available (33:337). The disadvantages of this chart include that it does not provide detailed information of individual characteristics and it does not recognize differing levels of defectiveness (33:337).

Average and Range (xR) Chart. The xR chart was chosen to measure cycle time due to its direct application to measurement of continuous values (variables)(9:53; 27:211; 31:65; 33:337; 35:95). An example of an xR chart is provided in Figure 10. The xR chart provides control limits which aid managers in determining

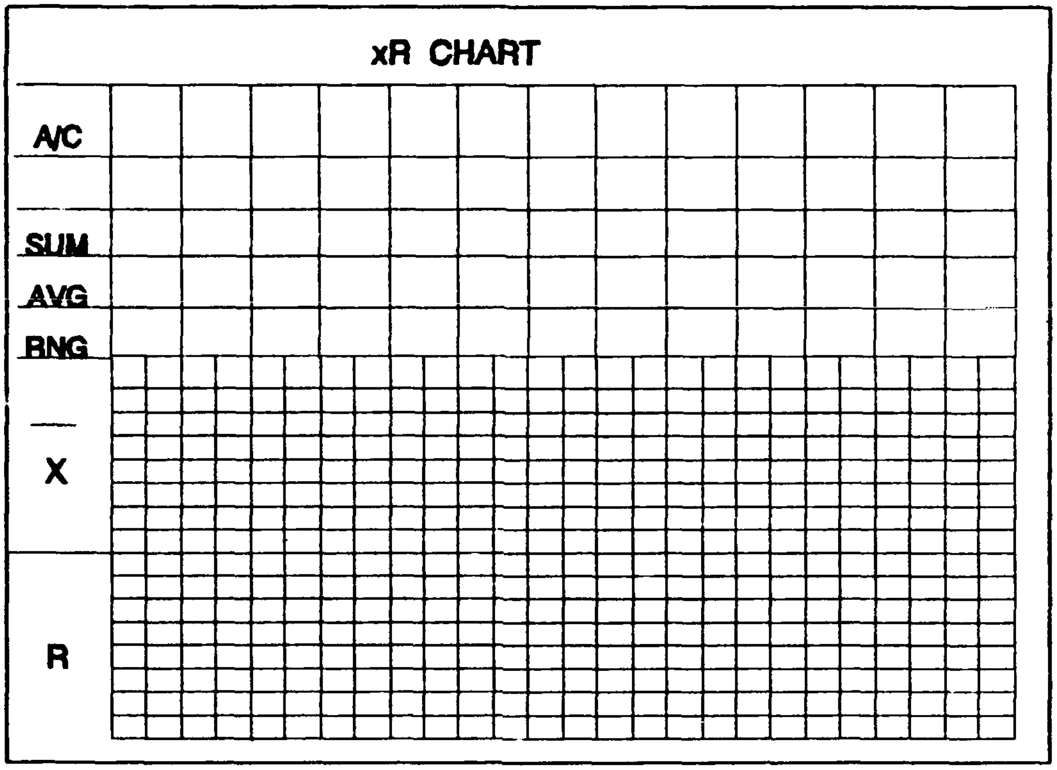


Figure 10. Average/Range Chart

whether data are in or out of control. This ability to recognize outliers enables managers to react quickly and adjust the process as required. Mathematical calculations required to construct and administer an xR chart are provided below:

Sample Average

$$(5) \quad \bar{X}=\frac{\Sigma x}{k}$$

where:

x = critical item cycle time
k = number of samples taken
x_{bar} = average cycle time

Sample Range

$$\bar{R}=\frac{\Sigma R}{k} \tag{6}$$

where:

R = range over which sample data are spread
k = number of samples taken
R_{bar} = average range

Special factors have been developed that are required to calculate upper and lower control limits. These factors are listed in Table 5 below (8:195).

Average Upper Control Limit

$$UCL_{\bar{X}}=\bar{\bar{X}}+A_2\bar{R} \tag{7}$$

where:

UCL_x = upper control limit for X bar
X_{bar} = average cycle time of weapon systems or MAJCOMs sampled
R_{bar} = average range over which sample data are spread
A_2 = special factor for control limit

Average Lower Control Limit

$$LCL_{\bar{X}}=\bar{\bar{X}}-A_2\bar{R} \tag{8}$$

where:

LCL_x = lower control limit for X bar
X_{bar} = average cycle time of weapon systems or MAJCOMs sampled
R_{bar} = average range over which sample data are spread
A_2 = special factor for lower control limit

Range Upper Control Limit

$$UCL_R = D_4 \bar{R} \tag{9}$$

where:

UCL_R = upper control limit for range
R_{bar} = average range over which sample data are spread
D_4 = special factor for upper control limit

Table 5. Control Factor Limits

n	A_2	D_4
2	1.880	3.268
3	1.023	2.574
4	0.729	2.282
5	0.577	2.114
6	0.483	2.004

n = number in the sample
A_2 = special factor for lower control limit
D_4 = special factor for upper control limit

Once the data are collected, the sample average and range (equations 5 & 6) are plotted on the upper and lower grid of the control chart. Normally 30 points of data are required to establish meaningful upper and lower control limits (10:181). Availability of sufficient historical longitudinal data falls short of this requirement as only three periods (quarters) worth of data were present. Because of this shortfall, the upper and lower control limits must be considered starting points which are to be recalculated and adjusted as more data become available in the future and the program progresses.

In short, these control limits act as bounds to determine whether data are in or out of control. As more control is exercised over the program, these limits contract signifying less variation in the process. Therefore, management's goal should be to get the system into control and then to shrink the control limits to as small as practical.

Scatter Diagram. In addition to the p and xR control charts, the scatter diagram was used to display the possible existence of correlation between percent defects and cycle time to aircraft availability. To determine if a correlation existed between the two measures and aircraft availability, two models were developed. The first model compared percent defects to aircraft availability and the second model compared cycle time to aircraft availability. Spearman's Rank Correlation of Coefficient was the calculation chosen to determine correlation (38:979-983). This calculation was used due to the non-normal distribution of available data, thereby requiring a non parametric technique be used (30). Mathematical calculations required to complete Spearman's calculation are as follows:

Sum of Squares uv

$$SS_{uv}=\sum (u_i-\bar{u})(v_i-\bar{v}) \tag{10}$$

where:

SS_{uv} = sum of squares uv
u_i = rank of the ith measurement in sample 1
v_i = rank of the ith measurement in sample 2
u_{bar} = average rank of sample 1
v_{bar} = average rank of sample 2

Sum of Squares uu

$$SS_{uu}=\sum (u_i-\overline{u})^2 \tag{11}$$

where:

SS_{uu} = sum of squares uu
u_i = rank of the ith measurement in sample 1
u_{bar} = average rank of sample 1

Sum of Squares vv

$$SS_{vv}=\sum (v_i-\overline{v})^2 \tag{12}$$

where:

SS_{vv} = sum of squares uu
v_i = rank of the ith measurement in sample 2
v_{bar} = average rank of sample 2

Spearman's Rank Correlation Coefficient

$$r_s=\frac{SS_{uv}}{\sqrt{SS_{uu}SS_{vv}}} \tag{13}$$

where:

r_s = Spearman's rank correlation of coefficient
SS_{uv} = sum of squares uv
SS_{uu} = sum of squares uu
SS_{vv} = sum of squares vv

Correlation of the two measures to aircraft availability is based on the value of r. As r approaches one or negative one there is evidence that a correlation exists (38:981-982). If r remains close to zero there is evidence that no correlation exists (38:982). As total MICAP period hours were used as the measure of aircraft availability (a reflection of aircraft non-availability), a positive r value was desired to establish the existence of a positive correlation with the measures percent defects and cycle time. The measurement of correlation is displayed using a scatter diagram plot with a significance level of .05 ($p < .05$) (see Figure 11). The software package of Statistix 3.1 was used to calculate Spearman's Rank Correlation of Coefficient (51:95).

Survey Measurement. Data collected from the survey of critical item managers were analyzed using content analysis (34:525). Each manager interviewed was categorized into a specific job function, for example, ALC CIM, SPM, MAJCOM focal point, etc. In addition, each manager's response concerning percent defects and cycle time was categorized as either recommended, not recommended, or no opinion (see Table 6). Categorization of manager responses in this

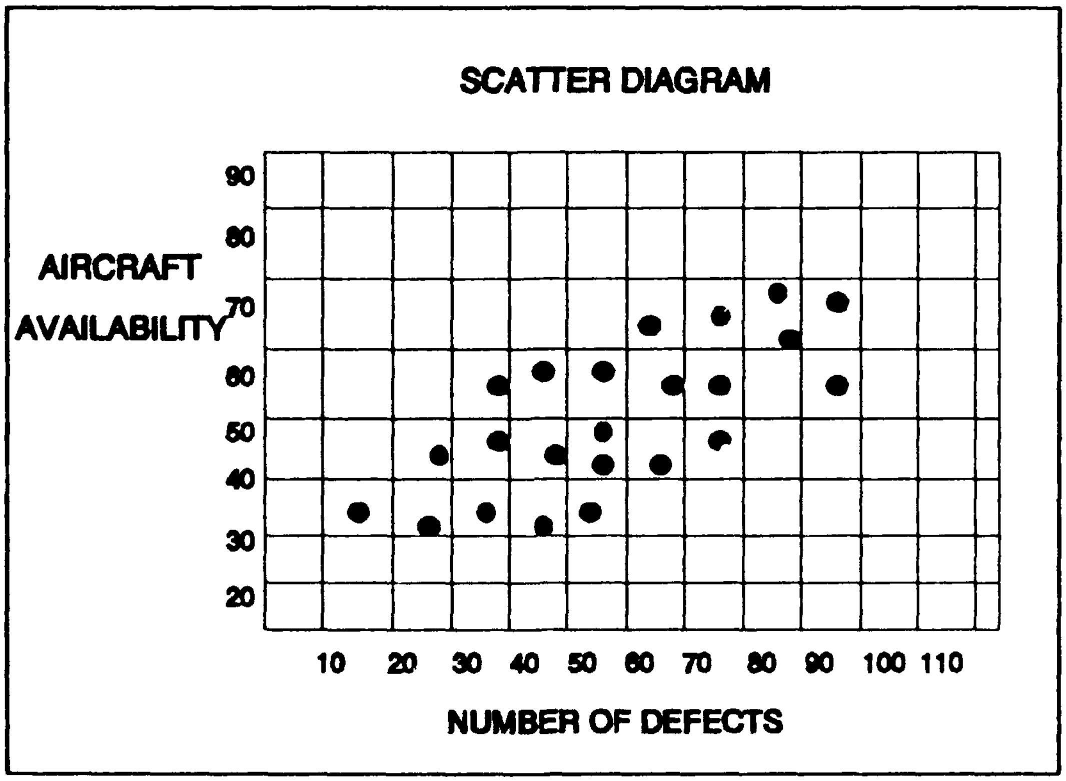


Figure 11. Scatter Diagram Plot

manner provided nominal measurement of data and identified existing trends among the various positions. To determine these trends, interviews were transcripted and in turn content analysis performed. A general and occupational

Table 6. Management View of Percent Defects/Cycle Time

Position	% Defects			Cycle Time			# Int
	Rec	No Rec	No Opn	Rec	No Rec	No Opn	
Div Chf							
SPM							
MAJCOM							
CIM							
HQ AFLC							
HQ LEYS							
AFAA							
Totals:							

consensus of opinions was compiled to display results of the survey. The experts interviewed in this study represented approximately the entire population for the CIP in relation to the weapon systems analyzed. Due to this fact, no statistical test was considered necessary and would have been inappropriate to determine the significance level of the results (30).

Chapter III Summary

This chapter has outlined the process and procedures used in data collection, data analyses, mathematical computation and survey organization. Basically two data collection methods were used, observation and survey. The major source of observed data came from the WSMIS/GWAM computer information system. Experienced critical item managers in the field were presented with observational conclusions and then surveyed for their opinion of the utility of percent defects and cycle time. The SQC charts chosen for use in this study were the p and xR charts. Also used was the scatter diagram to show the existence of correlation. Spearman's Rank Correlation Coefficient was used to determine if correlation existed between the two measures of this study and aircraft availability. Implementation of these concepts and the resulting conclusions are presented in Chapter IV.

IV. Findings and Analysis

Introduction

This chapter presents the findings resulting from applying the methodology presented in Chapter III. Due to non-availability of data, minor deviations from that plan were necessary. These deviations are fully outlined before presenting the research findings and analysis. Specifically, this chapter presents the developed control charts used to demonstrate how to evaluate the performance of the Critical Item Program (CIP) using the measures of percent defects and cycle time, the calculations of Spearman's Rank Correlation of Coefficient between the two measures and aircraft availability, and the opinions of critical item management experts concerning the use of these measures in the field.

Limitations of the Data

As mentioned above, the non-availability of data made it necessary to deviate from the established methodology. These deviations, although minor in nature, do effect the level of confidence in the overall data presented. To ensure the reader is aware of these shortfalls, these limitations are described below.

For the quarters reviewed (ending in the months of June 1990, September 1990, January 1991, and April 1991), the Weapon System Management Information System (WSMIS)/Get Well Assessment Module (GWAM) Critical Item Candidate List was not available in its entirety for Strategic Air Command (SAC) aircraft for the quarters ending September 1990 and January 1991. The only GWAM Critical Item Candidate List data that were available for these two quarters were for items managed by Warner-Robins Air Logistic Center (ALC). To provide measurable data points for the September 1990 and January 1991 quarters, Warner-Robins ALC managed items were reviewed as a subset of the SAC CIP. Therefore, data presented for percent defects for September 1990 and January 1991 reflect items managed at Warner-Robins ALC only and not all SAC aircraft. Though this limits the confidence of the measures for these two quarters in respect to the overall SAC program, the use of the data does demonstrate how these measures can be applied by different levels and organizations of the Air Force using the same techniques.

Another shortfall was the inability to determine whether items currently in the CIP, that were not candidates recommended by WSMIS/GWAM, met the criteria specified in Air Force Manual (AFM) 67-1. Individuals previously contacted who were to provide these data were unable to do so due to other pending requirements. Because of these missing data, it was not possible to quantitatively answer measurement question 1.

Findings

The findings in this chapter include the data collected to demonstrate the measures of percent defects and cycle time, the correlation of these measures to aircraft availability (using MICAP period hours), and the potential of these measures in field use according to experienced critical item managers.

Percent Defects. Data used to determine the measure of percent defects for each of the five SAC aircraft contained in this study were collected from SAC Critical Item lists, WSMIS/GWAM Critical Item Candidate lists, and WSMIS Automated Forms 74. Results of these efforts are provided in Table 7. From these data, p charts were developed to demonstrate the use of percent defects in evaluation of the CIP. As a reminder, defects include items in the CIP which were not recommended by WSMIS/GWAM, items that enter and leave the CIP on a recurring basis, and items in the CIP that do not meet preestablished MAJCOM criteria.

Due to insufficient historical information (generally 20 - 30 historic data points), meaningful upper control limits (UCL) were not able to be calculated using the formulas identified in Chapter III. In light of this shortfall, a UCL of 30% was implemented based on the expected CIP performance according to critical item management officials (36).

With the UCL set at 30%, the p control charts (Figures 12 - 17) clearly illustrate that most measures for percent defects exceed the UCL.

The E-4 percent defects measures (Figure 12) were very high, equalling or exceeding 100% for two of the four

Table 7. Percent Defects Data

B-52	Jun/90	Sep/90	Jan/91	Apr/91
Critical items in CIP:	62	23	30	86
Critical items not recommended by GWAM:	32	15	13	28
Recurring items:	n/m	n/m	n/m	34
CIP items not meeting MAJCOM criteria IAW AFM 67-1:	n/m	n/m	n/m	n/m
C-135				
Critical items in CIP:	100	22	18	115
Critical items not recommended by GWAM:	62	10	6	53
Recurring items:	n/m	n/m	n/m	30
CIP items not meeting MAJCOM criteria IAW AFM 67-1:	n/m	n/m	n/m	n/m
B-1				
Critical items in CIP:	33	8	8	22
Critical items not recommended by GWAM:	3	4	3	7
Recurring items:	n/m	n/m	n/m	7
CIP items not meeting MAJCOM criteria IAW AFM 67-1:	n/m	n/m	n/m	n/m
E-4				
Critical items in CIP:	6	5	5	5
Critical items not recommended by GWAM:	5	4	5	4
Recurring items:	n/m	n/m	n/m	2
CIP items not meeting MAJCOM criteria IAW AFM 67-1:	n/m	n/m	n/m	n/m

Table 7 (continued).

F-111	Jun/90	Sep/90	Jan/91	Apr/91
Critical items in CIP:	20	2	0	0
Critical items not recommended by GWAM:	3	0	0	0
Recurring items:	n/m	n/m	n/m	n/m
CIP items not meeting MAJCOM criteria IAW AFM 67-1:	n/m	n/m	n/m	n/m

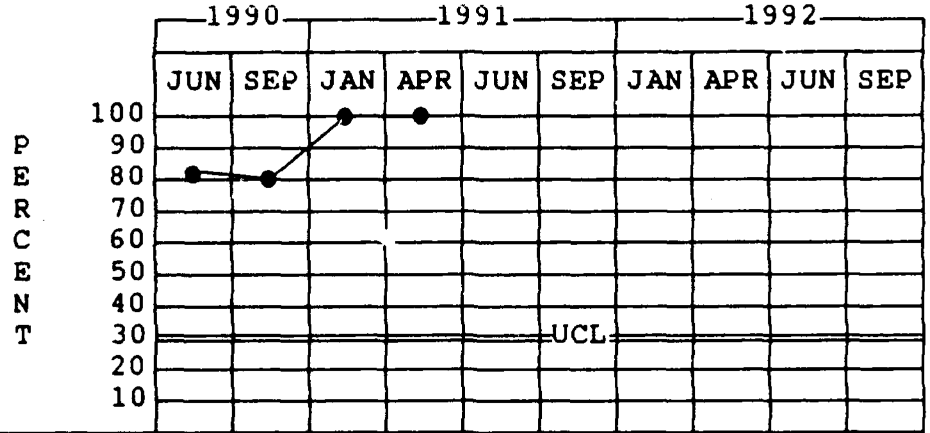
NOTE: n/m indicates the data were not able to be measured.

periods. This particular weapon system has very few items in the CIP due to its contractor logistics support (CLS) resupply structure. As a result, if only a few items have defects of those items in the CIP, high percent defects measurements will result.

The F-111 (Figure 13) is another weapon system with very little activity in the CIP. Because the F-111 items that were in the CIP during the first quarter contained no defect conditions, a low percent defects measure resulted. In the final three quarters for the F-111 aircraft, no items were added to the CIP resulting in zero defects due to zero items.

The C-135 is one of SAC's more active weapon systems in the CIP. This is evident by the number of items entered into the CIP each quarter (see Figure 14). The C-135 p control chart demonstrates a fluctuating performance with

MAJCOM: SAC
Aircraft: E-4



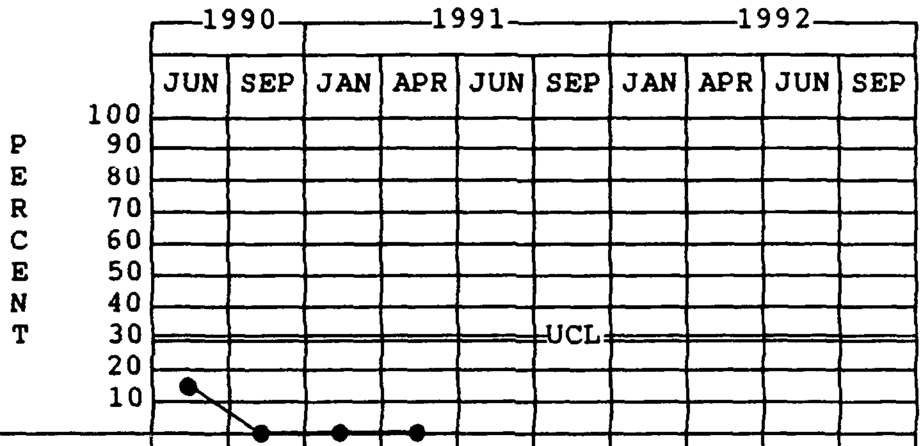
	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR	JUN	SEP
1. % DEFECTS	83	80	100	120						
2. # NOT GWAM IDENTIFIED	5	4	5	4						
3. # NOT MEET CRITERIA	-	-	-	-						
4. # RECURRING ITEM	-	-	-	2						
5. SUM DEFECTS	5	4	5	6						
6. # REVIEWED	6	5	5	5						
7. % DEFECTS	83	80	100	120						

LEGEND: # NOT GWAM IDENTIFIED = Items not identified by GWAM
NOT MEET CRITERIA = Items not fulfilling MAJCOM criteria
RECURRING ITEM = Items previously archived
% DEFECTS = (Sum Defects)/(# Reviewed)

Figure 12. E-4 p Control Chart

MAJCOM: SAC

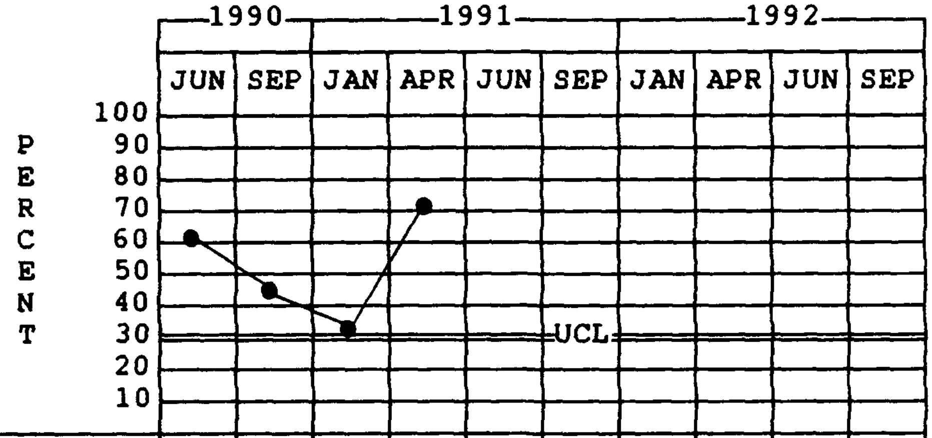
Aircraft: F-111



	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR	JUN	SEP
1. % DEFECTS	15	0	0	0						
2. # NOT GWAM IDENTIFIED	3	0	-	-						
3. # NOT MEET CRITERIA	-	-	-	-						
4. # RECURRING ITEM	-	-	-	-						
5. SUM DEFECTS	3	0	0	0						
6. # REVIEWED	20	2	0	0						
7. % DEFECTS	15	0	0	0						

Figure 13. F-111 p Control Chart

MAJCOM: SAC
Aircraft: C-135



	JUN 1990	SEP 1990	JAN 1991	APR 1991	JUN 1991	SEP 1991	JAN 1992	APR 1992	JUN 1992	SEP 1992
1. % DEFECTS	62	45	33	72						
2. # NOT GWAM IDENTIFIED	62	10	6	53						
3. # NOT MEET CRITERIA	-	-	-	-						
4. # RECURRING ITEM	-	-	-	30						
5. SUM DEFECTS	62	10	6	83						
6. # REVIEWED	100	22	18	115						
7. % DEFECTS	62	45	33	72						

Figure 14. C-135 p Control Chart

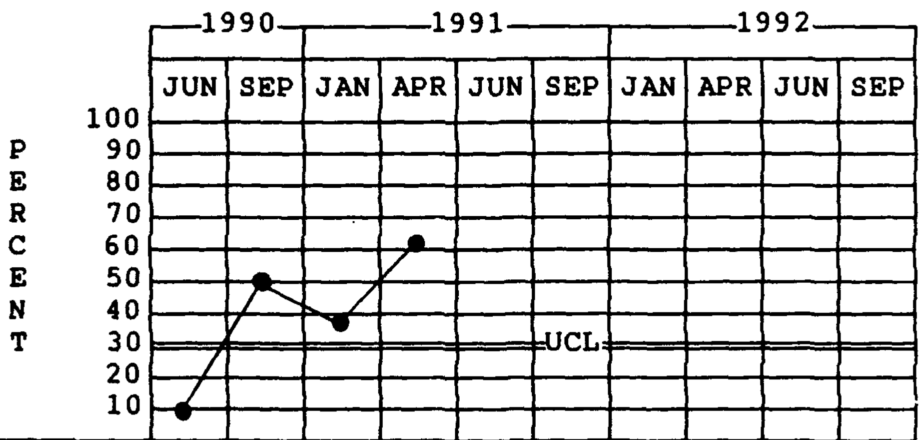
percent defects measures ranging from 33 to 72 percent. This fluctuation is consistent with control charts showing out of control processes, which suggests that the CIP is currently not in control.

The B-1 is also an active performer in the CIP. Like the C-135, the B-1's performance (Figure 15) also fluctuated widely, ranging from 9 to 63 percent. Though the B-1's initial quarter's performance fell below the UCL, the remaining quarters all registered measures above the process control range. This control chart, identifies wide variability and suggests a lack of control being experienced in the CIP.

Figure 16 presents the performance of the B-52. Like the C-135 and B-1, the B-52 displayed fluctuating performance above the established UCL. This is also indication of a process out of control.

For the five SAC aircraft overall, the average percent defects measure was 50%. This high percent defect rate indicates the strong potential for improvement. As two of the three defect conditions were not measured for the first three periods of the study (number not meeting criteria and number of recurring items), and one of the three defect conditions was not measured in the fourth period of the study (both shortfalls were due to non-availability of data and process time requirements), an even higher percent defects measure would probably have resulted had these

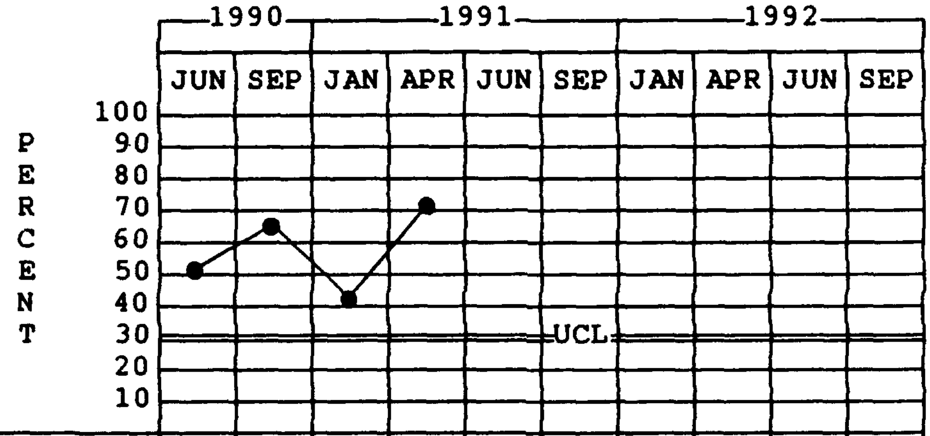
MAJCOM: SAC
Aircraft: B-1



	JUN 1990	SEP 1990	JAN 1991	APR 1991	JUN 1991	SEP 1991	JAN 1992	APR 1992	JUN 1992	SEP 1992
1. % DEFECTS	9	50	37	63						
2. # NOT GWAM IDENTIFIED	3	4	3	7						
3. # NOT MEET CRITERIA	-	-	-	-						
4. # RECURRING ITEM	-	-	-	7						
5. SUM DEFECTS	3	4	3	14						
6. # REVIEWED	33	8	8	22						
7. % DEFECTS	9	50	37	63						

Figure 15. B-1 p Control Chart

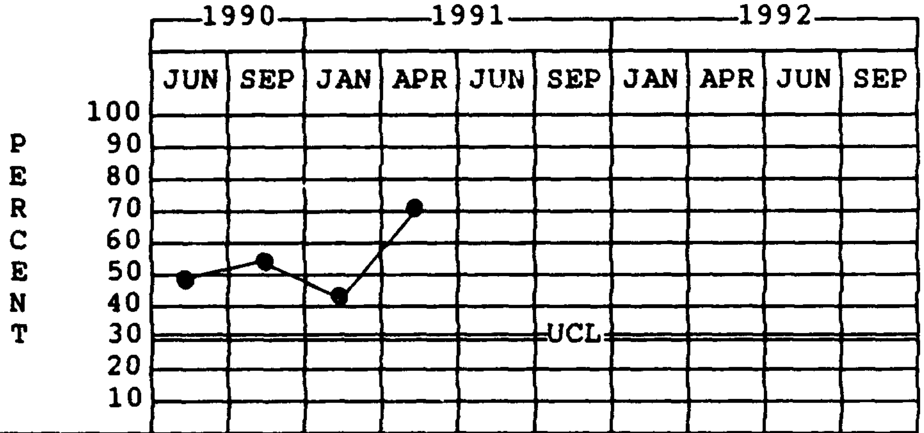
MAJCOM: SAC
Aircraft: B-52



	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR	JUN	SEP
1. % DEFECTS	51	65	43	72						
2. # NOT GWAM IDENTIFIED	32	15	13	28						
3. # NOT MEET CRITERIA	-	-	-	-						
4. # RECURRING ITEM	-	-	-	34						
5. SUM DEFECTS	32	15	13	62						
6. # REVIEWED	62	23	30	86						
7. % DEFECTS	51	65	43	72						

Figure 16. B-52 p Control Chart

MAJCOM: SAC
Aircraft: Overall



	1990 JUN	1990 SEP	1991 JAN	1991 APR	1991 JUN	1991 SEP	1992 JAN	1992 APR	1992 JUN	1992 SEP
1. % DEFECTS	48	55	44	72						
2. # NOT GWAM IDENTIFIED	105	33	27	92						
3. # NOT MEET CRITERIA	-	-	-	-						
4. # RECURRING ITEM	-	-	-	73						
5. SUM DEFECTS	105	33	27	165						
6. # REVIEWED	221	60	61	228						
7. % DEFECTS	48	55	44	72						

Figure 17. SAC Overall p Control Chart

conditions been able to be evaluated. Consequently, the large variability which is shown in these control charts would likely have been worse had the other data been available.

Correlation of Percent Defects to Aircraft Availability. Spearman's Rank Correlation of Coefficient was used to determine whether a correlation existed between the measures of percent defects and aircraft availability. The WSMIS/Readiness Assessment Module (RAM) was accessed to extract MICAP period hours for each quarter corresponding to each of the five mission design series (MDS)(see Table 8). Using the software package Statistix 3.1 (51), Spearman's

Table 8. Aircraft Availability Data to be Correlated to Percent Defects

	MICAP Period Hours			
	Jun/90	Sep/90	Jan/91	Apr/91
E-4	8715	9145	11005	22563
F-111	0	0	0	0
B-52	594880	1209852	1337557	530672
B-1	616680	609986	337790	303221
C-135	1921	3852	7598	2977
SAC Overall	1222196	1832835	1693950	859433

NOTE: MICAP period hours are the total hours a weapon system is not mission capable due to the lack of specific piece of equipment or spare part.

Rank Correlation of Coefficient was calculated comparing the aircraft availability values and the percent defects values for each MDS. Results of these calculations are provided in Figures 18 - 22.

As identified in the scatter diagrams, correlation values for percent defects to aircraft availability ranged from positive .80 to negative .80. This range by itself

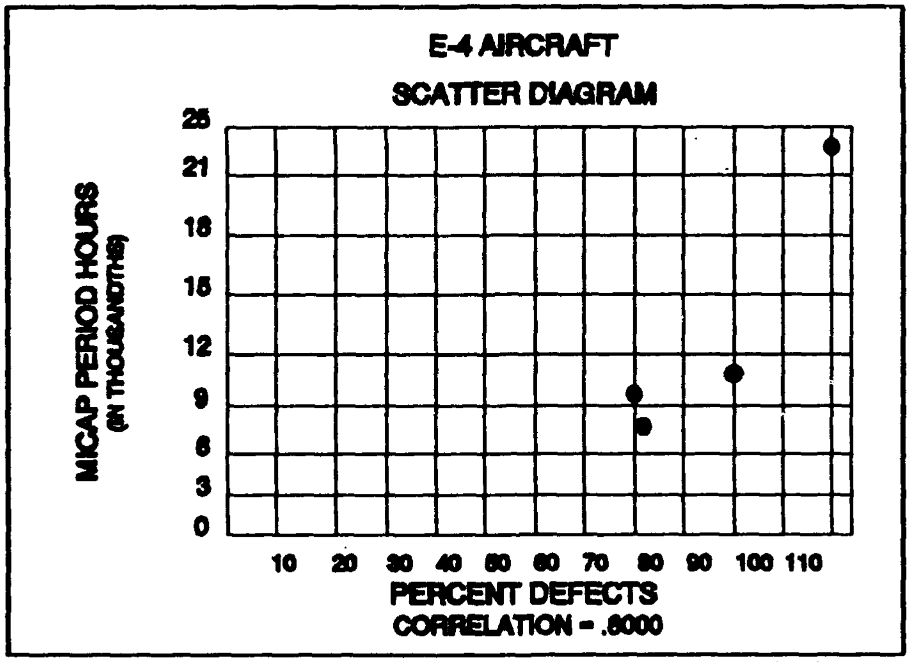


Figure 18. E-4 Correlation of MICAP Period Hours to Percent Defects

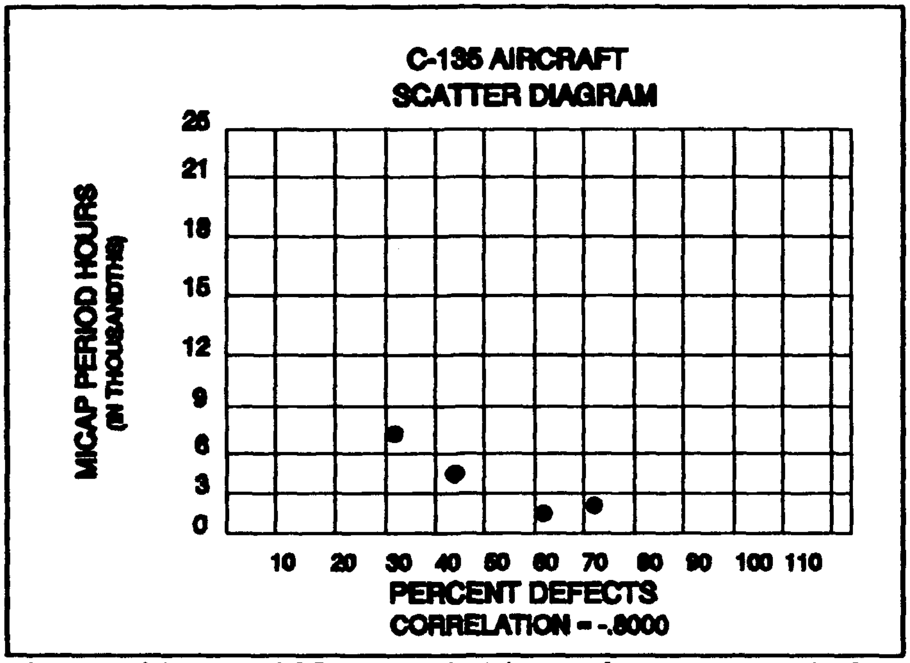


Figure 19. C-135 Correlation of MICAP Period Hours to Percent Defects

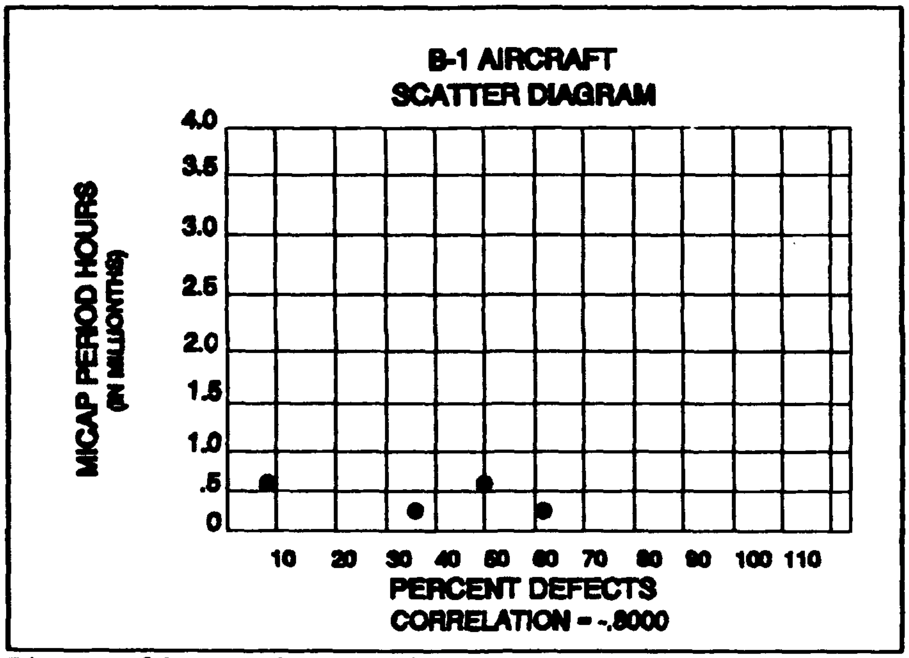


Figure 20. B-1 Correlation of MICAP Period Hours to Percent Defects

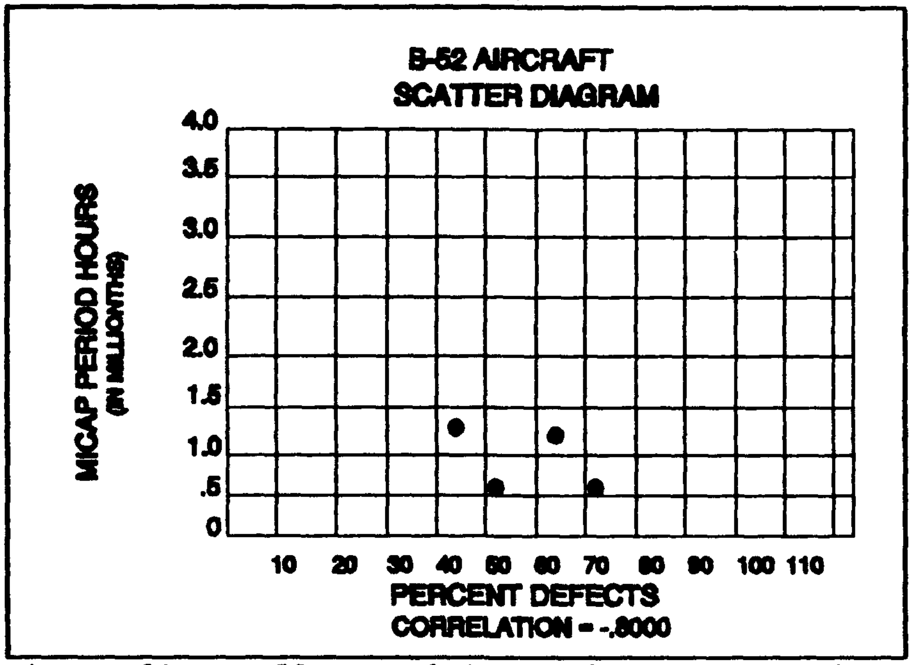


Figure 21. B-52 Correlation of MICAP Period Hours to Percent Defects

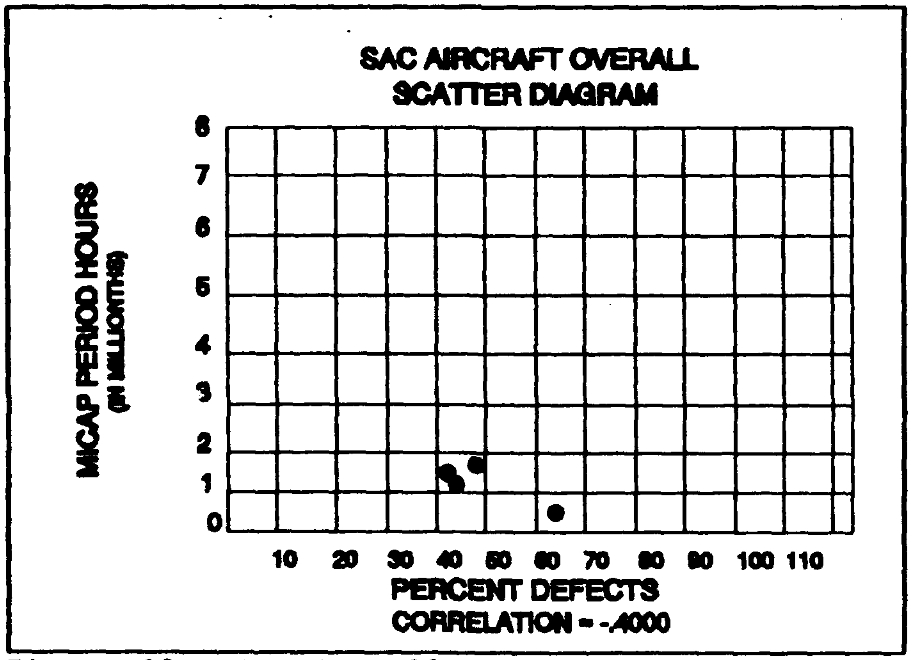


Figure 22. SAC Overall Correlation of MICAP Period Hours to Percent Defects

does not indicate a strong or consistent correlation between the measure of percent defects and aircraft availability. In order to establish that a correlation exists within a 95% confidence level requires that scores be greater than .90 (38:1212). As none of the scores fulfilled this requirement, one must logically conclude that a correlation does not exist.

In addition to individual measurement, an aggregate measure of percent defects to MICAP period hours was also computed. This resulted in a positive correlation of .3033. In order to reject at a .05 level of significance that a correlation did not exist, a value of greater than .377 was required (38:1212). As this was not achieved, further support was established that there was no correlation between percent defects and MICAP period hours.

Because the ability to observe each defect condition varied among the four periods measured, inflated scores resulted in the last period which distorted the correlation outcomes. To attempt to compensate for this situation, correlation values were recalculated comparing percent defects to aircraft availability in aggregate using a percent defect value based only on defect condition 1 (those items in the CIP which were not identified by WSMIS/GWAM), as this was measured consistently throughout all four periods. The results of this effort provided a positive correlation value of .3441. Again, in order to reject at the .05 significance level that no correlation existed, a value greater than .377 was required (38:1212). As this value was not achieved, one must again conclude that no correlation exists between percent defects and aircraft availability at the .05 level of significance.

One final correlation was run between the total number of items in the CIP for each weapon system and the respective MICAP period hours for that quarter. Results of this calculation provided a positive correlation of .2031. However, a value greater than .49 was required to reject at the .05 level of significance that no correlation existed (38:1212).

The confidence in the findings for aircraft availability and percent defects is limited due to the use of partial percent defect data for two of the four periods analyzed. Confidence in correlation results would be much stronger had full percent defect data been available for all four periods observed.

Cycle Time. Data used to determine the measure of cycle time were extracted from WSMIS/GWAM Critical Item Add/Delete reports. As mentioned in Chapter III, this method of determining cycle time only measures items that have completed the program. This was a shortfall in that it did not consider the cycle time of items currently in the program; however, this study was forced to accept this limitation as no other means of cycle time measurement was available.

Data were collected for the months of May, June and July of 1991 for the five SAC aircraft targeted in this study. All items deleted from the program for each respective MDS and month were totaled and an average calculated. The data for each MDS within each respective month was then summed, averaged, and ranged. Only three weapon systems, the B-1, C-135, and B-52, had measurable data. The other two weapon systems did not register any delete actions in the three months observed, resulting in no ability to measure cycle time for these aircraft. The cycle time calculations for each of the observed aircraft and SAC overall are provided in Figures 23 - 26.

Once again, 20 - 30 historical data points were necessary to calculate a meaningful UCL. The non-availability of historical data required the UCL for cycle time to be established based on critical item officials expectations of the program (36). Review of the charts identifies that all three aircraft had ranges in item cycle time that fall above the expected UCLs. The B-1 had a consistent range of 16 months, the C-135 ranged were from 7 to 18 months, and the B-52 had a consistent range of 18 months. As both UCLs (average and range) must not be exceeded, one must conclude that all three aircraft need management attention to correct cycle time deficiencies.

As indicated by the SAC overall average/range (xR) control chart (Figure 26), the average cycle time for SAC items in the CIP was between 6.1 and 6.4 months. In

CYCLE TIME
AVERAGE/RANGE CONTROL CHART
MAJCOM: SAC
YEAR: 1991
ACFT: B-1

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
DATA PTS					6	6	6	
SUM					62	62	62	
AVERAGE					10	10	10	
RANGE					16	16	16	

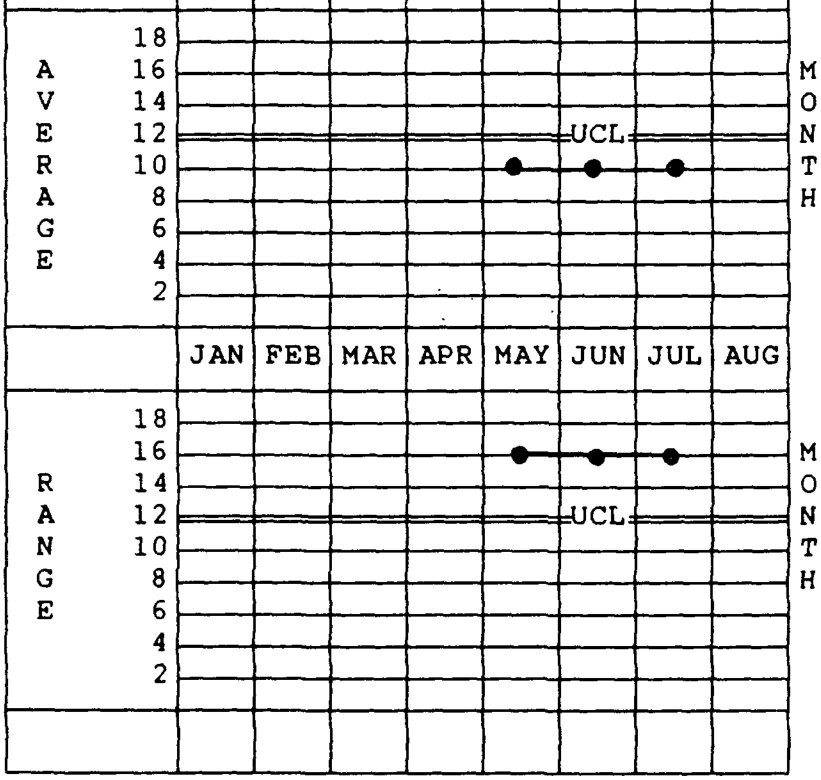


Figure 23. B-1 xR Control Chart

CYCLE TIME
AVERAGE/RANGE CONTROL CHART
MAJCOM: SAC
YEAR: 1991
ACFT: C-135

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
DATA PTS					15	14	14	
SUM					68	75	57	
AVERAGE					4.5	5.4	4.1	
RANGE					18	17	7	

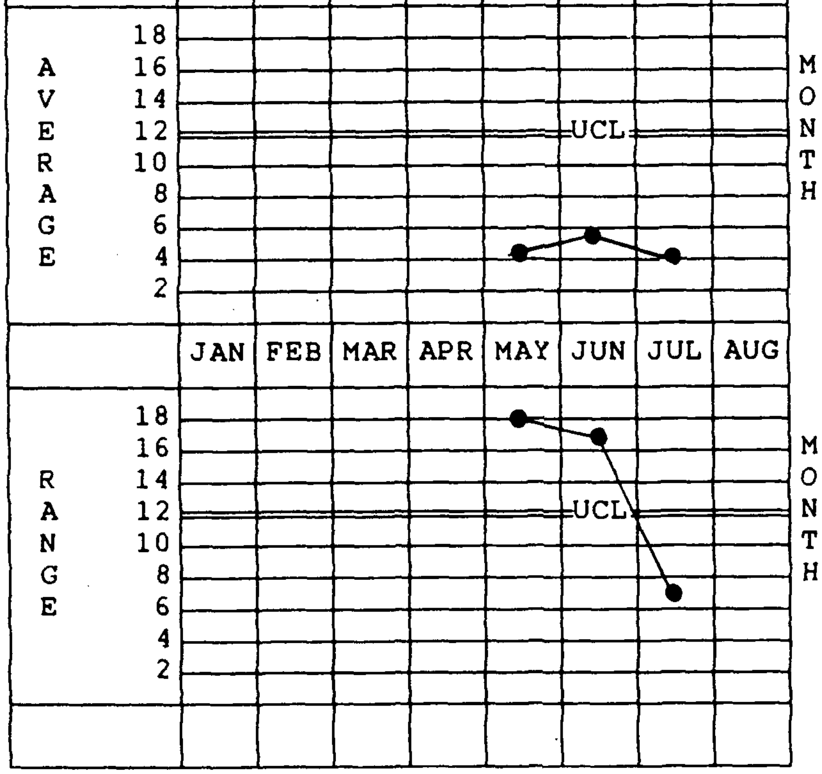


Figure 24. C-135 xR Control Chart

CYCLE TIME
AVERAGE/RANGE CONTROL CHART
MAJCOM: SAC
YEAR: 1991
ACFT: B-52

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
DATA PTS					25	24	24	
SUM					98	94	97	
AVERAGE					3.9	3.9	4.0	
RANGE					18	18	18	

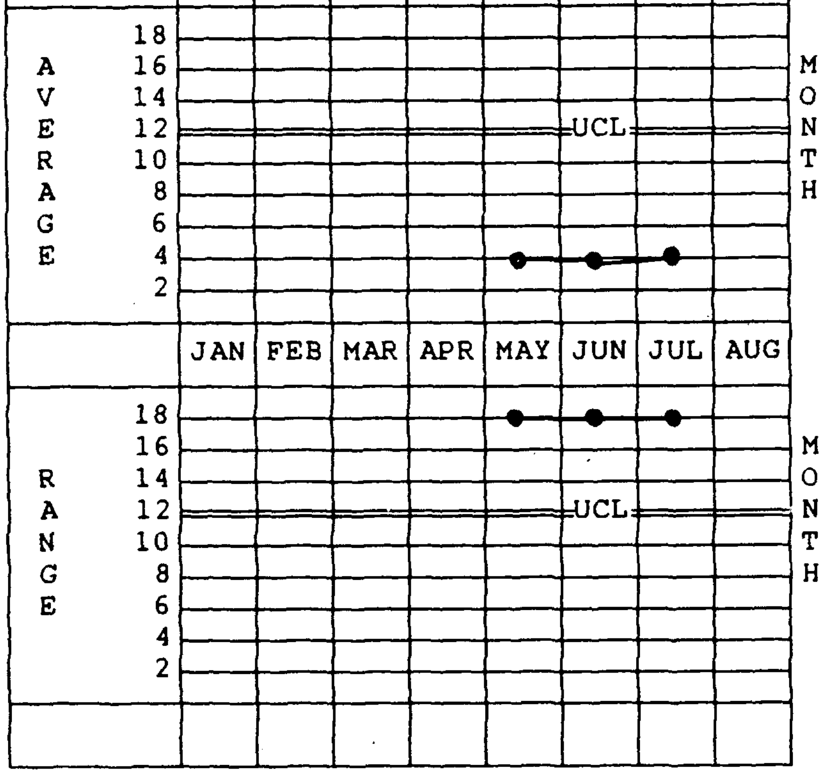


Figure 25. B-52 xR Control Chart

CYCLE TIME
AVERAGE/RANGE CONTROL CHART
MAJCOM: SAC
YEAR: 1991

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1	F-111					-	-	-	
2	B-52					3.9	3.9	4.0	
3	C-135					4.5	5.4	4.1	
4	B-1					10	10	10	
5	E-4					-	-	-	
6	SUM					18.3	19.3	18.1	
7	AVERAGE					6.3	6.4	6.1	
8	RANGE					6.4	6.4	6.3	

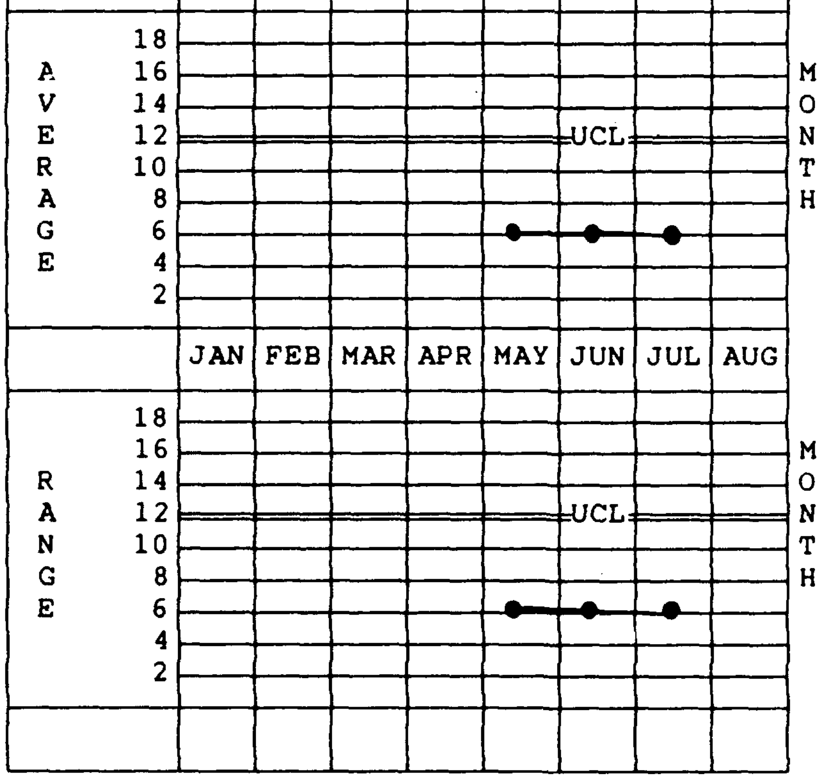


Figure 26. SAC Overall xR Control Chart

addition, cycle time for SAC items in the CIP had an average range of 6.3 to 6.4 months. The average and range values for cycle time consistently fell below the hypothetical UCLs, indicating that both the UCLs could be lowered.

Comparing the results from the individual MDS xR charts to the SAC overall xR chart, it becomes apparent the importance of measuring the programs performance at the lowest level possible to determine specific problems effecting the CIP. Evaluation of individual MDS xR charts identified the poor cycle time performance of the range UCL. Evaluation of the SAC overall xR chart indicated a consistent and controlled process. Therefore, evaluation of the SAC overall xR chart by itself would not have identified that individual processes were out of control. This observation clearly identifies the need to measure the CIP's performance at different levels in order to determine specific problem areas and the true performance of the program at a given organizational level.

Correlation of Cycle Time to Aircraft Availability. Spearman's Rank Correlation of Coefficient was used to determine whether a correlation existed between the measure of cycle time and aircraft availability (total MICAP period hours). The WSMIS/Readiness Assessment Module (RAM) was accessed to extract MICAP period hours for each month (May, June, and July 1991) for each of the five SAC MDSs. These values were then summed to determine an overall SAC aircraft availability value (total MICAP period hours, see Table 9).

Using the software package Statistix 3.1 (51), Spearman's Rank Correlation of Coefficient was calculated comparing the aircraft availability values to the average cycle time for each MDS with measurable data and the overall SAC cycle time value. Results of these calculations all provided a zero correlation between MICAP period hours and cycle time measurements.

Table 9. Aircraft Availability Data to be Correlated to Cycle Time

	MICAP Period Hours		
	May/91	Jun/91	Jul/91
B-1	278781	300655	224229
C-135	2977	1898	995
B-52	524028	374151	237212
SAC Overall	805786	676704	462436

NOTE: MICAP period hours are total MICAP hours accumulated for each item within a weapon system for the time period specified.

To further investigate the possibility of correlation between the two measures, the sum of cycle time hours within each MDS was also compared in aggregate to MICAP period hours. Results of this effort generated a positive correlation of .5255. In order to reject with 95% confidence that their was no correlation, a value greater than .6 was required to support the existence of a correlation (38:1212). As this was not achieved, this study must conclude that at the .05 level of significance no correlation exists between cycle time and aircraft availability (MICAP period hours).

The lack of correlation between cycle time and aircraft availability suggests that the CIP may not be managing the correct items. Had a positively correlated value resulted within the specified level of significance, then evidence of effective management of the CIP might have been concluded.

Once again, the number of data points (3) used in the calculation of individual MDS correlation values does not provide substantial confidence in their outcomes. Generally, the greater the number of data pairs available to correlate, the stronger the outcome of the test. Thus, findings for individual MDS correlations must be caveated with the need for additional calculation of correlation as more data become available in the future.

<u>Survey of Critical Item Managers</u>. In order to determine the potential of percent defects and cycle time for evaluation of the CIP, critical item managers from several levels within the Air Force were presented a written package (see Appendix B) explaining the measures, and then subsequently asked specific questions addressing the practicality for field use (see Appendix C). Of the 23 managers initially contacted, 22 managers completed the interview process. Based on these completed interviews,

critical item manager's opinions of the practical use of percent defects and cycle time were determined. Table 10 synopsizes the results of these interviews.

As indicated in Table 10, a large majority of the managers interviewed (73% for percent defects and 68% for cycle time) recommended these measures be considered for field application. The remaining managers interviewed either did not support the use of these measures or had no opinion at the time. The reasons for recommending or not recommending these measures were gathered during the interviews using questions contained in Appendix C. To further investigate management opinion of these measures, reasons for support and non support of these measures are discussed below.

Reasons for Supporting the Use of Percent Defects. A consistent reason for supporting the use of percent defects to evaluate the CIP's performance was the current lack of any measurement or evaluation capability of the program. Thirteen managers expressed frustration with the program because there was currently no means to receive feedback as to whether management actions that were implemented were effective. Therefore, managers generally welcomed any tool that would provide feedback on the program's performance.

Another popular reason supporting the use of percent defects was that it identified and highlighted the CIP's problem areas. Thirteen managers stated that by using this

Table 10. Management View of Percent Defects/Cycle Time

Interviewed Position	% Defects Rec	No Rec	No Opn	Cycle Time Rec	No Rec	No Opn	#
Division Chiefs	4	0	1	2	1	2	5
SPM	3	2	0	4	1	0	5
CIM	3	1	0	3	1	0	4
HQ AFLC	1	1	0	1	1	0	2
HQ USAF	0	0	1	0	0	1	1
MAJCOM	4	0	0	4	0	0	4
AFAA	1	0	0	1	0	0	1
Total	16	4	2	15	4	3	22
%	73	18	9	68	18	14	100

measure, they could determine if the correct items were being identified. By looking at the three defect conditions, managers maintained they could determine where the program was identifying the right items and where it was not.

Six managers also felt that percent defects could communicate how well the automated and manual critical item lists matched up. Managers maintain that WSMIS, a very expensive Air Force decision support system, is not being fully used due to the lack of confidence in its products. In order to improve confidence in WSMIS products, problem areas must be identified and corrected. Defect condition one, which identifies those items in the CIP that were not recommended as candidates by WSMIS/GWAM, provides such a comparison capability.

Eleven managers identified the ability of percent defects to communicate whether the criteria were being followed or not. In general, items submitted to be entered in the CIP should meet the preestablished criteria. However, managers maintain that there are special circumstances which justify entry of items into the CIP that do not meet MAJCOM criteria. To ensure that the system is not being abused, managers felt that identification of items entered into the CIP that do not meet criteria would allow further investigation into the legitimacy of these actions. Defect condition two, identification of items not fulfilling MAJCOM criteria, was identified by managers as providing this analysis capability.

One manager believed identification of seasonal trends was possible through tracking of percent defects. As identification of seasonal trends could be very beneficial to supportability improvements, this manager supported the use of percent defects.

Seven managers identified that use of percent defects would aid in determining whether the critical item selection criteria were correct. Managers claimed that this type of capability was needed in order to enable corrective actions to the existing program and build confidence in the products the program generates.

Five managers stated that the use of percent defects would enhance the communication and coordination between support and operational commands on CIP objectives. Manager's felt that common objectives and a management checks and balance capability were necessary to get the program back on track. They perceived percent defects would be able to provide such a capability.

In short, managers supporting the use of percent defects communicated the need for a quantifiable feedback mechanism which identified specific problem areas and established common objectives for all managers involved in the program. Based on these needs and their perception of how percent defects could be applied to the CIP, it was their opinion that percent defects could be instrumental in improving management of the program.

Reasons for Not Supporting the Use of Percent Defects. Of the 18% not supporting the use of percent defects, one reason given against its use, was the additional workload that it would generate. One non-supporting manager stated that implementation of the Total Quality Management (TQM) philosophy (perceived by this manager as producing a better product with less people), was not consistent with the creation of additional reporting and administrative requirements. Two other non-supporting managers emphasized the lack of resources, including money and personnel, necessary to support use of these measures. These managers emphasized that the current lack of resources was already affecting proper management of the program and that any additional administrative requirements would just add to the existing problem.

Another reason managers did not support using percent defects was the current performance of the automated and manual management systems. Three managers with this concern pointed out several shortfalls in this area. First, these managers claimed that the automated system is not real-time enough to allow a high degree of confidence in WSMIS/GWAM critical item candidates. These managers maintain that other automated systems that feed WSMIS/GWAM provide outdated data, resulting in the wrong items being identified as candidates. Concerning the manual management system, managers identified that pre-established criteria were not always followed by the MAJCOMs in selection of critical items. This disregard for the criteria, though many times justified, is not subject to evenly weighted negotiation between MAJCOM and ALC managers. Therefore, if the MAJCOMs demand that items not conforming to criteria be added to the CIP, ALC managers must comply. In their opinion, this would result in an inflated percent defects measurement, making the measurement less accurate and less useful.

Two managers felt that percent defects, though providing an overall evaluation of the program, did not provide enough detail to correct the problems occurring in the individual items themselves. These managers claimed that in order to truly be useful, measures that are used must be able to point to those items causing the problems in addition to what the problems are. Some of these managers confided that if percent defects could identify the problems occurring to the individual items verses the overall program, it would then be a useful measure.

A common reason for not recommending the use of percent defects was the additional reporting requirement that it would generate. Managers with this opinion (mainly ALC positions) were concerned with having to track and report to higher management on items for which they had little control. Because selection of critical items rests ultimately with the MAJCOMs, these managers felt their tracking and reporting to higher management would be fruitless given the ALC's minimal say in selection of critical items.

In summary, managers not supporting the use of percent defects in evaluation of the CIP based their opinions on the current lack of real-time operation of the automated system, MAJCOM nonconcurrence to pre-established critical item selection criteria, the existing lack of money and personnel resources necessary to accomplish administrative requirements, and the additional workload that would be placed on critical item managers resulting in little or no gain in effective management of the program.

Reasons for Supporting the Use of Cycle Time. Of the 22 managers interviewed, 68% supported the use of cycle time in evaluation of the CIP's performance. With this in mind, it should be noted that all managers both supportive and non-supportive of cycle time as a useful measure, identified that certain items managed by the program would be outliers in cycle time measurement. The reasons for this include pending weapon system modifications, contract lead times and other extenuating circumstances beyond critical item manager control which inherently drive up item cycle time. In spite of this, several reasons were identified for why cycle time would be useful to the management of the CIP.

One such reason was to provide management with an average measure for aid in establishing how long an item should remain in the program before it is expected to become well. Though some items will stay in the program for long periods for reasons stated above, fifteen managers believed an average cycle time measure would provide them a basis for measuring individual item performance. This would enable them to identify those items that have been in the program a long time which do not have a valid justification unlike those reasons stated above.

Others felt that cycle time would provide a good overall evaluation of how the program was performing as a whole. These managers believed that cycle time would be especially useful in providing a top management perspective of the program's performance.

Two lower level managers identified the usefulness of cycle time in improving get-well plan development and depot funding process times. By using cycle time, these managers believed more improvement could be accomplished by decreasing times involved in administrative actions and thereby speed the start of other process actions necessary in item get-well attainment.

Another management benefit identified with using cycle time was the ability to show customers (MAJCOMs) how support has been improved. According to six managers, use of cycle time measurement could quantitatively communicate the benefits of using the CIP by comparing CIP item cycle time to the expected lead times of items acquired through standard channels.

Two managers believed that the use of cycle time could enhance the ability to obtain required funding necessary to enable the CIP to operate properly. These managers stated that the CIP, though widely believed to be 100% funded, was only funded at about 60% - 70%. These managers also maintained that this shortfall prevented the effective management of the program resulting in its current performance. These managers believed that the use of cycle time as a measure would help communicate the need for additional funding by quantitatively and objectively evaluating the current program's performance.

In review, managers who support the use of cycle time in evaluating the CIP believe it will provide several benefits. These benefits include the establishment of CIP average processing times for use as bench marks, an evaluation capability for the overall program, a means by which to improve administrative and other processing times, a measure useful in communicating customer support levels, and a tool for use in obtaining required funding levels.

Reasons for Not Supporting the Use of Cycle Time. Of the 18% of managers who did not like cycle time as a measure, basically four reasons were given. The first and most common was the concern about outliers. As previously identified, some items exist which take an extensive amount of time (years in some instances) to get well. Managers not supporting the use of cycle time maintain that these outliers will drive up the overall cycle time average and make the measure useless.

Along the same thought, one manager identified that the aggregate measure established through the use of cycle time does not provide enough information to work individual items. The manager maintained that this shortfall prevents cycle time from being considered useful as it communicates that a problem exists but not exactly where.

Another critical item manager felt that cycle time was not useful because it was evaluated too late in the process. This manager believed that items must be identified and managed before they become critical otherwise the time required to make them well becomes unacceptably long. It was the belief that a measure must be implemented which provided a more proactive approach.

Finally, one manager stated that cycle time would not be a useful measure due to insufficient funding. This manager maintained that items that remained in the program for long periods of time were there due to a lack of funds to properly correct the problem causing such items to be critical. They maintained that because insufficient funding was available, identification of poor performance was useless as no action could be taken to correct the situation.

In short, managers not supporting the use of cycle time as a measure of the CIP's performance based their opinions on four things. These reasons were that too many long lead time items were present in the program, an aggregate measure was not useful in individual item management, cycle time was not consistent with a proactive approach, and insufficient funding for the program made measurement of cycle time useless.

Other Survey Findings. In completing the interview process, significant caveats and concerns were discussed with the critical item managers interviewed. As these conditions, in some cases, determined whether or not the manager did or did not recommend the use of either of the two measures, disclosure of the caveats is important. In addition, discussion of relevant concerns surrounding percent defects and cycle time and how they might be implemented are also important.

A caveat expressed by the vast majority of managers, was the need to have the measurement process automated. Managers emphasized that manual calculation of these measures would be infeasible given current manning levels and work loads. Several managers were averse to even 10 - 15 minute increases in workload necessary to post automated measurement calculations to administrative forms. One manager who did not recommend the use of these two measures, did support them in theory; however, he did not recommend their use due to the need to spend money in other areas of the program verses developing an automated measurement capability. On the other hand, numerous managers who did support use of the two measures, based their recommendation on the condition that the process would be automated.

Several concerns were also voiced by managers addressing how the measures might be used. Among these concerns, managers wanted to know at what level(s) of the Air Force that these measures would be used. In addition, several managers wanted to know if there would be a specific organization who would be responsible for monitoring performance of the CIP if the measures were implemented. Lower level managers were concerned that the measures would be used against them to make corrective actions that were out of their control due to misunderstanding by upper management. Because of this concern alone, several lower level managers did not recommend the use of either of the two measures.

Throughout all management levels of critical item managers contacted during this study, there was a consistent conclusion that the CIP was not functioning as it was designed. As no formal measures exist to evaluate the program, only subjective opinions could be gathered concerning its performance. The majority of these opinions clearly indicated that the overall CIP's performance was considered poor. The emphasis placed on particular CIP problems varied depending on the type of organization contacted.

In general, managers in support organizations emphasized the lack of funding as driving the poor performance of the CIP. They maintained that their ability to properly correct problem items added to the CIP was directly related to funding levels received. As they explained, the reason that expensive long lead time items remain in the CIP for years, is that only a few assets may be corrected in a given period due to the inadequate funding. These managers believed that given proper funding, recurring and expensive items identified as critical could be managed more effectively.

Managers from lower level support organizations emphasized the need to decrease work load, streamline administrative functions, and have a stronger voice in management of the program. These lower level support managers also felt burdened for having responsibility to correct a problem for which they had little or no control. Two lower level support managers perceived the use of percent defects and cycle time as the creation of another reporting requirement for which they would have to provide answers to questions they currently are not responsible for. Other support organization managers expressed frustration because they have no means to determine if their current efforts within the program were of any benefit to their customers. In short, there was a divergence of opinion among lower level support managers. The majority of these managers agreed that a measurement capability was desirable. On the other hand, 40% of the managers at this level were against increased administrative workload that would result from implementation of the measures

Managers from operational organizations emphasized the need to identify the correct items, expedite corrective actions, and improve inter-organizational communication. MAJCOM responses indicated a more urgent need for feedback on the CIP's performance in order to improve current process limitations. Of all the managers interviewed, it was operational managers who expressed the strongest desire to see an evaluation capability for the CIP developed and implemented.

Chapter IV Summary

In this chapter, findings resulting from implementation of Chapter III's methodology were presented. Included in these findings were the developed control charts for percent defects and cycle time, results of Spearman's Rank Correlation of Coefficient calculations and the opinions of experienced critical item managers addressing the practicality of percent defects and cycle time for field use. Chapter V presents the conclusions and recommendations resulting from the information and analysis presented in Chapters I - IV.

V. Conclusions and Recommendations

Introduction

The purpose of this research was to examine the potential of the two measures percent defects and cycle time to evaluate the Air Force Critical Item Program (CIP). To accomplish this task, actual data were collected and control charts constructed to demonstrate the potential of the two measures identified above. The research also compared percent defects and cycle time measures to aircraft availability measures to determine whether a correlation existed between them. Finally, an introductory package (Appendix B) describing percent defects and cycle time was presented to 22 experienced critical item managers from various levels and positions within the Air Force. After reviewing this package, critical item managers were asked several questions (Appendix C) addressing the potential of these measures for field use.

Conclusions

As outlined in Chapter I and reiterated in Chapter III, two investigative questions were examined to address the requirements posed in this study's problem statement. To thoroughly research each investigative question, several associated measurement questions were also addressed. Having completed the findings portion of this study, sufficient information now exists to make conclusions regarding investigative and measurement questions.

Investigative Question 1. Investigative question 1 asks, "Does measurement of percent defects aid the Air Force in managing the CIP effectively?" In addressing this question, five measurement questions were also asked. From these measurement questions the following conclusions were reached.

In answering measurement question 1, it was not possible to compare items added to the CIP that were not recommended by WSMIS/GWAM. As a result, data were not available to quantitatively answer whether items in the CIP met MAJCOM criteria. However, the description of this defect condition was included in Appendix B and was presented to experienced critical item managers. Of these managers, the majority supported the need to consider this defect condition in measurement of the CIP's performance. This concern by managers supports the prospect that items are currently in the program that do not meet MAJCOM criteria. While support from these managers is encouraging, the data should still be evaluated to more completely assess this important issue.

In addressing measurement question 2, quantitative data were available. As demonstrated by the p control charts exhibited in Chapter IV, items in the CIP were not found to consistently correspond to items identified by WSMIS/GWAM. In comparing these two lists, an average defect rate of 50% was found. This value confirms that items in the CIP do not acceptably correspond to items recommended by WSMIS/GWAM.

Analysis of measurement question 3 was limited to only one quarter's data. For this quarter (ending the month of April 1991), all items contained on the list were reviewed to determine if they had been entered and deleted from the CIP before. As a result of this analysis, an average of 34% of the items in the program in April 1991 were recurring items. This high percentage suggests that many of the same items do enter and leave the CIP on a recurring basis.

The Spearman's Rank Correlation of Coefficient values were calculated for percent defects measures, including all defect conditions for each MDS, and aircraft availability. The results of these calculations ranged from positive .80 to negative .80. The overall correlation value calculated was negative .40. A value of .9 or greater was required to substantiate a correlation within a .05 level of significance. As this was not achieved, no correlation was concluded for these calculations. An aggregate correlation of the combined MDSs was also accomplished. This resulted in a positive correlation of .3033; however, a value greater than .377 was required to substantiate a correlation at the .05 level of significance. Again, the conclusion that no correlation existed was reached for a .05 level of significance. To attempt to compensate for the inability to measure all defect conditions in each quarter, percent defects measures for defect condition one (which was measured in all four quarters) was also aggregately correlated against aircraft availability (MICAP period hours) for each MDS. The result of this calculation generated a correlation value of .3341. As with the original test, a value greater than .377 was required to substantiate the existence of a correlation with a .05 level of significance. Once again, it was determined that no correlation existed with a .05 level of significance. Further analysis showed that no correlation existed between MICAP period hours and the number of items entered into the CIP for a given weapon system. Correlation calculations for this test resulted in a correlation value of .2031; however, a value greater than .49 was required to establ[illegible] significance at the .05 level. These findings all support that the wrong items are being managed in the CIP.

Due to the use of partial percent defects data for two of the four periods analyzed, the confidence in these results is weakened to a small degree. Nevertheless, this study concludes that no correlation exists between percent defects and MICAP period hours or for MICAP period hours and the number of items entered into the CIP.

A survey of 22 critical item managers was completed using information and questions contained in Appendices B and C. Results of this process were summarized in Table 9. The high percentage of managers recommending the use of percent defects (73%), strongly suggests that critical item managers find this measure useful. Of all managers interviewed, only 18% of the managers did not recommend the use of percent defects. The remaining managers (9%) had no opinion.

From the findings stated above concerning individual measurement questions, several conclusions can be reached. First, managers believe that items are entering the CIP that do not meet MAJCOM criteria. Second, items recommended by WSMIS/GWAM do not consistently correspond to items actually entered into the CIP. Third, over 30% of those items evaluated were identified as having entered and left the CIP at a previous date. Fourth, current calculations indicate that there is no correlation between aircraft availability and percent defects or the number of items entered into the CIP at the .05 level of significance. Fifth, 73% of critical item managers interviewed supported the further development of percent defects for field use. Based on these determinations, this study concludes that the measurement of percent defects could aid the Air Force in managing the CIP.

Investigative Question 2. Investigative question 2 asks, "Does measurement of cycle time aid the Air Force in managing the CIP effectively?" In addressing this question, three measurement questions were also asked. From these measurement questions the following conclusions were reached.

Cycle time was measured by looking at WSMIS/GWAM Add/Delete reports. The value for "months critical" was averaged within each of the five MDSs for items shown as deleted on these reports. From these data, both average and range information were gathered. This information was then consolidated at the MAJCOM level producing a SAC overall cycle time measurement. As a result of this effort, individual MDS cycle time measures were found to cover from 3.9 to 10 months, while range measures within an MDS covered from 7 to 18 months. Overall MAJCOM values for cycle time ranged from 6.1 to 6.4 months for average and 6.3 to 6.4 months for range. Within each MDS, little variation was noticed for average values and all were within UCL control limits. However, range values did show variation and all measured MDSs exceeded the established UCL. Between MDSs there was considerably more variation (from 3.9 to 10 months for average values and 7 to 18 months for range values). Addressing measurement question 6, within each MDS there was very poor cycle time performance. For the MAJCOM as a whole, cycle time performance appeared to be in control. These measurements established the importance of multi-level evaluation and provided a basis for further use of these measures with SAC weapon systems in the future.

As was the case with percent defects, very few data periods were available to calculate Spearman's Rank Correlation of Coefficient between cycle time and aircraft availability (three periods, May, June, and July 1991). Resulting calculations provided a zero correlation between these two measures for both individual MDSs and SAC overall. Aggregate correlation calculations using the sum of cycle time data and the total MICAP period hours generated a positive correlation of .5255. However, a value of greater than .6 was required to substantiate the existence of a correlation within a .05 level of significance. As this was not attained, the resulting conclusion was again that no correlation existed at a .05 level of significance. Based on these results, management must conclude at this time that there is no correlation between aircraft availability and cycle time at the .05 level of significance.

As stated above, survey of 22 critical item managers was completed using information and questions contained in Appendices B and C. Results of this process were summarized in Table 9. The percentage of managers recommending the use of cycle time (68%), suggests that critical item managers find this measure useful. Of all managers interviewed, only 18% of the managers did not recommend cycle time be used. The remaining managers (14%) had no opinion.

From the findings stated above addressing individual measurement questions, several conclusions have been reached. First, cycle time measurements were out of control within each MDS, however, they were in control for SAC overall. Second, correlation values for cycle time and aircraft availability indicated no correlation at a .05 level of significance. Third, 68% of the critical item managers interviewed supported the further development of cycle time as a measure of the CIP's performance. Based on these determinations, this study concludes that the measurement of cycle time could aid the Air Force in managing the CIP more effectively.

Overall Objective. The objective of this study was to test the proposition that the measures of percent defects and cycle time could provide the Air Force with a useful tool for evaluating the performance of the CIP. In reaching this objective, actual data were gathered and measured using percent defects and cycle time with their respective control charts. The correlation of these measures to aircraft availability was also determined. Finally, results of the above efforts were presented to experienced critical item managers in the field to determine the potential of the two measures for field use. Implementation of the above research resulted in the conclusion that both percent defects and cycle time measures could be useful in the effective management of the CIP. Though the use of partial data weakened the confidence in correlation results, applied measurement of the data and subsequent interview of critical item managers substantiated the usefulness of these measures.

A clear outcome of this research was the need for some form of evaluation for the CIP's performance. Managers at every level fully supported the development of some kind of measurement technique and perceived it as necessary in order to improve the current performance of the program. All managers agreed that they needed some form of feedback to determine when and if corrective actions taken are effective. Therefore, it is the overall conclusion of this study that both percent defects and cycle time could provide the Air Force with a useful tool for evaluating the performance of the CIP.

Recommendations

A test case should be performed in an operational environment to validate the functionality of these two measures in relation to the CIP. This test would provide a broader understanding of the mechanics needed to successfully implement these measures Air Force wide. In addition, an operational test would provide an actual determination of the usefulness of these two measures in real management of the CIP.

This study also recommends that cycle time objectives be established for items managed within the CIP. Current lack of cycle time objectives has resulted in many items remaining in the program for years at a time without receiving the proper management attention. Establishment of cycle time objectives would provide a baseline time for getting items through the program and a tool for managers of extreme problem items to receive additional resources.

Further development of automated tracking and measurement capabilities are also necessary. Several shortfalls in the current automated system must be corrected in order to institute the measures of percent defects and cycle time. The enhancement and development of automated capabilities was emphatically stressed by all managers, due to the labor and time consuming effort required to apply these measures through manual methods. Without automation, managers stated they would not support the use of the two measures due to insufficient resources. Specific details are identified in the following paragraphs.

The first automated improvement should be the ability to determine the cycle time of items currently maintained in the CIP. As identified in Chapters III and IV, the current system is only able to aggregately report cycle times on items deleted from the program. In order to determine true cycle time measurement and prevent management work-arounds which divert adverse attention, the cycle time of items currently maintained in the CIP as well as items deleted from the CIP must be able to be determined.

The second automated improvement required is the ability to compare items recommended as candidates by WSMIS/GWAM to those actually entered into the CIP. This is necessary to determine how effectively GWAM is identifying those items perceived as most critical by the MAJCOMs. This would aid in improving both automated and manual processes. The value of this capability for the automated process would include determining the appropriateness of the criteria and the accuracy of the data within WSMIS. The value to the manual process would include decreased workload in the current manual correlation of these two lists. Also, as the CIP begins to improve and more confidence develops in GWAM products, MAJCOM workloads would be significantly decreased due to fewer resources being used in manual tracking of the program.

The third automated improvement required is the ability to determine the criteria status of items in the CIP which are not recommended as candidates by the WSMIS/Get Well Assessment Module (GWAM). This capability must be established to determine if items not recommended by GWAM and entered into the CIP are truly critical. Even under ideal conditions, some items will have justification to be in the program even though they were not recommended by GWAM. The proposed option would readily enable the MAJCOMs and SPMs to double check these type items to ensure their addition to the CIP was properly justified.

The fourth automated improvement required is the ability to easily identify items that are recurring within the CIP. A time frame would have to be established so that WSMIS could search backward through archived files to determine which items recur in the program within a specified amount of time. This would provide the history of such items and enable managers to perform additional analysis to determine the reasons for their reoccurrence.

Once managers are aware of the overall condition of the CIP, they will need to know which individual items are in need of corrective action. Therefore, several managers recommended that the ability to identify the individual items having defect conditions would be essential. This capability is not explicitly necessary to accomplish the evaluation of the CIP's performance using percent defects and cycle time; however, this recommendation is a logical next step in providing automated tools to critical item managers for direct improvement of the program.

Guidance must be established identifying at which levels CIP performance evaluation will be accomplished. During the course of this study, managers were concerned as to what level and which organizations the measures were to be applied. This, of course, must be negotiated between operational and support organizations; however, the author of this study recommends that measurement capability be designed to enable use of these measures at all levels and organizations involved with CIP management. This will enable both consistency and flexibility of measurement throughout the entire program.

To ensure the proper use of these measures, thorough education of all managers who will be exposed to their products must also be accomplished. These measures, percent defects and cycle time, are designed to enhance and contribute to continuous improvement of the process they monitor. Theoretically, as the CIP's performance is improved, more attention can be given to proactively manage the lower two hurdles of the CIP (problem and potential critical). To achieve this objective, critical item managers at all levels must be thoroughly familiar with the purpose and meaning of the measures that evaluate its performance. Only through this awareness will proper management actions be recognized and implemented. Without such awareness, misinformed managers will likely waste resources as well as degrade the program's improvement of weapon system availability.

Chapter V Summary

This chapter has stated the conclusions of this study and provided several recommendations for pursuing the use of percent defects and cycle time in measurement of the CIP's performance. As a result of researching investigative and measurement questions, this study has determined that percent defects and cycle time could be useful for the effective management of the Air Force CIP. However, only through further research and implementation of these two measures will direct results be gained. To address the further research and development of these measures, several recommendations were provided. Included in those recommendations was the implementation of a formal test of these measures in a field environment, establishment of guiding cycle time objectives, automation of the measurement process in conjunction with WSMIS, development of an automated capability for managers to identify individual items possessing defect conditions, and the education of managers who will use these measures to improve the program.

The author of this study believes that the need for a CIP evaluation capability was clearly established. For only through meaningful measurement of a system's performance can management determine which actions are necessary to promote continuous improvement.

Appendix A: Commonly Used Acronyms

ACIN	Automated Critical Item Network
AFAA	Air Force Audit Agency
AFLC	Air Force Logistics Command
AFLCR	Air Force Logistics Command Regulation
AFLMC	Air Force Logistics Management Center
AFM	Air Force Manual
ALC	Air Logistics Center
AWP	Awaiting Parts
CLS	Contractor Logistics Support
CIM	Critical Item Manager
CIP	Critical Item Program
DOD	Department of Defense
ES	Equipment Specialist
FAD	Force Activity Designator
GWAM	Get Well Assessment Module
IMS	Item Management Specialist
LCL	Lower Control Limit
MAJCOM	Major Command
MDS	Mission Design Series
MICAP	Mission Capable
MM	Materiel Manager
NMCB	Not Mission Capable Both
NMCM	Not Mission Capable Maintenance
NMCS	Not Mission Capable Supply
NORS	Not Operationally Ready Supply

PMS	Production Management Specialist
POS	Peacetime Operating Stock
RAM	Readiness Assessment Module
REALM	Requirements Execution Availability Logistics Module
SAC	Strategic Air Command
SAFE	Supportability Analysis Forecasting and Evaluation System
SAM	Sustainability Assessment Module
SPM	System Program Manager
SQC	Statistical Quality Control
SRD	Standard Reporting Designator
TAC	Tactical Air Command
TQM	Total Quality Management
UCL	Upper Control Limit
UMMIPS	Uniform Materiel Movement and Issue Priority System
WSF	Weapon System Factor
WSMIS	Weapon System Management Information System

Appendix B: Information Package for Critical Item Managers

PERCENT DEFECTS AND CYCLE TIME

Two Potential Measures for Evaluation of the CIP

Background

The Air Force Critical Item Program (CIP) has been an official management concern of both operational and supporting commands since the height of the Vietnam War (9:1). This valid concern is due to the strong impact that scarce parts and equipment can have on weapon system availability, and ultimately on the successful outcome of operational missions. Over the last two and a half decades, numerous studies, selection criteria, and administrative systems have been developed for this program in hopes of improving weapon system availability (1; 2; 5; 8; 9; 10). Though incremental improvements have been noted, substantial disagreements still exist between operational and supporting commands concerning management of the CIP (6). This disagreement has slowed improvements to the program in the past and continues to do so today.

A major shortfall of the current program (identified in a recent Air Force Audit Agency study and recognized by CIP officials) is a means of evaluating the CIPs performance (3; 6). Because of this shortfall, common goals and management objectives are difficult to communicate between operational and supporting organizations. Establishment of common measures for CIP performance could improve communication among commands and thereby improve attainment of stated goals and objectives. Continuation of the program without establishment of a performance evaluation capability is most likely to retain the functional differences now occurring between operational and supporting commands.

To address this issue, an AFIT Thesis has been directed at analyzing possible measures for evaluating CIP performance. Through review of measurement practices of both private industry and government organizations, two measures, percent defects and cycle time, have been identified as potentially beneficial to the CIP (4; 7; 11). These measures used together, could provide a means for increasing communication of common goals and objectives among operational and supporting commands. The remainder of this report will therefore concentrate on a brief description of how these measures can be applied to the CIP.

CIP Pitfalls

In determining which measures to analyze, an in-depth study was accomplished addressing the requirements of the CIP. From this study, several pitfalls currently occurring in the program were identified. These pitfalls are listed below:

1. Items selected into the CIP are not identified by the Weapon System Management Information System (WSMIS)/Get Well Assessment Module (GWAM.

2. Items selected into the CIP do not meet preestablished MAJCOM criteria in accordance with AFM 67-1.

3. Items previously having been deleted from the CIP reenter the program due to recurring problems.

Each of these conditions can be described as a defect of the program. For the purposes of this study, a defect is defined as an item fulfilling a prescribed defect condition (one of the three pitfalls stated above). Every item entering or maintained in the CIP has the potential of possessing one or all of these defects. These defects are attributes in nature, in that CIP items either fulfill or do not fulfill the defect condition. Subsequently, each item in the CIP can also be measured for each of these conditions. The goal of such measurement is to track the occurrence of each condition in order to reduce future defects through appropriate management action. As defects are reduced, the performance and effectiveness of the CIP will improve. Alternately, if defects increase, recognition of this increase is immediate, also enabling appropriate management action. The obvious goal for all organizations involved in CIP management would be to reduce the number of defects to an absolute minimum. Agreement on this common goal between operational and supporting organizations would facilitate negotiation of specific management actions and criteria necessary to realize their goal. In short, this would facilitate removal of functional barriers and promote a more unified approach to managing critical items.

Another pitfall identified was the time necessary to process an item through the CIP. This time includes identification of the item, development of a get-well plan, approval of the get-well plan, implementation of actions specified by the plan, and finally deletion of the item from the CIP once it is considered well. Though the CIP is designed to expedite acquisition and/or repair of critical items, variation in item cycle time ranges from one month to upwards of two years. The upper bound of this variation strongly suggests there is the possibility for improvement. Reduction of cycle time would improve weapon system availability and allow limited resources to be applied to other problem items more quickly. Assuming continuous improvement (as management of the system is designed to do), resources would eventually be available for more preventative actions than are currently possible. Concern for cycle time is also important to ensure management does not take actions which might reduce defects while simultaneously increasing cycle time. Private industry experience has proven that the use of these two measures together can produce vast improvements in process quality (7; 11).

Using the Measures of Percent Defects and Cycle Time

Before describing the measures of percent defects and cycle time, the reader is encouraged to review Attachments 1 and 2 so as to be generally familiar with their structure and content. Included in these attachments are instructions on how each chart is developed.

One of the major benefits of using these two measures is that they can be used at all levels of an organization easily and with clear understanding (11). In turn, application of these measures to the Air Force CIP can effectively be used starting at the unit level all the way up through the Air Force level. This is a powerful characteristic due to the application of the same language and measurements, thus enabling all levels of management to strive for the same goals and objectives. To apply these measurements, two well established control charts are used. P charts (for percent defectives) are used to track defects, and xR charts (also called average range charts due to their tracking of average and variation values within a process) are used to track cycle time. Each of these charts is described below.

P Chart. As mentioned above, the P chart is used to track defects. As the CIP is updated each quarter, defects would be calculated quarterly too. To accomplish this, each defect condition is evaluated for each item and a sum total for each condition annotated in the appropriate column of the P chart (see Attachment 1, Lines 2-4). Once all items have been evaluated for defect conditions, a grand total of all defects is calculated (see Attachment 1, Line 5). This number is then divided by the total number of CIP items reviewed to determine the percent defects measure (see Attachment 1, Lines 5-7). The percent defects measure is then carried to Line 1 of the chart and graphically annotated. The upper control limit (UCL) is a preestablished guideline to alert management when the process is in or out of control. The UCL is calculated using the 20 most recent data points and the appropriate formula identified in Attachments 1 and 2. Because data are not currently maintained, 20 historic data points were not available. Therefore, UCLs shown in the three attachments are hypothetical. Any measures annotated above the UCL signifies that management action is necessary to explain and/or correct the out of control situation. Measurement of defects using this chart identifies to management how well the CIP is performing for the overall area being measured, and breaks down the CIPs performance within each defect condition. This provides management with significant information necessary to make appropriate corrective actions.

xR Chart. The xR chart is used to track cycle time. Because items are deleted from the CIP every month, this chart can be updated monthly. xR charts work best when at least five equal sample areas are measured together. In the Air Force for example, this could be Mission Design Series (MDS), and/or Air Logistics Centers (ALC), and/or Major Commands (MAJCOM). To update the chart, the average cycle time for the selected areas is totaled to establish a summed value (see Attachment 2, Lines 1-6). This value is then divided by the number of entries to calculate an average value (see Attachment 2, Line 7). Next, the range over which the cycle time occurred among the selected areas is determined. This value is the largest cycle time measure minus the smallest cycle time measure within the selected areas for that month (see Attachment 2, Line 8). Once the average and range are calculated, the results are graphically annotated. For cycle time to be in control, both the average and range results must fall below the UCL boundary lines. If either UCL boundary line is breached, then management should take action to explain or correct the situation. Measurement of cycle time by this means ensures that offsetting values do not communicate a false measure of process control.

Continuous Improvement

Several of the management benefits attainable through these measures have already been described, including: better organizational communication, better defined goals and objectives, and specific identification of problem areas. These, however, are not the only beneficial applications for percent defects and cycle time. The basic premise of these measures is to instill the process of continuous improvement. This is accomplished by continually shrinking the variation in defects and cycle time once the system has been brought under control. As described earlier, all measures must fall under the upper control limit in order to be in control. The continuous process of bringing the system under control and then shrinking down the UCL will eventually lead to a system operating at near optimal performance. Attachment 3 provides a full application of the P and xR charts for five SAC aircraft including: B-1, B-52, C-135, E-4, and F-111 aircraft. The purpose of this attachment is to allow the reader to view one possible application of these measures using comparatively realistic data. As indicated by these charts, the current CIP is far from being in control. A cumulative average of percent defect rates shows that measures currently range from 43 to 65 percent. This is far above the hypothetical UCL level of 30 percent. This indicates to management that action must be taken to bring defects back to a level where they are in control. Cycle time averages between 6.5 to 7.0 months with variability of 6.4 to 8.1 months. These figures are below the possible UCL of 12 months indicating that the system is in control and therefore, a lower UCL can be established to strive for better performance.

Data Limitations. Due to the nonavailability of complete historic information, portions of the charts in Attachment 3 could not be completed with full or in some circumstances actual data. Data contained in the P charts have full data for the months of June and April. Data reported for the months of September and January are for items managed at Warner-Robbins ALC only. In addition, in evaluation of the three defect conditions, # NOT GWAM IDENTIFIED was evaluated for all months, # RECURRING ITEM was evaluated for the month of April only, and # NOT MEET CRITERIA was not evaluated at all due to time limitations to collect such data. Addressing cycle time, four data points were deemed necessary to demonstrate the usefulness of the xR chart; however, only data from May and June were available. To ensure that the usefulness of this chart was properly communicated, data were arbitrarily extrapolated for all SAC aircraft for the months of March and April. All other data contained in these charts are actual.

Conclusion

Once again, the purpose of this presentation is to introduce two possible measures for evaluation of the CIP. It is directed at field experts, who will be asked to provide their opinions regarding 'he potential and practicality of these measures as applied to the continuous improvement of the CIP. Where possible, full and actual data were used in presentation of these two measures. Where data were not available, subsets or extrapolated data were presented as stated above. Readers are urged to review this report thoroughly in order to fully understand the application of the measures percent defects and cycle time presented in this report.

PERCENT DEFECTS
P CONTROL CHART
MAJCOM: __________
Aircraft: __________

		1990		1991				1992				1993	
		JUN	SEP	JAN	APR	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR
	100												
P	90												
E	80												
R	70												
C	60												
E	50												
N	40												
T	30						UCL						
	20												
	10												
1. % DEFECTS													
2. # NOT GWAM IDENTIFIED													
3. # NOT MEET CRITERIA													
4. # RECURRING ITEM													
5. SUM DEFECTS													
6. # REVIEWED													
7. % DEFECTS													

LEGEND:
NOT GWAM IDENTIFIED = CIP item not identified by GWAM
NOT MEET CRITERIA = CIP item not fulfilling MAJCOM criteria
RECURRING ITEM = CIP item previously archived
% DEFECTS = (Sum Defects) / (# Reviewed)

Page 1 of 2 Attachment 1

P Chart Completion Instructions

Line	Instructions
1	This value is carried from line 7, once all calculations have been completed. Data is then graphically annotated in the chart above line 1.
2	Items selected to the CIP as critical are compared to those items identified by the WSMIS/GWAM Candidate List for all three hurdles. Items in the CIP which are not identified in the WSMIS/GWAM Candidate List are considered a defect. The total of these defects is entered on line 2.
3	Items selected to the CIP are reviewed to determine if they meet current MAJCOM criteria. Items failing to meet criteria are considered a defect. The total of these defects is entered on line 3. Automated capability to perform this review is currently not available.
4	Items leaving and reentering the CIP on a recurring basis are considered defects. The total of these defects is entered on line 4. This value can be determined by reviewing archived Form 74s.
5	This is the sum total of lines 2 - 4.
6	This is the total number of items reviewed for defect conditions
7	Percent defects is calculated by dividing the value of line 5 by the value of line 6.

P Chart Upper Control Limit Formula:

$$UCL=\bar{p}+3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \tag{1}$$

where:
UCL = upper control limit
p_{bar} = average number of defects
n = sample size

NOTE: UCL values used in this study's charts are hypothetical due to nonavailability of data.

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CYCLE TIME
AVERAGE/RANGE CONTROL CHART
MAJCOM: __________
YEAR: __________

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	F-111												
2	B-52												
3	C-135												
4	B-1												
5	E-4												
6	SUM												
7	AVERAGE												
8	RANGE												

	18													
A	16													
V	14													M
E	12						UCL							O
R	10													N
A	8													T
G	6													H
E	4													S
	2													

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	18													
	16													
R	14													M
A	12						UCL							O
N	10													N
G	8													T
E	6													H
	4													S
	2													

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xR Chart Completion Instructions

Line	Instructions
1 - 5	This is the average cycle time for each identified MDS as determined from data extracted from the monthly WSMIS/GWAM Add/Delete Reports.
6	This is the sum of the averages for all MDSs for the specified month.
7	This is the overall average cycle time calculated by dividing line 6 by the number of measured MDSs for the specified month.
8	This is the range over which individual MDS averages occurred. This value is calculated by subtracting the smallest MDS cycle time average from the largest MDS cycle time average in each month. Average and range values are then graphically annotated in the appropriate charts below line 8.

Average Upper Control Limit

$$UCL_{\bar{x}} = \bar{\bar{x}} + A_2 \bar{R} \qquad (2)$$

where:

UCL_{xbar} = upper control limit for x_{bar}
x_{bar} = average cycle time of individual weapon systems
X_{barbar} = average of the average weapon system cycle time
R_{bar} = average range over which sample data are spread
A_2 = special factor for control limit

Range Upper Control Limit

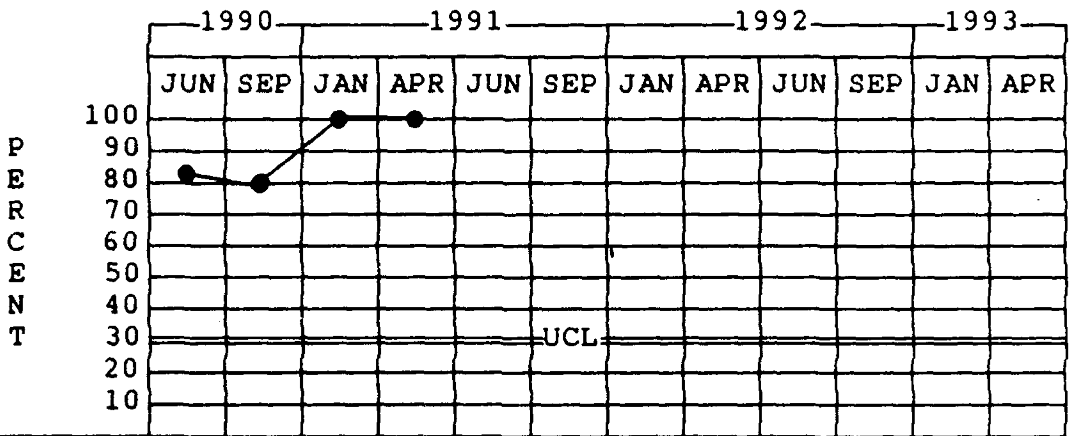
$$UCL_R = D_4 \bar{R} \qquad (3)$$

where:

UCL_R = upper control limit for range
R_{bar} = average range over which sample data are spread
D_4 = special factor for upper control limit

NOTE: UCL values used in this study's charts are hypothetical due to nonavailability of data.

PERCENT DEFECTS
P CONTROL CHART
MAJCOM: SAC
Aircraft: E-4



	1990		1991				1992				1993	
	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR
1. % DEFECTS	83	80	100	120								
2. # NOT GWAM IDENTIFIED	5	4	5	4								
3. # NOT MEET CRITERIA	-	-	-	-								
4. # RECURRING ITEM	-	-	-	2								
5. SUM DEFECTS	5	4	5	6								
6. # REVIEWED	6	5	5	5								
7. % DEFECTS	83	80	100	120								

LEGEND: # NOT GWAM IDENTIFIED = CIP item not identified by GWAM
NOT MEET CRITERIA = CIP item not fulfilling MAJCOM criteria
RECURRING ITEM = CIP item previously archived
% DEFECTS = (Sum Defects) / (# Reviewed)

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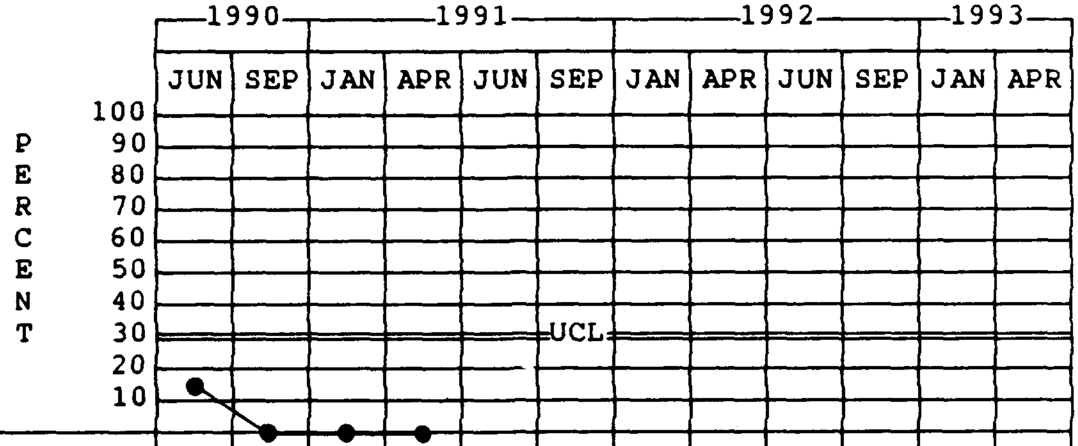
PERCENT DEFECTS
P CONTROL CHART
MAJCOM: SAC
Aircraft: F-111

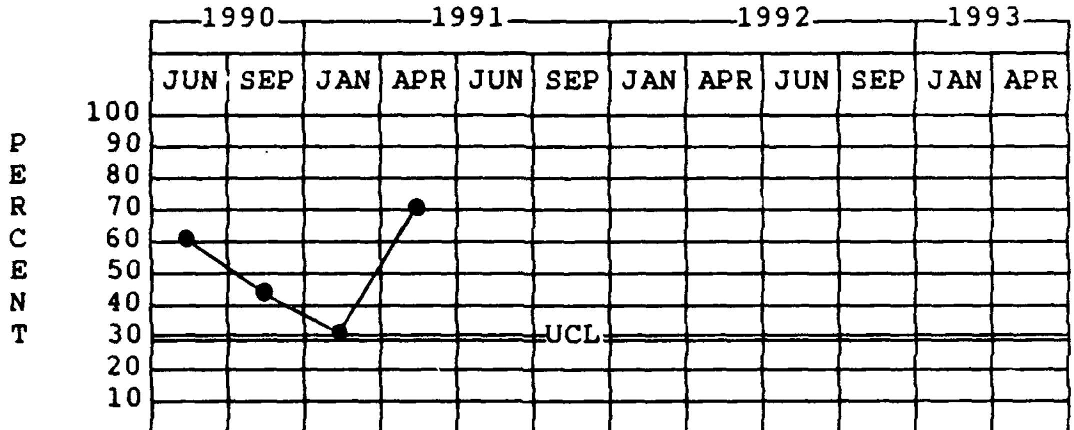


	JUN 1990	SEP 1990	JAN 1991	APR 1991	JUN 1991	SEP 1991	JAN 1992	APR 1992	JUN 1992	SEP 1992	JAN 1993	APR 1993
1. % DEFECTS	15	0	0	0								
2. # NOT GWAM IDENTIFIED	3	0	-	-								
3. # NOT MEET CRITERIA	-	-	-	-								
4. # RECURRING ITEM	-	-	-	-								
5. SUM DEFECTS	3	0	0	0								
6. # REVIEWED	20	2	0	0								
7. % DEFECTS	15	0	0	0								

LEGEND: # NOT GWAM IDENTIFIED = CIP item not identified by GWAM
NOT MEET CRITERIA = CIP item not fulfilling MAJCOM criteria
RECURRING ITEM = CIP item previously archived
% DEFECTS = (Sum Defects) / (# Reviewed)

Attachment 3

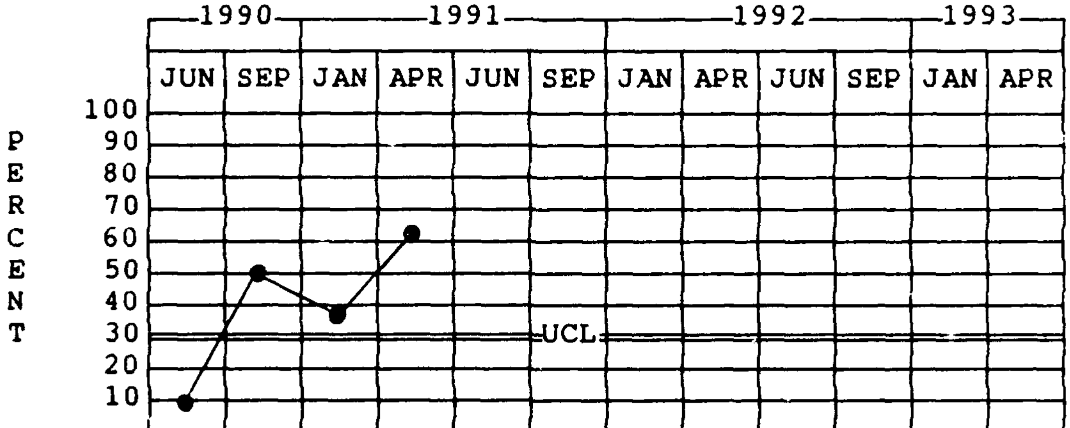
PERCENT DEFECTS
P CONTROL CHART
MAJCOM: SAC
Aircraft: C-135



	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR
1. % DEFECTS	62	45	33	72								
2. # NOT GWAM IDENTIFIED	62	10	6	53								
3. # NOT MEET CRITERIA	-	-	-	-								
4. # RECURRING ITEM	-	-	-	30								
5. SUM DEFECTS	62	10	6	83								
6. # REVIEWED	100	22	18	115								
7. % DEFECTS	62	45	33	72								

LEGEND: # NOT GWAM IDENTIFIED = CIP item not identified by GWAM
NOT MEET CRITERIA = CIP item not fulfilling MAJCOM criteria
RECURRING ITEM = CIP item previously archived
% DEFECTS = (Sum Defects) / (# Reviewed)

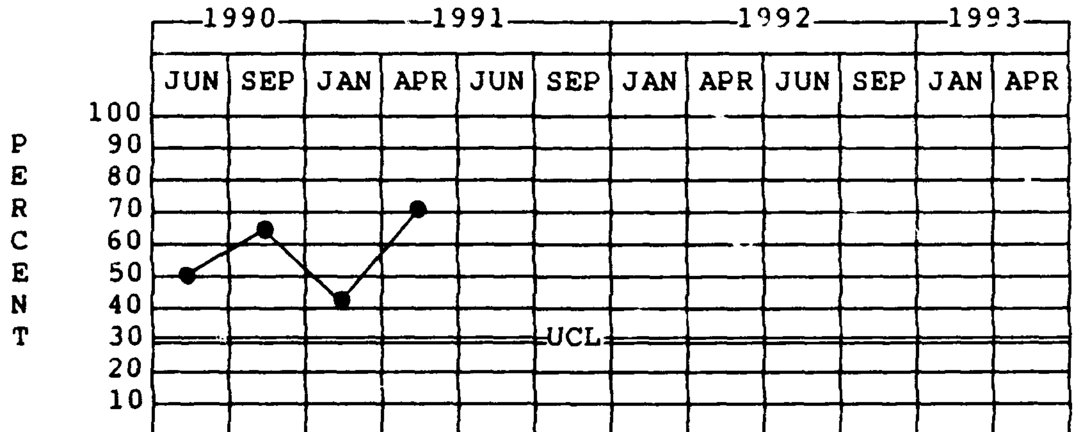
PERCENT DEFECTS
P CONTROL CHART
MAJCOM: SAC
Aircraft: B-1



	1990 JUN	1990 SEP	1991 JAN	1991 APR	1991 JUN	1991 SEP	1992 JAN	1992 APR	1992 JUN	1992 SEP	1993 JAN	1993 APR
1. % DEFECTS	9	50	37	63								
2. # NOT GWAM IDENTIFIED	3	4	3	7								
3. # NOT MEET CRITERIA	-	-	-	-								
4. # RECURRING ITEM	-	-	-	7								
5. SUM DEFECTS	3	4	3	14								
6. # REVIEWED	33	8	8	22								
7. % DEFECTS	9	50	37	63								

LEGEND: # NOT GWAM IDENTIFIED = CIP item not identified by GWAM
NOT MEET CRITERIA = CIP item not fulfilling MAJCOM criteria
RECURRING ITEM = CIP item previously archived
% DEFECTS = (Sum Defects) / (# Reviewed)

PERCENT DEFECTS
P CONTROL CHART
MAJCOM: SAC
Aircraft: B-52



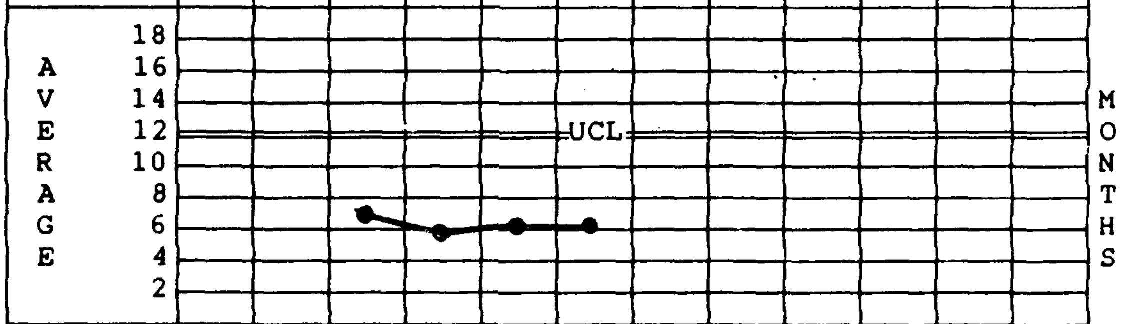
	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR	JUN	SEP	JAN	APR
1. % DEFECTS	51	65	43	72								
2. # NOT GWAM IDENTIFIED	32	15	13	28								
3. # NOT MEET CRITERIA	-	-	-	-								
4. # RECURRING ITEM	-	-	-	34								
5. SUM DEFECTS	32	15	13	62								
6. # REVIEWED	62	23	30	86								
7. % DEFECTS	51	65	43	72								

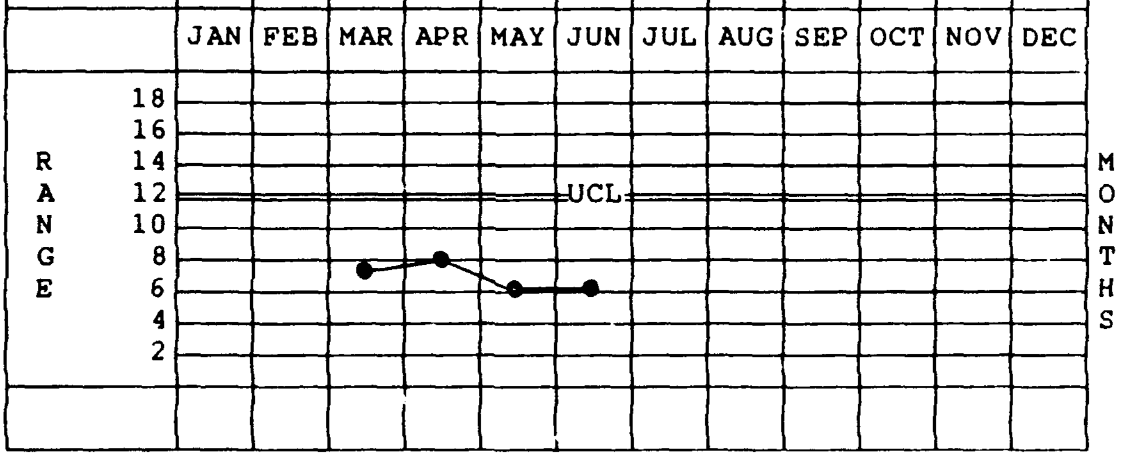
LEGEND: # NOT GWAM IDENTIFIED = CIP item not identified by GWAM
NOT MEET CRITERIA = CIP item not fulfilling MAJCOM criteria
RECURRING ITEM = CIP item previously archived
% DEFECTS = (Sum Defects) / (# Reviewed)

Attachment 3

CYCLE TIME
AVERAGE/RANGE CONTROL CHART
MAJCOM: SAC
YEAR: 1991

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	F-111			-	4.5	-	-						
2	B-52			4.7	5.2	3.9	3.9						
3	C-135			6.3	5.3	4.5	5.4						
4	B-1			12	11	10	10						
5	E-4			4.9	3.1	-	-						
6	SUM			28	29	18	19	>VALUES ROUNDED					
7	AVERAGE			7	5.8	6.3	6.4	>VALUES ROUNDED					
8	RANGE			7.6	8.1	6.4	6.4	>VALUES ROUNDED					





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Attachment 3

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Appendix C: Questions Critical Item Managers Were Asked

1. Do you believe any benefits will be gained by using percent defects to measure the CIP performance? If yes, what are they?

2. Do you believe any disadvantages will result by using percent defects to measure the CIP's performance? If yes, what are they?

3. Do you believe any benefits will be gained by using cycle time to measure the CIP performance? If yes, what are they?

4. Do you believe any disadvantages will result from using the measure of cycle time to measure the CIP's performance? If yes, what are they?

5. How is the CIP being measured now?

6. What are the benefits gained by the measures currently used to manage the CIP?

7. What are the disadvantages realized by the measures currently used to manage the CIP?

8. Do these current measures produce effective management of the CIP?

9. Having been presented and considered the measures of percent defects and cycle time, would you recommend these measures be used? Why, or why not?

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Vita

Captain Robert R. Lee was born on 6 March 1964 in Oxnard California. He graduated from Mesa High School in Mesa, Arizona, in 1982. In 1986, he graduated from Arizona State University in Tempe, Arizona with a Bachelor of Science in Management. Immediately following graduation he was commissioned a second lieutenant in the United States Air Force. He has since been assigned to Eglin AFB, Florida where he served in various management positions including base level and acquisition logistics. During his assignment at Eglin AFB, he graduated from Troy State University in Troy, Alabama, with a Master of Science in Management. He entered the School of Systems and Logistics, Air Force Institute of Technology, in May 1990. Captain Lee's next assignment is to Warner Robins Air Logistic Center, Robins AFB, Georgia.

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REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this study was to evaluate the potential of two measures, percent defects and cycle time, to measure the overall performance of the Air Force Critical Item Program (CIP). The need for such study was generated from the current absence of any measurement system available to evaluate the CIP. This research used these two measures with actual data, evaluated the correlation between aircraft availability and percent defects and cycle time, and analyzed management perceptions addressing the usefulness of these measures for field use. Performance of this analysis resulted in support for these measures by over two thirds of the critical item managers interviewed. As a result, this study concluded that both of these measures, percent defects and cycle time, could be useful to the Air Force in managing the CIP effectively.

14. SUBJECT TERMS
Criticality, Quality Control, Performance Measures, Critical Item, Continuous Improvement

15. NUMBER OF PAGES
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Unclassified	Unclassified	Unclassified	UL

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3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Please estimate what this research would have cost in terms of manpower and/or dollars if it had been accomplished under contract or if it had been done in-house.

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4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3 above), what is your estimate of its significance?

   a. Highly Significant b. Significant c. Slightly Significant d. Of No Significance

5. Comments

________________________ ________________________
Name and Grade Organization

________________________ ________________________
Position or Title Address