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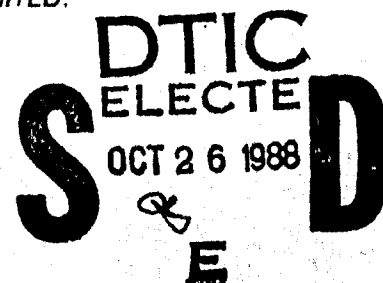
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A STUDY ON THE OPERATIONAL AND LOGISTICS IMPACT ON SYSTEM READINESS

Westinghouse Electric Corporation

Frank M. Krantz, Gino L. Liberati and Joseph F. Fanzone

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Several prediction techniques are used to predict the maintainability characteristics of a system or equipment during its design and development. These predictions are updated throughout the development and production process. The maintainability characteristics are often demonstrated and validated at official program milestones prior to system fielding such as development test and evaluation (DTE), operational test and evaluation (OTE), and maintainability demonstrations. Even so, the actual maintenance and repair times experienced in the field are usually significantly larger than the times predicted and demonstrated. This report addresses the results of a study conducted to identify and quantify the major field factors and influences which impact Air Force maintenance of ground electronic systems and equipment. This knowledge will enable future systems to incorporate designs with a resultant increased readiness and availability. Knowledge of the factors related						
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to maintenance practices also will enable planning for increased real operational performance.

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SUMMARY

The purpose of this study, "Operational and Logistics Impacts on System Readiness", RADC Contract Number F30602-85-C-C018, was to identify the major factors and operational influences which affect system equipment maintainability. Methodology was to be developed for translating contract specified values for mean time to repair (MTTR) into repair times which can be expected in the operational environment.

The study team designed and used a comprehensive survey technique to capture the experience and expertise of Air Force maintenance personnel. The survey centered on the factors which affect maintenance of ground electronic command, control, communications and intelligence (C³I) equipment.

128 USAF maintenance personnel were interviewed at 17 Air Force and Air National Guard field operational locations to learn from their experience in the repair of ground electronics equipment. Survey personnel held preliminary discussions with unit commanders and ranking officers at each site, to explain the study's purpose and intended protocols. This secured outstanding cooperation from the Air Force maintainers. Individual interviews formed the basis for development of "round tables" or expert panels which established consensus estimates of the effects of the operational environment. These frank and comprehensive discussions not only quantified such effects, but also identified

several unanticipated areas of concerns which bear on field maintenance issues.

Survey personnel also examined extensive historical maintenance and repair records for selected Air Force equipment, including AFM 66-1 and Equipment Status Report (ESR) information, as well as data documented in prior reports bearing on the study topics.

The three initial site visits functioned as pretests of survey protocols and interview techniques. The next 11 site visits served as the primary data collection activity. The three final trips were used for confirmation of the developed estimates. Since the confirmation data correlated well with the primary data obtained at the 11 previous sites, the data was combined to generate translation factors based on data from the broadest base of all 14 sites.

Maintenance personnel responses indicated that operational factors affecting repair time are appropriately divided into 3 types: those which were not appropriately accounted for in the original inherent MTTR predictions; those which effectively add a fixed amount of time to each maintenance action and are independent of other factors; and those which multiply maintenance time, i.e., whose effect is directly proportionate to the length of the corrective maintenance time. Factors can also be classified as either generally applicable to predicting field MTTR, or only applicable in specific cases. This procedure recognizes that a single transition factor, applicable

to all fielding locations across the entire range of operational conditions, would provide little insight into the actual field situation at a given site. Therefore a family of transition factors (called "k factors") was derived, to be utilized in specific instances to forecast field operational MTTR. The first k factors adjust the inherent predicted MTTR through a developed function (F) to account for conditions not fully considered during the initial prediction of an active maintenance MTTR. The adjusted or overall inherent MTTR are then multiplied by the multiplicative k factors to form an estimate of active MTTR. The additive k factors add specific increments to the active MTTR. This process is stated in the following translation formula:

$$MTTR(field) = \{ F[M_I, K_I] \times K_M \} + K_A$$

where:

- M_I = inherent predicted MTTR
- K_I = k factors used to develop adjusted MTTR
- K_M = multiplicative k factors
- K_A = additive k factors

Consensus values for individual k factors are developed based upon the career experience of Air Force maintenance personnel surveyed. These values are:

<u>ADJUSTMENT K FACTORS</u>	<u>PERCENTAGE</u>	<u>TIME</u>
Cables and Connectors	0.31	1.3 Hr
CNDs	0.06	Developed per System

<u>MULTIPLICATIVE K FACTORS</u>	<u>VALUE</u>
Climatological	1.3-4.7
Maintenance Induced	1.22
NBC Gear	1.10

<u>ADDITIVE K FACTORS</u>	<u>VALUE</u>
Policy and Procedures	$0.48 + P_r$ (0.39) hr
Spares Availability	1.3 hr
Cables and Connectors	0.08 hr

where $P_r = 1$ if system incorporates redundancy
 $= 0$ if system does not incorporate redundancy

The values show that standard prediction techniques for MTTR substantially under-estimate required field active maintenance time. Estimates of field operational MTTR can be increased as much as 5 times due to simply a very cold environment. Such transition factors have been documented and provide a logical methodology for translating predicted MTTRs into the realistic operational values required by Air Force planners. It is recommended that these factors be used in all applicable cases in order to improve the correlation between predicted active MTTR and the MTTR that is experienced in the field. These factors represent consensus values and should be treated as such. If more specific information is known about equipment adjustment factors or base characteristics where the system in question will be deployed, the reliability or maintainability engineer can formulate his/her own set of constants using this method.

The significant drivers of field active maintenance time are discussed below. These drivers include the cables and connectors problems, the time delay for receiving spare parts, and induced failures associated with maintenance actions.

- o Spares delay time is clearly the most significant driver for extremely long repair times. This can run as high as 10 times predicted MTTR, even when a spare is available on the base. This points to a need to examine the general spares acquisition policy in order to determine the validity of the spares prediction assumptions.
- o Cables and connectors account for a significantly higher percentage of failures than predicted. Maintenance personnel stated that cables and connectors account for up to 50 percent of basic failures at some bases. Such failures affect MTTR through increased manual troubleshooting, because FD/FI for these components is not well covered by automated FD/FI techniques including BIT.
- o Technicians attributed an average increase of 21 percent in repair time to the need to correct problems induced by maintenance actions themselves. The largest increase was 70% at one base.

A number of points were brought up by USAF personnel during site survey discussions. These comments and salient points provide valuable insight into the maintenance environment and are therefore included as related observations. Among the points brought out were:

- o Long logistics delay times when obtaining spares encourage detailed troubleshooting at the base level, even without appropriate technical data or schematics, which in turn greatly increases recorded repair time.
- o Greater complexities and redundancy of new electronic systems and equipments increases the maintenance time, however the increased equipment reliabilities were felt to more than compensate for the maintenance and repair time increases, especially when redundant capability allows maintenance to be performed with the equipment operating in an "amber state". This means that either the system is operating using its redundant capability or operating in a degraded state of operation.
- o High system/equipment reliabilities do create a problem by increasing the time between maintenance actions of any specific type, with consequent decrease in the technician's familiarity with the required actions. Consequently, most maintenance units use failures as opportunities to conduct impromptu

hands-on training when a failure does not cause significant loss of coverage. This action generates misleadingly high repair times. This distorts the maintenance time data seen in failure reporting systems.

- o Many USAF maintainers identified preventive maintenance as a major cause of subsequent failures in ground electronics equipment. The magnitude of this cause varied among the bases and could not be specifically quantified based on the gathered data.
- o Tools negatively impact field maintenance when not immediately available, as for some non-standard items, and in extreme cold, when shattering has been reported.
- o Nuclear/biological/chemical (NBC) protective gear increases maintenance task times by a factor of two to five. This factor does not impact current observed field MTTR, since NBC gear is only worn for training during peacetime activities, but could be critical in wartime.
- o Some personnel stated that certain maintenance activities simply cannot be performed while wearing the NBC protective ensemble.
- o Historical data sources for Air Force equipment repair actions show wide variations in repair time and contain little or no information on

concurrent conditions or description of fault detection/fault isolation (FD/FI) processes which affect repair time. They are thus of little use in identifying or quantifying factors affecting operational MTTR.

One especially interesting spin-off of survey investigations was the emergence of the Phillips head screw as the clear choice of Air Force ground electronics equipment maintainers for a common screwhead. Out of 71 technicians responding, the Phillips head was preferred by 40, or over 56%. The Phillips head was chosen by three times as many maintenance personnel as the next most popular choice. Reasons given for this include the resistance of the Phillips head to stripping which is a concern to the maintenance personnel. The suggestions for a common screwhead for all equipments decreases the number of tools required and the time to obtain the needed tool.

The results of study investigations led to a number of recommendations for consideration by the Air Force. These include:

- o MTTRs for ground C³I equipment should be increased by a factor ranging from 3.5 to 12.3 over their presently inherent predicted values to estimate operational repair time, the exact value to depend on climate and other fielding conditions.

- o Inherent MTTR prediction procedures (and perhaps reliability predictions as well) should be re-examined to place more emphasis on cable and connector failure modes.
- o Preventive maintenance intervals should be lengthened wherever failure data support such action, in order to decrease subsequent failures induced by maintenance.
- o More frequent maintenance exercises with technicians in NBC gear should be considered to promote greater skill and confidence, and to supply feedback on any tasks which cannot be accomplished in the protective ensemble, so that the tasks can be redefined and/or equipment modified to accommodate necessary maintenance.
- o Future studies of operational impacts on repair times would greatly benefit from more comprehensive and detailed data collection, which could be facilitated by automated interactive data capture made possible through provision of maintenance-aiding microcomputers.
- o Training and technical guidance for ground equipment maintenance should be augmented, perhaps through automated technical order (TO) delivery coupled with artificially intelligent diagnostics in a portable microcomputer aid such as alluded to above.

- o Tool quality bears close consideration at all locations, but especially for equipment fielded in extreme cold environments.
- o Consideration should be given to greater use of the Phillips in future systems and as a possible common screwhead for equipments.

For future efforts, the study team recommends similar investigations on airborne electronics, to establish whether there is any perceptible difference between the two types in the behavior of operational MTTR relative to predicted values. This would help shed further light on the nature and magnitude of causal factors. Further study is also recommended for the maintenance problems posed by cables and connectors, with emphasis on identifying fundamental causes and promising remedies.

PREFACE

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1.0 INTRODUCTION

1.1 General

This study of "Operational and Logistics Impacts on System Readiness" identifies the principal factors which cause a system's field maintenance time to be significantly greater than that predicted during system development. The investigation focused upon Command, Control, Communication and Intelligence (C³I) ground based systems. Instead of recorded maintenance data, the study drew upon the highly experienced Air Force senior maintenance personnel for its primary source of information. Rather than performing strictly statistical analysis of recorded maintenance data lacking background and explication, the study method provided insights into problems as seen by actual system maintainers.

The study was also aimed at developing a factor to quantify the relationship between predicted and actual mean time to repair (MTTR) values. No single "k factor" applicable across all field conditions was found. A number of k factors representing the effects of varying field conditions and practices were derived along with the functional form of their relative effects. These are described along with methods for applying these factors to quantify the relationship between predicted and actual MTTR for a range of specific field environments, maintenance practices and use scenarios. The resultant relationship is quantified as a range of multiplicative and additive values.

1.2 Objective

The study contract, F30602-85-C-0018, was let by the Air Force Rome Air Development Center (RADC) to identify those operational or environmental factors which effect the maintainability of Air Force C³I electronic ground-based systems. Specific interest was in those factors which cause the differences between field experienced mean time to repair times and those predicted during system development.

1.3 Scope

Contractual specification values of maintainability (mean time to repair) of C³I systems reflect those values which are controllable by design and which can be expected to occur under ideal conditions of repair for single failures. This is referred to as the intrinsic maintainability. Fielded equipment rarely comes close to achieving the intrinsic maintainability. In order to effectively plan for the integrated logistics support of C³I ground-based systems, Air Force planners need to know which factors affect field maintainability and to what extent. This study identifies the operational, environmental and logistics factors which adversely affect active repair time and provides observed ranges of affect.

To obtain the required results the investigators analyzed historical maintenance data as well as performed field investigations at 17 Air Force sites. The investigations were structured to cover a

representative cross section of ground-based C³I equipment and a variety of equipment environments. Some of the factors which could influence maintainability which were considered by this study are: maintenance concept, local maintenance policies, supply and support equipment effectiveness, climate, human factors, equipment reliability and "cannot duplicate" (CND) rates.

1.4 Summary of Results

The approach taken in this study is unique. Rather than rely on recorded maintenance data that was already determined to be inadequate, biased, and incomplete, the study team went straight to a prime source of information: the Air Force maintenance personnel who repair the electronic systems in the field. Seventeen Air Force bases in diverse locations were visited and their senior maintenance personnel interviewed in order to elicit the major maintenance problems and concerns actually encountered in the field. This enabled the determination of the major operational factors, external conditions and influences that impact electronic systems and equipment maintenance and readiness.

Data collected from interviews and surveys of senior level, experienced personnel form the basis for this study and the findings. The first three bases visited were used to develop the survey method and questions. Data questionnaires were used as guides by the interviewers and completed at the remaining fourteen visited bases. The gathered information was used to

determine the principal operational field and logistics factors that impact Air Force maintenance, make the repair actions more complex and require more time than is generally predicted. These drivers of field mean time to repair (MTTR) are:

1. Depot planned repairs that are actually repaired in the field and lengthy depot repair cycle time.
2. Exclusion of some failure influences in predicting MTTR; especially cable and connector failure rates and cannot duplicate failures.
3. Spares availability and stockage locations.
4. Climate.
5. Method of recording operational (field) time to repair.
6. Deferred maintenance and mission priorities.
7. Impact of nuclear/biological/chemical (NBC) gear on repair time.
8. Built in test (BIT)/fault isolation test (FIT) adequacy.
9. Learning syndrome associated with performing maintenance on an infrequent basis caused by high equipment reliability.

Seven specific transition factors were derived from gathered data to quantify the major field impacts. These transition factors are called k factors. Each k factor acts as a delta increment in the time to perform active corrective maintenance, taken as the MTTR. The k factors are naturally classified into two categories by way of their functional effects. One class is comprised of multiplicative factors, which act to increase the

time required for each subtask in the field by a certain percentage, and thus function as magnifiers of predicted MTTR. The second class is that of additive factors, which are quantities added to the predicted repair time value in order to transition to a field value. The k factors quantified through this study are:

<u>MULTIPLICATIVE K FACTORS</u>	<u>VALUE</u>
1. Climatological Impact	
> 90 degrees F	1.34
0 < x < 32 degrees F	1.9
-20 < x < 0 degrees F	3.1
< -20 degrees F	4.7
2. Impact Factor for Maintenance Induced Failure	1.22
3. NBC Protective Gear Impact	$(1 - t) + (t * 2.3)$
where t = percentage of time NBC gear is worn during the repair action.	

<u>ADDITIVE K FACTORS</u>	<u>VALUE</u>
Policy and Procedures	$0.48 + P_r (0.39) \text{ hr}$
Spares Availability	1.3 hr
Cables and Connectors	0.08 hr
where $P_r = 1$ if system incorporates redundancy	
$P_r = 0$ if system does not incorporate redundancy	

When calculating field MTTR, several k factors must in general be used in an appropriate sequence. First, a parametric equation incorporates factors for cables and connectors and cannot duplicate (CND) conditions, both of which are found to be underestimated in the prediction of inherent MTTR. This results in an overall inherent MTTR derived from predicted MTTR. The inherent MTTR is then multiplied by those multiplicative factors applicable to the specific field environment under consideration, and the remaining additive factors then

added, to give the total expected field MTTR. Thus, the following translation formula is developed:

$$MTTR(\text{field}) = \{ F[M_I, K_I] \times K_M \} + K_A$$

where:

M_I = inherent predicted MTTR
 K_I = k factors used to develop adjusted MTTR
 K_M = multiplicative k factors
 K_A = additive k factors

The MTTR adjustment factors are developed to be:

ADJUSTMENT FACTORS	PERCENTAGE	TIME
Cables and Connectors	0.31	1.3 Hr.
Cannot Duplicate (CND)	0.06	Developed per System

The formulation of these constants is documented in this report. These values were developed using data obtained at bases located across the country. It is recommended that the additive and multiplicative constants be used in all applicable cases in order to improve the correlation between predicted mean-time-to-repair (MTTR) and the MTTR that is experienced in the field. These must be applied in a judicious manner depending on specific characteristics of the system or equipment under analysis and the planned operational conditions. To the extent that information is available specific to the base(s) where the system in question will be deployed, the reliability or maintainability engineer can readily employ the methodology derived in this study to compute and apply values for these k factors more specific to the situation of interest.

2.0 STUDY DETAILS

2.1 Approach

The approach used in this study centered on the collection and analysis of data collected from the most informative prime source, those Air Force maintenance personnel who work with the ground based electronic systems under study. Surveys and interviews were conducted at various Air Force bases with senior level experienced maintenance officers and technicians. Their day-to-day experience with the operational factors which impact repair time forms the basis for the translation factors from predicted to field repair times. The study results are therefore based on the best experience the Air Force has to offer, that of its own personnel.

The methodology used to implement this approach was to develop a series of "expert panels" on field repair operations. The makeup of these panels comprised of the people most knowledgeable of maintenance, people which could provide valuable insight into the known divergence of MTTR between predicted and observed values. When possible, maintenance actions were observed as they took place. Data documenting failure reports were also reviewed. The overall results from all sources were then summarized to form the basis for this report.

The approach employed took advantage of the study team's extensive military logistics and support background, comprising decades of experience in these areas. It emphasized the experience and understanding

of veteran maintenance personnel as a primary source for valid and comprehensive data. It also capitalized upon their appreciation of the field repair situation. It used to advantage the presence of a personal on-site interviewer to gather this data. A knowledgeable interviewer could flexibly identify which questions to ask, and could follow up immediately on crucial issues to obtain the necessary detail. The "human touch" was also seen as critical to reduce the technician's resistance to questioning by reinforcing his sense that what he has learned in his job is important, that his input is valued, and that something meaningful will result from his cooperation.

The method used to perform this study differed from the originally planned traditional approach. This original plan was to conduct this study in an empirical quantified fashion; that is, to gather data during the term of the contract which would then be analyzed exhaustively to reveal the salient non-design factors affecting observed MTTR values in the field. The object was to conduct a full scale, statistically based analysis of these factors and their relative impacts on MTTR which would quantify the impacts. This would then form the basis for identification of the major factors driving increased field MTTRs.

This type of empirical analysis, while providing the highest degree of accuracy and confidence for its results, is heavily dependent on the scope, quantity and validity of collected data. The study encountered insurmountable difficulties associated with a lack of

accurate information in existing maintenance data systems. Examination of existing Air Force maintenance and repair data showed that field factors which directly impact maintenance time were not recorded in any of the data bases. This caused the existing data banks to be inadequate for this study. In addition, data analyzed from several AF maintenance data collection systems introduced concerns about the validity and bias of much of the data.

Once it had been established that existing maintenance data systems alone were inadequate for purposes of this study, a survey data questionnaire was developed to be completed by Air Force technicians for the specified equipment at each visited site. This highly detailed questionnaire was designed to collect equipment repair data to be used instead of the information in the recorded maintenance data systems. Data that was pertinent to all the initially identified field environment impact factors was included for collection through a lengthy data collection forms. The effectiveness of this approach was tested in three preliminary site visits. Results showed that there was a lack of repair action data returning from the visited sites. Since the accuracy (and hence the eventual utility) of statistical estimates depends crucially upon the sample size, this repair data collection approach was discarded and a more useful approach developed. The revised approach consisted of interviews and surveys with experienced maintenance personnel. The original data questionnaires were modified so as to be readily used by interviewers as a guide for their surveys, and

as a record to be filled out by the interviewers subsequent to their discussions with maintenance personnel. The original program of site visits was expanded to ensure the collection of experience data from a large number of maintenance personnel.

The approach was based on the study team's experience in electronic equipment maintenance, its skills in drawing out salient observations from Air Force technicians, and the extensive knowledge resident in the experience of the technicians who operate and service the field equipments. It was felt that the attitude and perception of the technician who fixes the equipment is a better guide to the actual situation that exists than a set of numbers which are incomplete and possibly biased.

2.2 Data Collection

Data collection efforts followed the approach discussed in Section 2.1 for conduct of the study. Preliminary research was performed to familiarize the survey team with equipment design characteristics, maintenance concepts and technical orders. This research served to define the data necessary for the study. Fourteen Air Force bases were targeted as prime sites to be visited, on the basis of their usage of the systems selected for examination. To pave the way for site visits, the study team contacted the base commander or maintenance chief of each base, and discussed with him the study objectives and the interview procedures that would be followed. On the basis of these

discussions, visits were scheduled and procedures refined.

2.2.1 Site Survey Preparation

A number of preparatory steps and analyses were taken in order to lay a solid and comprehensive foundation for the site surveys prior to the actual gathering of maintenance-related data from the selected sites. This preparation tapped retrospective professional and corporate knowledge bases, current status and concepts of Air Force maintenance policies, procedures culled from separately sponsored site visits, and projections of the future maintenance environment. From this knowledge base, a list of prospective factors which might affect MTTR was developed and the relative importance of each estimated. This list went through several iterations before forming the basis for site survey questionnaires which were used by the survey team to guide their interviews.

2.2.1.1 Professional Experience

As a point of departure for data collection procedures, an initial listing of factors which may account for the difference between predicted MTTR and operational (field) time to repair was generated. This initial list was reviewed and revised by the team as a whole. Subsequent personal interviews, panel-like discussion, and "brainstorming" sessions were conducted with experienced field, support, and maintenance personnel within the Westinghouse organization. Results

of these sessions were used to revise and expand upon the identified factors. Those will be identified and discussed later in this section.

2.2.1.2 Separately Sponsored Site Visits

Members of the study team visited two Air Force Bases early in February 1985 through arrangements by the Air Force Coordinating Office for Logistics Research (AFCOLR). These trips were arranged prior to the receipt of this contract and were made to observe operational and intermediate level maintenance activities on site. While oriented to airborne equipment (FB-111, KC-135, B-52, and EC-135), the direct exposure to maintenance activities afforded by these visits provided valuable insights into the Air Force maintenance environment and problems.

Three additional bases were visited in April 1985. These trips were again arranged by AFCOLR. Operation and maintenance were observed for equipment used by the Space Command (SPACECOM), North American Aerospace Defense (NORAD), and Aerospace Defense Command (ADCOM). The equipment observed included data processing systems, communications, cryptography and radar. Pertinent insights were extracted from the extensive trip reports and used to further modify the initial factor list for this study. These visits and pertinent observations are further described in Part 1 of Appendix D, Related Activities to the Contract.

2.2.1.3 Literature Search

A computerized literature search was conducted using the following key words, individually and in combination:

Maintainability, operational, maintenance, C3, C3I, MTTR, Repair Time.

Several technical reports and articles pertinent to this study were identified. These were obtained and reviewed for background information. Unfortunately, most of the research and investigation into operational influences and field impacts were related to system equipment reliability, not to maintainability. These identified factors and environmental impacts that influence the equipment reliability, measured as the mean time between failures (MTBF), to be different from the predicted value.

Two technical reports were particularly useful for background and information:

1. Operational Influences on Maintainability, RADC-TR-77-193, July 1977.
2. The Use of Air Force Field Maintenance Data for R&M Assessment of Ground Electronic Systems, RADC-TR-79-103, April 1979.

The first report was useful to initially identify operational and logistics concern areas which impact

maintainability. It also provided guidance on methods to pursue the study investigation. The second report was helpful to identify Air Force sources of maintenance data and some of the concerns associated with its use. The documents used during this study are identified in the list of references shown in Appendix B.

2.2.1.4 Field Data Review

A review of maintenance and supply field records was undertaken in order to refine and confirm prior estimates of the relative importance of each of the factors which may account for the difference between predicted MTTR and operational (field) time to repair. With the addition of historical information to supplement experience, first hand observations, and future projections, it was possible to arrive at a definitive list of candidate factors influencing discrepancies between predicted and field MTTR values. This list was used to determine the nature and scope of data to be gathered.

2.2.2 Development of Data Collection Methodology

As preliminary work moved forward, effort turned to detailed development of the methodology for collecting data. From the start it was recognized that to obtain a valid and complete picture of the various factors affecting operational maintenance, there was no substitute for going into the field and surveying the skilled technicians who are the people most intimately acquainted with this activity on a day to day basis.

Development of data collection methodology therefore focused on techniques to elicit solid information from Air Force maintainers in the course of visiting the sites where they practice their trade.

As with any other instrument of measurement, a survey must be calibrated. Even the most carefully designed survey program must be tested and in most cases fine-tuned to promote efficient collection of usable data. A survey program was therefore created that was amenable to dynamic modification and pretested through a set of initial site visits. Using this approach, a policy of direct interviews with technicians evolved. This approach was used to elicit the necessary depth of information and to draw upon the knowledge base of their accumulated maintenance experience.

The field data review afforded a prior measure of the relative importance of each of the factors affecting repair time. This was combined with insights culled from first hand observations to generate initial provisional judgements of the relative effect of each candidate factor on corrective repair time. These initial judgements are tabulated in Table 2-1 along with identification of whether each factor would involve quantitative or qualitative data and an estimation of whether supporting data would be available.

2.2.3 Site and Hardware Selection

The initial data collection and analysis described in paragraph 2.1 provided sufficient rationale to select

TABLE 2-1. MTTR Factors History

Factor	Quan	Qual	Avail	Effect
Maintenance concept:				
Two level		x	x	vs
Three level		x	x	vl
Depot planned/repaired in field	x		x	m
Field planned/repaired at depot	x		x	vs
Built-in-test / fault-isolation test (BIT/FIT):				
Adequacy	x		x	vl
Augmented by test equipment for BIT	x		x	vs
Augmented by test equipment for FIT	x		x	vl
Command decisions:				
Deferred maintenance		x	x	vs
Operational hours	x		x	s
Environmental characteristics:				
Proximity to supplies	x		x	vs
Lighting		x	x	vs
Climate		x	x	vl
Adequacy of spares (actual vs provisioned):				
Number	x		x	m
Type	x		x	m
Adequacy of test eqpmt. (actual vs recommended):				
Number	x		x	m
Type	x		x	m
Adequacy of tools (actual vs recommended):				
Number	x		x	l
Type	x		x	l
Adequacy of technical manuals:				
Number	x		x	vs
Type	x		x	vs
Classification	x		x	vs
Up-to date		x	x	vs
Complete		x	x	vs
Skills required (planned vs actual)		x	x	vs

TABLE 2-1. MTTR Factors History - (continued)

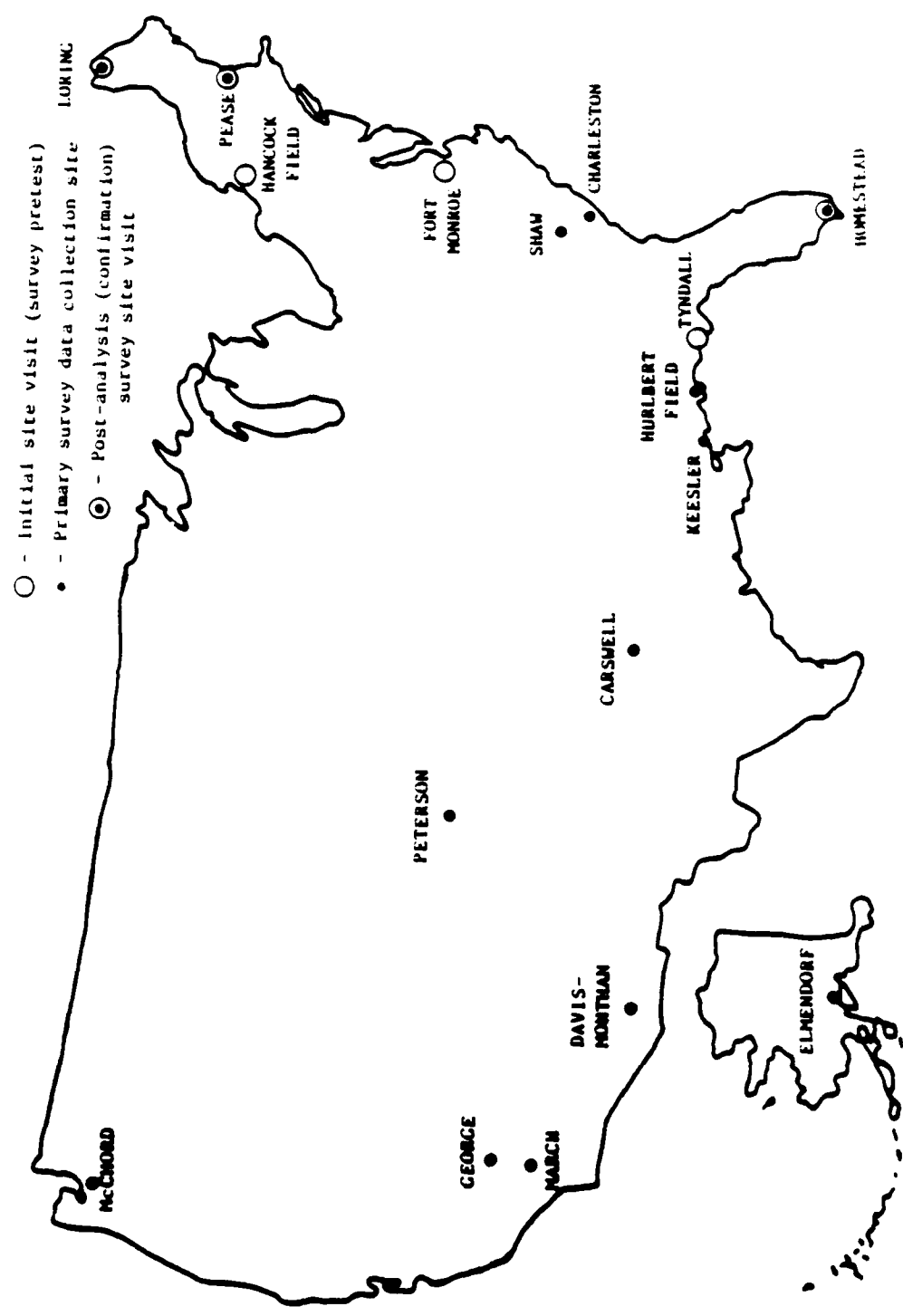
Factor	Quan	Qual	Avail	Effect
Training provided:				
Career		x	x	vs
Non-career		x	x	m
Manpower	x		x	vs
Mean logistic delay time (MLDT):				
Shipment time	x		x	m
Depot repair cycle time	x		x	l
Return shipment time	x		x	m
Depot replacement time	x			vs
Mission priorities		x	x	s
Spares stockage				
(including inventory control)	x		x	m
Depot maintenance expertise		x		vs
Contractor support		x		vs
Method of recording operational				
(field) time to repair:				
Including preparation	x		x	vl
Including clean-up	x		x	vl
Including MLDT	x		x	vl
Elapsed time x crew size =				
maintenance manhours	x		x	vl
Learning syndrome				
(high MTBF / high MTTR)	x		x	m
Cannot duplicate (CND) failures	x		x	vl
Not repairable this station (NRTS)	x		x	l
Quality of predicted MTTR:				
Degree of optimism	x		x	s
Margin of error				
in MIL-STD-472 approach	x			s
Including all failure modes		x		m
Variance in system configuration				
from established baseline		x	x	l

KEY: vs = very small, s = small, m = medium,
l = large, vl = very large.

seventeen (17) sites to be visited. The selected sites are identified on the map shown in Figure 2-1. Each location maintains Air Force ground electronics systems which perform Command, Control, Communications, and Intelligence functions. The units and sites visited were:

- | | |
|---|-----------------------|
| 1. 72nd Tactical Control
Flight (TCF) | Fort Monroe, VA. |
| 2. 108th Tactical Control
Flight (TCF) | Hancock Field, NY |
| 3. 2021st Information System
Squadron (ISS) | Tyndall AFB, FL |
| 4. 2163th Information System
Squadron (ISS) | Peterson AFB, CO |
| 5. 437th Military Airlift Wing
(MAW) | Charleston AFB, SC |
| 6. 507th TAC Air Control Wing
(TAIRCW) | Shaw AFB, SC |
| 7. 727th Tactical Control
Squadron (TCS) | Hurlburt Field, FL |
| 8. Technical Training
Development | Keesler AFB, MS |
| 9. 7th Avionics Maintenance
Squadron (AMS) | Carswell AFB, TX |
| 10. 602nd TAC Air Control Wing
Wing (TAIRCW)
and 41st Electronic Combat
Squadron (ECS) | Davis-Monthan AFB, AZ |
| 11. 2067th Information System
Group (ISG) | George AFB, CA |
| 12. 33rd Information System
Group (ISG) | March AFB, CA |

Figure 2-1: Geographical Distribution of Sites Visited for Data Collection



- | | |
|---|-------------------|
| 13. 442nd Avionics Maintenance Squadron (AMS) and 46th AMS | McChord AFB, WA |
| 14. 41st Electronic Combat Squadron (ECS) 11th Tactical Control Group (TCG) 1931st Information System Wing (ISW) and 1930th Information System Squadron (ISS) | Elmendorf AFB, AK |
| 15. 1916th Communications Squadron and 509th Avionics Maintenance Squadron (AMS) | Pease AFB, NH |
| 16. 2192nd Information System Squadron (ISS) | Loring AFB, ME |
| 17. 1942nd Communications Squadron and 31st Tactical Fighter Wing (TFW) | Homestead AFB, FL |

Site visits were performed in three groups, depending upon their purpose. The first three site visits were used to test the survey technique and repair data questionnaire forms. The next 11 sites were visited to conduct interviews and surveys in accordance with the revised study approach. The final three site visits focused on collecting information to confirm results and conclusions based on the previous visits. This confirmation data was then combined with the other collected survey data to provide a larger base for

factor quantification. The key in Figure 2-1 identifies each site location based on the purpose for the visit.

The hardware systems discussed and examined during the visits included all types of ground electronics used in command, control, communications and intelligence (C³I). Systems specifically observed for the study included the following:

- Tactical Air Control System (AN/TPS-43)
- Airport Surveillance Radar System (AN/GPN-20, 21)
- Precision Approach Radar System
(AN/FPN-62, AN/GPN-22)
- Satellite Communication System (AN/GSE-44)
- Radio Equipment (AN/GRC-211, AN/GRC-212,
AN/ARC-164)

The airport surveillance radar systems, precision approach radar systems, and radio equipments were stationed at every visited site. The satellite communication system was stationed at Peterson AFB, Elmendorf, Carswell, and March AFBs. The tactical air control system was observed at Shaw, Keesler, Elmendorf, Hurlbert Field, Davis-Monthan, and Homestead AFBs.

The complexity of the systems ranged from fairly straight forward radio equipments to the latest in complex radars and data processing equipment in the AN/GPN-21 and the AN/GPN-22. The built-in-test (BIT) capability of the systems also ranged from none in some radios to BIT sufficient to detect and isolate faults to the subsystem level in the radars and satellite

communication system. No observed system had a BIT capability to fault isolate malfunctions beyond the subsystem level.

2.2.4 Initial Site Visits

As indicated in paragraph 2.1, initial visits were made to three Air Force sites (as listed in Table 2-2). These visits served to test the original survey data collection techniques devised for the study and to identify and isolate the causes of any shortcomings in the survey protocols. Survey procedures and techniques were subsequently restructured in order to compensate for shortfalls in data quantity and quality which were identified as a result of these initial efforts. Direct interaction with command and maintenance personnel was found to be essential in order to gather the needed survey data.

Table 2-2: Initial Site Visit Locations

<u>SITE LOCATION</u>	<u>DATE OF VISIT</u>	<u>UNITS</u>
Ft. Monroe, VA	8/06/85	72 TCF
Hancock Field, NY	8/27/85	113 TCF
Tyndall AFB, FL	9/18/85	2021 ISS

Positive results were obtained from the visits themselves, when the survey team interacted directly with the responsible Air Force command and maintenance elements. However, the insufficiency and incompleteness of subsequent failure data returned by the visited commands also demonstrated serious and potentially crippling difficulties with a formal data collection plan.

A particularly significant end result of this approach was the granting of permission to inspect unique data files which units kept to meet their own perceived needs. The unit files included data on typical equipment failures, causes, and severity. These resources provided preliminary insights into many of the issues identified for consideration in the study.

As a result, it was determined that in order to collect the amount and detail of data required to draw usable conclusions, the survey technique had to be adjusted. In the subsequent site visits, efforts would continue to inform, interest, and involve all key maintenance personnel of the units surveyed, and to use the developed questionnaires as a guide in personnel interviews. The depth of interviews would however increase, and maintenance personnel would be encouraged to bring forth observations based on their total experience with Air Force electronics equipments. Contemporary experience with recently fielded systems was emphasized to gather information that would be most useful and accurate in estimating repair times for future systems. Individual interviews would be pursued,

and technician "round tables" set up to establish consensus on the characteristics of interest to the repair time question.

2.2.5 Data Collection Site Survey Visits

2.2.5.1 Methodology

When the study survey team visited a base, it first met with the unit commander and maintenance chief to refamiliarize them with the study and the survey team's intended activities. Meetings ensued with maintenance team leaders for the subject equipment, both as a group and individually.

Interview surveys were conducted with the senior level experienced maintenance personnel to identify the major operational and logistics impacts that influence maintenance time. The interviews were structured to follow the major points set forth in the originally developed questionnaire. The experience of the maintenance personnel was also tapped in order to quantify these identified impact areas. Interviews were conducted both individually and in group situations to develop a consensus for each unit and/or site.

2.2.5.2 Data Collection Sites

Data was collected at 14 Air Force bases or sites through surveys and interviews. These were conducted both with individual personnel and in group environments. The sites visited for analysis data

collection are listed in Table 2-3. These selected sites were selected to provide a wide range of climatological environments as well as the most probability for differences in base policy and practices. Surveys and interviews were conducted with senior level maintenance officers and technicians. Table 2-4 lists the rank of each survey participant for each of the 14 sites.

2.2.5.3 Post Site Visits

Site survey composite forms were filled out by the study survey team after the site surveys were conducted. (A blank form is included as Appendix E.) These composite forms were then used during the analysis phase of the study. The completed site survey composite forms for the 14 site visits are included in this report as Appendix F. Major operational field influences on MTTR were then defined by tabulating and reducing the accumulated information in accord with a set of consistent analysis techniques as part of the analytical phase.

Communication with the surveyed sites was required and accomplished after the site visits through follow-up telephone conversations. These were used to ensure the correct recording and interpretation of gathered survey data.

Table 2-3: Site Visit Locations for
Survey and Data Collection

<u>SITE LOCATION</u>	<u>DATE OF VISIT</u>	<u>UNITS</u>
Shaw AFB, SC	2/11/86	507 TACW
Charleston AFB, SC	2/12/86	437 AMS
Hurlbert Field, FL	3/03/86	727 TCS
Keesler AFB, MS	3/04/86	Tech Training
Carswell AFB, TX	3/05/86	7 AMS
Petterson AFB, CO	3/06/86	2163 ISS
Davis-Monthan AFB, AZ	3/10/86	602 TACW
		41 ECS
March AFB, CA	3/11/86	33 ISG
George AFB, CA	3/12/86	2067 ISG
McChord AFB, WA	3/21/86	442 AMS
		46 AMS
Elmendorf AFB, AK	3/24-25/86	41 ECS
		11 TCG
		1931 ISW
		1930 ISS
Loring AFB, ME	10/28-29/86	2192 ISS/CS
Pease AFB, NH	11/25/86	1916 CS
		509 AMS
Homestead AFB, FL	3/03-04/87	1942 CS
		31 TFW

Table 2-4. Number and Rank of Maintenance Personnel
Interviewed at Each Site

AF BASE	MAJ	CAPT	LT	E-9	E-8	E-7	E-6	E-5	E-4	E-3	CIV
1	1	2				1		2	2		
2		1		1		1					
3			1		1	1	4	2	4		
4					1	2	2		1		2
5					1	1	1	1	4		
6					1	1	1	1	1		
7	1			1	2		1	1			
8	1		1	1	1	1	1	1	1		
9			1				3	3		3	
10				2							
11	1	1	1	1	2	5	1	1		1	2
12		1				1					2
13	LC 1	2			1	4	1	3		1	
14		1		1		2	1	4	4		
TOTALS	5	8	4	7	9	19	16	19	16	5	6

2.2.6 Supplemental Data Sources

2.2.6.1 Air Force AFM 66-1 Failure Repair Data

A significant amount of data on a Tactical Air Defense Radar was available to Westinghouse as the designer and provider of this type of radar. In order to supplement, and ultimately substantiate the data collected during the study activities, four computer runs reflecting Air Force collected AFM 66-1 failure and repair data on a tactical air defense radar were obtained for the three years between July 1982 and June 1985. Analysis of this data revealed significant incompleteness in the recorded maintenance data. This forced the AFM 66-1 data source to be considered non-conclusive.

2.2.6.2 Air Force Equipment Status Reports

Several visited sites provided recorded maintenance data to the study survey team in order to supplement the surveys and interviews. This generally consisted of computerized data summaries and information from maintenance data collection (MDC) systems. A computerized maintenance data run from the Equipment Status and History Reporting (ESR) system was provided at one visited location. This listing contained maintenance data on all equipment supported or maintained by their personnel. The codes for interpretation of the recorded data was also provided. Analysis showed this data to also be incomplete. Biases in the data was also identified through follow-up

discussions with maintenance personnel who record this data.

2.3 MTTR Driver Identification

The first phase of the analysis was to identify the basic areas of influence on maintenance time resulting from operational and logistics support conditions. In order to determine this was, a comprehensive strawman was developed listing as many potential impact areas as possible. This initial listing was based on the study team's over 100 man-years of experience in electronic systems design, maintenance and logistics support. After its preparation, the strawman list was presented to and discussed with Westinghouse field engineering and services personnel. These individuals support Air Force airborne and ground electronic systems around the world under all kinds of operational and logistics environments. Their input, based upon field experience, drove a second iteration of identified impact areas and developed the relative effect of each impact area on the maintenance and repair time. The relative effects were very small, small, medium, large, and very large.

The final list of operational and logistics factors evolved through incorporation of observations, comments, and data collected from the Air Force site surveys. This data was used to update and finalize the identification and relative effect of each factor. The final list of operational and logistics impact areas is presented in Table 2-5.

TABLE 2-5. MTTR Factors Determination

Factor	Effect
Maintenance concept:	
Two level	M
Three level	M
Depot planned/repaired in field	VL
Field planned/repaired at depot	VS
Built-in-test / fault-isolation test (BIT/FIT):	
Adequacy	VL
Augmented by test equipment for BIT	VS
Augmented by test equipment for FIT	M
Command decisions:	
Deferred maintenance	L
Operational hours	S
Environmental characteristics:	
Proximity to supplies	M
Lighting	S
Climate	VL
NBC Protective Gear	L
Adequacy of spares (actual vs provisioned):	
Number	L
Type	M
Adequacy of test equipment (actual vs recommended):	
Number	M
Type	M
Adequacy of tools (actual vs recommended):	
Number	M
Type	M
Adequacy of technical manuals:	
Number	VS
Type	M
Classification	VS
Up-to date	VS
Complete	S

TABLE 2-5. MTTR Factors Determination (Continued)

Factor	Effect
Skills required (planned vs actual)	S
Training provided	M
Manpower	S
Mean logistic delay time (MLDT):	
Shipment time	M
Depot repair cycle time	VL
Return shipment time	M
Mission priorities	L
Spares stockage	
(including inventory control)	L
Depot maintenance expertise	M
Contractor support	VS
Method of recording operational	
(field) time to repair:	
Including preparation	VL
Including clean-up	VL
Including MLDT	VL
Elapsed time x crew size =	
maintenance manhours	VL
Learning syndrome	
(high MTBF / high MTTR)	L
Cannot duplicate (CND) failures	L
Not repairable this station (NRTS)	M
Quality of predicted MTTR:	
Degree of optimism	M
Margin of error	
in MIL-STD-472 approach	S
Including all failure modes	L
Variance in system configuration	
from established baseline	M

KEY: VS = very small, S = small, M = medium,
L = large, VL = very large.

The study concentrated on those factors identified as having a very large (VL) or large (L) effect on maintenance activity and time. Five impact factors were evaluated as having a very large effect. These were:

- o Depot planned/repairs in the field - This refers to the observed and stated tendency of maintenance personnel to go beyond the simple remove and replace and to perform internal repair of assemblies instead of sending them on to the depot for repair. This extended repair was performed at the vast majority of sites surveyed. The general rationale for this was attributed to the large time delay experienced in receiving an item sent to the depot for repair. There is definitely a "repair it here" philosophy reflected in base policy and procedures at the operational sites. Such practice requires more maintenance time for diagnostics and troubleshooting, increases the amount of maintenance induced problems, and impacts the number and availability of spares.
- o BIT/FIT adequacy - This relates to the level of confidence maintenance personnel have in the BIT and FIT capability of fielded systems. Generally this is not very high at most bases. The common perception is that BIT/FIT is usually good for system go/no-go indications but not for identification and specific determination of faulty items. This increases the amount of troubleshooting activity and time. It also serves to increase the emphasis on personnel training so that

they become familiar with the equipment. A few bases have systems with more specific BIT, but this is the exception rather than the rule. At every base, some of the BIT/FIT inadequacies can be directly traced to the amount of maintenance problems dealing with cables and connectors and to the lack of BIT/FIT with these items.

- o Climate - This refers to the impact various climates have on performing maintenance and the additional time required and was stated at every surveyed base.
- o Depot repair cycle time - This refers to the turn around time (TAT) required to send faulty items to the depot, repair them, and cycle them back to the operational sites. The lengthy time encourages more maintenance to be performed at the operational sites. This is closely tied to the first identified impact area and was stated at every base.
- o Method of recording operational (field) time to repair - This includes the time consuming activities that must be accomplished when performing maintenance but are not usually included in predicting maintenance time. This included a significant amount of paperwork which was stated at every visited base. All these items have a direct impact on the recorded maintenance time and were the subject of many questions asked during the site surveys.

Eight factors were evaluated to have a large effect on maintenance activity and time. These are:

- o Deferred maintenance - This refers to the large number of failures which do not cause the system to become in-operable. These failures are not critical to the system in that the system can still operate in a reduced state, sometimes with full capability. The system is said to be in an "amber state" with this type of failure. Maintenance can be performed at the time of failure or can be deferred or delayed until another time. The capability of the system to continue performing with a failure while maintenance is being performed, tends to reduce the urgency associated with completing the maintenance action and increases the maintenance time. This also permits additional time for training and familiarization opportunities which is included in base policy and procedures. This tendency was observed at every visited base.

- o Nuclear/Biological/Chemical gear - This refers to the increased problems and time required to perform maintenance when wearing NBC protective gear. This impact area is included because it was identified by the surveyed maintenance personnel as being of significant concern to them. This impact was only stated at the 10 bases which practiced with NBC gear or had individuals which had experience with NBC gear.

- o Number of spares - The number of spares at the operational site has a direct influence on the level of maintenance performed and was stated at every visited base. Spares are usually a rare commodity. Maintenance is performed to a lower level when spares are scarce in order to bypass sending a faulty item to the depot for repair. The time required to determine whether a spare is available is included in the recorded maintenance time.
- o Mission priorities - This refers to the opportunity to delay maintenance performance in accordance with mission priorities. The system capability to continue operation with some failures permits this command decision. This impacts maintenance actions and time in many of the same ways as deferred maintenance decisions.
- o Spares stockage - This refers to the location of the base spares supply and the average logistics delay to request and obtain a required spare item. This time is generally included in the recorded maintenance time at every base.
- o Learning syndrome - This refers to the problems associated with performing maintenance on an infrequent basis. This is caused by the high reliability inherent in the C³I systems. This was more a concern at some bases than at others. Reactions to this syndrome include a high emphasis on training at most bases (included in base

policies and procedures) and increased maintenance time to familiarize personnel with the equipment whenever mission priorities permit.

- o Cannot duplicate (CND) failures - This refers to the maintenance activities and time extended to address the CND problems presented by fielded systems and equipments. This includes associated problems with power supplies, humidity, and cables and connectors. More maintenance time is consumed in diagnostics and troubleshooting in response to these CND problems. CND failures was not stated to be a common problem and could not be specifically quantified at many surveyed bases.
- o Including all failure modes when predicting MTTR - This refers to the lack of including the proper emphasis on cables and connectors problems when first predicting MTTR values. Cables and connectors account for a high percent of the total maintenance problems encountered in the field. Maintenance personnel feel that not enough design attention is focused on them.

SECTION 3.0 ANALYSIS RESULTS AND APPLICATION

3.1 Identification of Quantifiable K Factors

The primary goal of this study was to identify and quantify the relationship between the predicted time to repair electronic systems and the actual repair times achieved in the field. The MTTR drivers identified in Section 2 are conceptual in nature. It was therefore necessary to examine the data collected in site surveys to establish what impacts could be quantified and how these could be identified with the conceptual MTTR drivers. Such a procedure is common in statistical data analysis techniques, where underlying causes of variation are not immediately accessible but related variables may be used to quantify their effects.

Specific impact elements have been identified to account for the majority of this difference between predicted and achieved times. These elements have been quantified through the development of several adjustment factors or k factors which can be applied to the predicted time values to transform them to expected field values. Table 3-1 sets forth how these elements reflect the MTTR drivers of section 2.6 in quantifiable form.

These k factors act as direct adjustments to inherent MTTR values, or as multiplicative and additive adjustments for translating inherent MTTR to field MTTR values, depending on the specific subject element. These adjustments are discussed in section 3.2.

Table 3-1: Relation of MTTR Drivers to Quantifiable
K Factors

<u>MTTR DRIVERS</u>	<u>K FACTORS REFLECTING IMPACT</u>
Not all failure modes considered	Cables, cabling, connectors k_{cc} Cannot Duplicate conditions k_{cnd}
Spares availability	Spares availability impact k_{sp}
Climatological	Climatological impact k_{cli}
Learning syndrome	Maintenance induced failures impact k_{ind} Base policies and practices k_{bpp}
Nuclear Biological Chemical protective gear	NBC gear impact k_{NBC}
Operational repair time recording methods	k_{sp} , k_{bpp} , k_{ind}
Deferred maintenance and mission priority considerations	k_{bpp}
BIT/FIT	k_{cc} , k_{cnd}
Depot planned/field repaired	(Non-quantitative: impacts MTTR through resource loading)

3.2 Functional Forms

The k factors for conversion of predicted inherent MTTR into operational MTTR fall naturally into two classifications, reflecting their functional form or effect upon MTTR. Some k factors are multiplicative; they act equally on every subtask of the repair process, and thus increase MTTR by a percentage of that which would otherwise be expected. An impact which results in a 50 percent increase in repair time would be represented by a multiplicative factor of 1.5.

A second class of impact is additive in effect. Such impacts are incorporated as k factors which must be added to the predicted repair time in order to derive an MTTR which will be valid in the field. An additive k factor represents the impact of an activity which is not accounted for in predicted MTTR and which is performed with every repair process. Such an activity which requires 20 minutes to perform would have the effect of adding 20 minutes to each predicted time. Note that additive factors must have a dimensional unit while multiplicative factors cannot have a dimensional unit.

Impacts to MTTR can be caused either by inherent factors which are not adequately accounted for in MTTR prediction algorithms, or as a result of the effects of conditions specific to the field. The factors to account for field specific conditions are either multiplicative or additive. Thus, to properly transition predicted MTTR to a field value, the k factors are applied in three steps. Predicted inherent

active MTTR must first be adjusted directly to reflect those inherent impacts not completely accounted for in prediction algorithms. The frequency of failures found in site surveys which are attributable to cables and connectors and cannot duplicate conditions shows that these two failure modes are generally underestimated during the original repair time prediction. The associated k factors are therefore applied directly to predicted inherent MTTR. Section 3.2.1 describes the mathematical adjustment procedure which utilizes these k factors.

Impacts specific to field conditions act upon the actual inherent MTTR, and therefore are properly included only after the original predicted inherent active MTTR has been adjusted. These factors and their corresponding adjustments in terms of k factors are set forth in sections 3.2.2 and 3.2.3.

3.2.1 Direct Adjustments to Inherent MTTR

Site survey results indicate that the impact upon MTTR of maintenance actions attributable to cables and connectors (CC) and cannot duplicate (CND) conditions is underestimated by MTTR prediction algorithms. These failure modes are not specific to any set of field conditions, but rather directly affect inherent MTTR. Predicted inherent MTTR must therefore be adjusted for these impacts before field-specific k factors are applied.

To adjust inherent MTTR for CC and CND failure modes, the following notation is first introduced:

λ_{PR}	=	System Failure Rate (Predicted Causes)
$\Delta\lambda_{CC}$	=	Additional Failure Rate Contribution of Cables and Connectors
$\Delta\lambda_{CND}$	=	Additional Failure Rate Contribution of CND Rate
P_{CC}	=	Proportion of all Maintenance Actions Attributed to Cables and Connectors
P_{CND}	=	Proportion of all Maintenance Actions Attributed to CND Actions
$MTTR_{PR}$	=	Predicted (Inherent) Mean Time To Repair (MTTR)
$MTTR_{IN}$	=	Adjusted (Actual) Inherent MTTR
$MTTR_{CC}$	=	MTTR for Cables and Connectors Maintenance Actions
$MTTR_{CND}$	=	MTTR for CND Maintenance Actions

Inherent operational MTTR is calculated through the adjustments represented by the equation

$$MTTR_{IN} = \frac{\lambda_{PR} MTTR_{PR} + \Delta\lambda_{CC} MTTR_{CC} + \Delta\lambda_{CND} MTTR_{CND}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}}$$

The failure rates corresponding to CND conditions and the additional contribution of cables and connectors are unknown. However, over a fixed time period T the proportion of repair actions attributable to these causes will be approximately equal to

$$P_{CC} = \frac{\Delta\lambda_{CC}T}{\lambda_{PR}T + \Delta\lambda_{CC}T + \Delta\lambda_{CND}T} = \frac{\Delta\lambda_{CC}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}}$$

(Assuming the failure rates of cables and connectors are significantly understated in the prediction)

and

$$P_{CND} = \frac{\Delta\lambda_{CND}T}{\lambda_{PR}T + \Delta\lambda_{CC}T + \Delta\lambda_{CND}T} = \frac{\Delta\lambda_{CND}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}}$$

The expression for $MTTR_{IN}$ may now be rewritten as

$$MTTR_{IN} = \frac{\lambda_{PR}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}} MTTR_{PR} + \frac{\Delta\lambda_{CC}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}} MTTR_{CC} + \frac{\Delta\lambda_{CND}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}} MTTR_{CND}$$

Substituting the expressions for P_{CC} and P_{CND} ,

$$MTTR_{IN} = \frac{\lambda_{PR}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}} MTTR_{PR} + P_{CC} MTTR_{CC} + P_{CND} MTTR_{CND}$$

Finally, it is noted that

$$\frac{\lambda_{PR}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}} = 1 - \frac{\Delta\lambda_{CC}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}} - \frac{\Delta\lambda_{CND}}{\lambda_{PR} + \Delta\lambda_{CC} + \Delta\lambda_{CND}}$$

$$= 1 - P_{CC} - P_{CND}$$

Thus the expression for $MTTR_{IN}$ reduces to

$$MTTR_{IN} = (1 - P_{CC} - P_{CND}) \cdot MTTR_{PR} + P_{CC} \cdot MTTR_{CC} + P_{CND} \cdot MTTR_{CND}$$

Essentially, this formula implies that to adjust predicted inherent MTTR, the MTTR values for repair of failures caused by cables and connectors and CND conditions must be included along with the MTTR for failure modes already considered by the equation. All MTTRs are then weighted by the relative proportion of failures attributable to the corresponding failure modes. This notion is intuitively appealing as well as mathematically sound. It follows therefore that if the rates of occurrence of CND's and of failures on cables and connectors are either underestimated or ignored and/or if the time necessary for maintenance on CNDs and cables or connectors is larger than the average value prediction for equipment as a whole (or larger than was anticipated then $MTTR_{IN} > MTTR$).

3.2.2 Factors with Multiplicative Effect

The k factors with multiplicative effect are those that impact each task and sub-task step of the repair

process. Thus, there full impact is proportional to the complexity or length of the active maintenance action. The multiplicative factors identified through this study are:

1. Climatological Impact
2. Maintenance Induced Impact
3. NBC Gear Impact

3.2.3 Factors with Additive Effect

The k factors with additive effect are those that impact each repair process equally regardless of its job task length or complexity. The additive factors identified through this study are:

1. Spares Availability Impact
2. Policy and Procedures Impact
3. Cables and Connectors Field Impact

This last impact area should not be confused with the cables and connectors failure modes impact which was included in inherent MTTR in section 3.2.1. It is a result of practices common in the field for maintaining cables, cabling and connectors. The k factors involving these components are discussed in section 3.3.4.

3.3 Analysis of Survey Data

3.3.1 Climatological Impact

The survey team questioned Air Force personnel about the effects of climate on the repair times for ground electronics equipment. The temperature range of 32 F to 90 F is identified as the normalized condition with an adjustment factor value of 1.0. In the experience of most of the technicians surveyed, extremely hot weather (over 90 F) has little or no impact on the time required to effect a repair. However, extremes of cold were widely identified as impacting maintenance to a significant degree.

There is no precise consensus among maintenance personnel as to what precisely constitutes "extremely cold weather". As might be expected, those stationed in warmer climates feel that any temperature below freezing (32 F) qualified as extreme cold which would affect maintenance. In higher latitudes, there is greater sensitivity to temperature variations. Here two levels of below-freezing effects were identified, the less severe occurring between 0 F and 32 F and the more severe at temperatures below 0 F. At two decidedly cold-climate sites, there is a further sensitivity to temperatures below -20 F, which is not duplicated at the other bases where survey results were obtained for this analysis.

Some technicians identified degree of cold with wind chill factor rather than absolute temperature.

Since this factor essentially relates wind velocity and temperature to an equivalent temperature in still air, the analysis did not differentiate between the two measures of cold.

Table 3-2 presents the results of the survey for extremes of heat and cold. It can be seen that the interviewed personnel generally feel more of an adverse effect upon maintenance time in temperatures below freezing than in extremely high temperatures. This may be attributable to the added burden imposed by gloves and insulated garments.

Technicians at many bases surveyed did not specifically estimate an impact for the extreme cold range (-20 F to -40 F). This appears to be due more to lack of experience in such conditions, rather than a conscious opinion that the impact did not differ from that cited for the next less severe range. Therefore, for purposes of generating the consensus effect for those ranges, only responses specific for that range are used.

The survey results give an adjustment factor value for four different temperature ranges:

- 1.34 - over 90 degrees F
- 1.9 - between 0 and 32 degrees F
- 3.1 - between 0 and -20 degrees F
- 4.7 - and below -20 degrees F.

Since these temperature ranges are exclusive, the impact values for each range can simply be multiplied by

Table 3-2: Effects of Climate/Temperature Impact on Maintenance Time

QUESTION: By what factor is active maintenance action time multiplied by the necessity to work in extremely cold and/or hot environments?

USAF BASE	RESPONSES INCLUDED IN CONSENSUS	MULTIPLICATIVE FACTOR				
		EXTREME COLD			EXTREME HEAT	
		0 - 32 F	< 0 F	< -20 F	TEMPERATURE	FACTOR
1	4	2	4	---	> 100 F	2
2	3	---	---	---	> 90 F	1
3	6	2	---	---	> 90 F	1
4	7	3	4	4	> 100 F	1.15
5	6	2	3	---	> 100 F	1.25
6	3	1.5	2	---	> 100 F	2
7	6	1.4	2	---	> 90 F	1.25
8	5	2	3.5	---	> 95 F	1.25
9	8	2	3.5	---	> 100 F	1.5
10	2	2	4	---	-----	---
11	13	1.5	2.5	5	-----	---
12	3	(*)	(*)	(*)	---	---
13	6	2	---	(**)	---	---
14	8	(***)	(***)	(***)	---	---
WEIGHTED SUMMARY	80	1.9	3.1	4.7		1.3

NOTES: A factor of one indicates no change in maintenance action time, a factor of two indicates maintenance action time is doubled, etc.

* - Base 12 personnel responded that "they were used to the cold".

** - Base 13 personnel stated that maintenance at temperatures below -35 F is "impossible".

*** - At Base 14, "it never gets too hot or too cold" according to the maintenance personnel.

the percent of time the temperature is in that range and the results summed. This results in the equation

$$\begin{aligned} \text{MTTR}_F = [& (1.34 * t_1) + (1.0 * t_2) \\ & + (1.9 * t_3) + (3.1 * t_4) \\ & + (4.7 * t_5)] \text{ MTTR (predicted)} \end{aligned}$$

where MTTR_F = delta increment to MTTR to account
for field factor

t_1 = percent of time temperature is greater
than 90 F

t_2 = percent of time temperature is between
32 and 90 F

t_3 = percent of time temperature is between
0 and 32 F

t_4 = percent of time temperature is between
0 and -20 F

t_5 = percent of time temperature is less
than -20 F

The k factor for climatological effects on maintenance is therefore defined by:

$$\text{MTTR}_F = k_{cli} * \text{MTTR}_{IN}$$

or

$$\begin{aligned} k_{cli} = & (1.34*t_1) + (1.0*t_2) + (1.9*t_3) \\ & + (3.1*t_4) + (4.7*t_5) \end{aligned}$$

= k factor for climatological impact

3.3.2 Maintenance Induced Impact

An important question posed to Air Force personnel was whether the correction of problems caused by other maintenance actions contributed significantly to repair time. Action to correct faults caused or induced in the course of performing other maintenance may take place during the action in question, during subsequent maintenance undertaken for other reasons (e.g., routine scheduled or preventive maintenance), or as a separate action which is initiated solely as a result of the problem induced. In the first two cases, the induced problem extends the duration of the repair procedure already under way, and thus increases field MTTR.

The third class of actions to correct maintenance induced actions may essentially be disregarded since it was found never to occur. If a maintenance induced damage is not noticed immediately, the problem will generally be caught during tests immediately prior to putting the system back into service. In either event, its correction is undertaken as part of that same maintenance action which caused it.

The k factor for maintenance induced impact is utilized to account for the time spent to perform the additional corrective maintenance actions which are caused or induced by the original maintenance. Table 3-3 presents the survey results for maintenance induced failures. Estimates of this percentage, collected from 66 maintenance personnel at 13 sites, range from two to 70 percent as shown. The consensus value for each base

Table 3-3: Effects of Maintenance Induced Impact on Maintenance Activity

QUESTION: What percent of maintenance actions result in additional repair activity caused or induced by the original maintenance action?

		PERCENTAGE											
		0	20		40		60		80		100		
<u>USAF BASE</u>	<u>NUMBER OF RESPONSES</u>		10		30		50		70		90		<u>CONSENSUS FIGURE</u>
		:	:	:	:	:	:	:	:	:	:	:	
1	2	:	X	:	:	:	:	:	:	:	:	:	10 %
		:	:	:	:	:	:	:	:	:	:	:	
2	3	:	X	:	:	:	:	:	:	:	:	:	5 %
		:	:	:	:	:	:	:	:	:	:	:	
3	5	:	X-----			X	:	:	:	:	:	:	20 %
		:	:	:	:	:	:	:	:	:	:	:	
4	7	:	X-----		X	:	:	:	:	:	:	:	20 %
		:	:	:	:	:	:	:	:	:	:	:	
5	(no response)	:	:	:	:	:	:	:	:	:	:	:	----
		:	:	:	:	:	:	:	:	:	:	:	
6	1	:	X	:	:	:	:	:	:	:	:	:	5 %
		:	:	:	:	:	:	:	:	:	:	:	
7	5	:	X-----				X	:	:	:	:	:	30 %
		:	:	:	:	:	:	:	:	:	:	:	
8	7	:	X-----			X	:	:	:	:	:	:	15 %
		:	:	:	:	:	:	:	:	:	:	:	
9	7	:	X-----			X	:	:	:	:	:	:	50 %
		:	:	:	:	:	:	:	:	:	:	:	
10	2	:	XX	:	:	:	:	:	:	:	:	:	4 %
		:	:	:	:	:	:	:	:	:	:	:	
11	13	:	X-----			X	:	:	:	:	:	:	20 %
		:	:	:	:	:	:	:	:	:	:	:	
12	2	:	X---X	:	:	:	:	:	:	:	:	:	15 %
		:	:	:	:	:	:	:	:	:	:	:	
13	8	:	X-----			X	:	:	:	:	:	:	30 %
		:	:	:	:	:	:	:	:	:	:	:	
14	4	:	X---X	:	:	:	:	:	:	:	:	:	5 %
		:	:	:	:	:	:	:	:	:	:	:	
WEIGHTED SUMMARY	66	:	X-----				X	:	:	:	:	:	21.8 %

was determined by either a single point estimate for the base or by a weighted averaging of individual responses to the survey question, with increased weight given to seniority and/or rank. Table 3-4 shows a point graph histogram of the responses from the interviewed maintenance personnel to the question concerning maintenance induced impact. The general consensus value is 21.8 percent as weighted over all 13 sites. The general consensus value is obtained by multiplying the consensus for each site by the number of responses at that site, then summing these results over the 13 surveyed sites and dividing by the total number of responders (which is 66 here). The general consensus value means that over one-fifth of all maintenance actions, whether corrective or preventive, result in additional maintenance being performed, with additional time expended.

It was assumed that a fault induced by maintenance requires, on the average, no more or less time to rectify than other failures. The effect of an added percentage of faults is thus to increase MTTR by the same percentage. This value is multiplied directly to the predicted MTTR to account for this situation. The multiplicative factor value is thus given by::

$$MTTR_F = (1 + 0.22) * MTTR_{IN} = k_{ind} * MTTR_{IN}$$

or

$$k_{ind} = 1.22 = k \text{ factor for maintenance induced impact}$$

Table 3-4: Histogram of Responses to Question on Maintenance Induced Impact.

USAF BASE	NUMBER OF RESPONSES	PERCENTAGE											CONSENSUS FIGURE
		0	10	20	30	40	50	60	70	80	90	100	
1	2	:	2	:	:	:	:	:	:	:	:	:	10 ‡
2	3	:	3	:	:	:	:	:	:	:	:	:	5 ‡
3	5	:	1 1	1 1	:	:	1	:	:	:	:	:	20 ‡
4	7	:	1 1 1	2 1 1	:	:	:	:	:	:	:	:	20 ‡
5	(no response)	:	:	:	:	:	:	:	:	:	:	:	----
6	1	:	1	:	:	:	:	:	:	:	:	:	5 ‡
7	5	:	1 1	1 1	1 1	:	:	1	:	:	:	:	30 ‡
8	7	:	1 2 2	:	1	1	:	:	:	:	:	:	15 ‡
9	7	:	3	1	:	3	:	:	:	:	:	:	50 ‡
10	2	:	2	:	:	:	:	:	:	:	:	:	4 ‡
11	13	:	1 5 1 3 2	1	:	:	:	:	:	:	:	:	20 ‡
12	2	:	1 1	:	:	:	:	:	:	:	:	:	15 ‡
13	8	:	1	1 1 1 1 3	:	:	:	:	:	:	:	:	30 ‡
14	4	:	1 2 1	:	:	:	:	:	:	:	:	:	5 ‡

The additional induced maintenance is attributed to such factors as difficult access to the equipment, environmental expansion or contraction of edge connectors, and pressures to meet system operational requirements.

Interviewed personnel cited the impact of failures induced by maintenance as a compelling reason to reduce the amount of preventive maintenance performed. They emphasize that corrective and preventive maintenance result in the same percentage of additional maintenance actions induced. "If it isn't broken, don't fix it" is thus a common sentiment among field maintenance personnel.

3.3.3 Nuclear/Biological/Chemical (NBC) Gear

The current impact of nuclear/biological/chemical (NBC) protective gear on observed MTTR is minimal, since such gear is worn in peacetime only for the limited duration of certain training and readiness exercises. Should the circumstances arise where maintenance actions must routinely be carried out in protective gear, its impact would be of extreme potential significance.

Maintenance personnel were asked about the impact of NBC gear upon maintenance time. Survey results are shown in Table 3-5. It should be noted that this analysis is based upon significantly fewer responses (39 maintenance personnel) than for other areas covered in the survey. Technicians are understandably reluctant to attribute numerical factors to the NBC gear, feeling

Table 3-5: Effects of Impact of NBC Gear on Maintenance Time

QUESTION: By what factor is repair time increased by working in NBC protective gear?

		PERCENTAGE											CONSENSUS
USAF BASE	NUMBER OF RESPONSES	0	1	2	3	4	5	6	7	8	9	10	FIGURE
1	3	:	:	X	:	:	:	:	:	:	:	:	2
2	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----
3	3	:	:	:	X----	X	:	:	:	:	:	:	3
4	3	:	:	:	X-----	X	:	:	:	:	:	:	4
5	3	:	X	:	:	:	:	:	:	:	:	:	1
6	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----
7	5	:	X--X	:	:	:	:	:	:	:	:	:	2
8	4	:	:	:	X----	X	:	:	:	:	:	:	3
9	9	:	:	X-----	X	:	:	:	:	:	:	:	2
10	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----
11	3	:	:	X-----	X	:	:	:	:	:	:	:	3
12	2	:	:	X	:	:	:	:	:	:	:	:	2
13	4	:	:	X	:	:	:	:	:	:	:	:	2
14	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----
WEIGHTED SUMMARY	39	:	X-----	X	:	:	:	:	:	:	:	:	2.3

that they lack the experience to justify such factors. Those estimates which the study team elicited range for the most part from factors of one to ten, i.e., maintenance in the NBC ensemble takes from the same time to ten times as long as the identical task in standard peacetime clothing. The consensus for each base was determined by a weighted averaging of the individual responses to survey questions, with increased weight given to seniority and/or rank. Table 3-6 shows a point graph histogram of the responses from the interviewed maintenance personnel to the question concerning maintenance in NBC gear. The weighted overall consensus is 2.3 times longer to perform maintenance in NBC gear as based on the responses from 39 maintenance personnel experienced with NBC gear usage. This is calculated by first multiplying the consensus at each site by the number of responses from that site, then these results are summed across the 10 sites with experience in NBC gear use and the sum divided by the total number of responders (39 here).

A significant number of maintenance personnel stated that from their experience, some maintenance actions are impossible to perform while wearing NBC gear. These responses could not be numerically factored into the analysis, but are considered extremely important to the Air Force. They are therefore discussed in Section 4 of this report.

The k factor for NBC gear accounts for that additional time to perform maintenance caused by wearing NBC gear. The weighted average value for this increase

Table 3-6: Histogram of Responses to Question on NBC Gear Impact.

USAP BASE	NUMBER OF RESPONSES	PERCENTAGE										CONSENSUS FIGURE	
		0	1	2	3	4	5	6	7	8	9		10
1	3	:	:	3	:	:	:	:	:	:	:	:	2
2	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----
3	3	:	:	:	2	1	:	:	:	:	:	:	3
4	3	:	:	1	:	2	:	:	:	:	:	:	4
5	3	:	3	:	:	:	:	:	:	:	:	:	1
6	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----
7	5	:	1	4	:	:	:	:	:	:	:	:	2
8	4	:	:	:	3	1	:	:	:	:	:	:	3
9	9	:	:	5	2	2	:	:	:	:	:	:	2
10	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----
11	3	:	:	2	:	:	:	:	:	:	:	1	3
12	2	:	:	2	:	:	:	:	:	:	:	:	2
13	4	:	:	4	:	:	:	:	:	:	:	:	2
14	(no experience)	:	:	:	:	:	:	:	:	:	:	:	----

in maintenance time is 2.3. This should be multiplied by the percent of time NBC gear is used at a particular base or with a particular system. Thus, the form of the equation to adjust for the use of NBC gear on MTTR is:

$$k_{NBC} = [(1 - t) + (2.3 * t)] = k \text{ factor for NBC gear impact}$$

Here t represents that fraction of time during which NBC gear is used ($0 \leq t \leq 1.0$). For example, if NBC gear is never used at a site, $t=0$ and $k_{NBC} = 1.0$ for no impact on predicted active repair time. If NBC gear is always used, $t = 1.0$ and $k_{NBC} = 2.3$ in agreement with the survey results.

The present use of NBC gear ranges from none to one week each quarter (8 percent) for the sites surveyed. If this is true across the Air Force, the k factor value for NBC gear use at a particular site or with a particular system ranges from a minimum of 1.0 (no impact) to a maximum of 1.10 (10 percent increase in active repair time) for a base or system utilizing NBC gear 8 percent of the time.

3.3.4 Spares Availability Impact

This impact factor accounts for that portion of the recorded maintenance time which is actually the time required to obtain a spare item to accomplish repair. Interviewed personnel in visited units were almost unanimous in citing spares availability as a major time driver in the duration of maintenance actions.

Spares availability plays a critical role in determining logistics impact on maintenance time. MTTR predictions are predicated on the required spare being immediately available.

Survey responses identify three sources for spares: on-base supply, lateral supply at an associated base, and the depot. Even when a spare is available from a nearby source (on-base or lateral), obtaining it will typically require 30 minutes to three hours. Merely to establish that no spare is available locally requires a similar period. When spares must be obtained from remote sources (depots), the logistics delay incurred can range from several days to a year. This option is avoided whenever possible, for obvious reasons.

In theory, the time required to obtain a spare is considered in mean logistics delay time (MLDT) and is specifically excluded from predicted MTTR. Maintenance personnel who participated in this study indicated that on the contrary, reported field repair times frequently include the time to obtain a spare, particularly from local supply. This represents a significant increase in recorded repair time, since predicted MTTRs for ground electronics equipment (e.g., tactical control radar) are on the order of 30 minutes.

Even when spares come from the depot, this effect may be present. Once the necessity to obtain a spare from the depot is recognized, the resultant delay is typically recorded as logistics delay time ("not mission capable - supply" or NMCS) and not included in repair

time. However, time invested prior to this action in establishing that no spare is locally available is generally recorded against maintenance activities--again, a factor of 30 minutes to 3 hours.

Eleven of the fourteen sites responded to questions concerning spares situation and availability. Survey responses of the percent of use for each of the three sources for spares is shown in Table 3-7. The average time to obtain a spare from each source is also shown.

The time required to obtain a spare varies for each source. The time to obtain a spare from the local base supply would probably be the only time element included in the recorded maintenance activity time. The average time to obtain a spare is 1.3 hours as weighted by the percent of time spares are drawn at each of the 11 responding sites. The average time to obtain a spare from lateral supply at site number 6 is short enough (3.5 hours) to suggest this is also recorded as active maintenance time. This time was therefore included in the weighted average. The weighted average is calculated by first multiplying the time to obtain a spare by the percent of the occurrence, then summing these results across the 11 responding sites and dividing by the summed percent of occurrence. The additive factor to account for obtaining a spare is:

$$k_{sp} = 1.3 \text{ hours} = k \text{ factor for spares availability impact.}$$

Table 3-7: Effects of Spares Availability Impact on Maintenance Time

QUESTION: What percentage of corrective maintenance actions require spares to be obtained from local, lateral and depot locations? What is the mean time to obtain a spare from each type of location?

SPARES AVAILABILITY

USAF BASE	LOCAL (ON BASE)		LATERAL (NEARBY BASE)		DEPOT	
	Percent Required	Time to Obtain	Percent Required	Time to Obtain	Percent Required	Time to Obtain
1	80	2 hr	20	48 hr	----	----
2	----	----	----	----	----	----
3	50	1 hr	20	48 hr	30	168 hr
4	*	*	*	*	*	*
5	50	0.5 hr	40	48 hr	10	168 hr
6 **	40	0.5 hr	50	3.5 hr	10	168 hr
7	----	----	----	----	----	----
8	20	3 hr	60	168 hr	20	336 hr
9	50	0.75 hr	30	48 hr	20	336 hr
10	70	1 hr	20	48 hr	10	> 2000 hr
11	80	0.5 hr	20	36 hr	***	***
12	50	0.63 hr	35	42 hr	15	252 hr
13	20	0.5 hr	60	96 hr	20	168 hr
14	35	2 hr	50	72 hr	15	336 hr

Values enclosed by solid lines identified as likely inclusions in repair time rather than logistics delay time.

NOTES: * - Training base, no maintenance performed on site.
 ** - Numerous nearby lateral bases.
 *** - Lateral base includes depot.

The spares availability impact is an additive factor to the predicted repair time which accounts for the requirement to obtain a spare item in order to accomplish the repair action. This time requirement is considered part of the logistics and administrative delay time and is not included in predictions of mean time to repair by definition. This time must be added to the predicted system mean time to repair in translation to a field environment.

3.3.5 Cables and Connectors

Personnel were queried as to the relative importance of cabling and connectors as system failure causes. This question was stated as to prohibit the inclusion of other factors from influencing this impact area, as were all the survey questions. Table 3-8 illustrates the range of responses from 78 maintenance personnel at the 14 sites visited during primary data collection. This table shows that while the individual responses ranged from 5 to 90 percent, consensus values are concentrated between 10 and 40 percent. The consensus for each base was determined by a weighted averaging of individual responses to survey questions, with increased weight given to seniority and/or rank. Table 3-9 shows a point graph histogram of the responses from the interviewed maintenance personnel to the question concerning cables and connectors maintenance. The overall consensus, weighted across all 14 bases, is that 31 percent of all failures are ultimately due to cables, cabling and/or connectors. This was calculated by first multiplying the percent of cable and connectors

Table J-8: Effects of Cables and Connectors Impact on Maintenance Activity

USAF BASE	NUMBER OF RESPONSES	PERCENTAGE																		CONSENSUS FIGURE	
		0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85		90
1	6	:	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	30 %
2	3	:	:	:	:	:	X	:	:	:	:	:	:	:	:	:	:	:	:	:	30 %
3	3	:	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	30 %
4	5	:	:	:	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	30 %
5	6	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	10 %
6	2	:	:	:	:	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	37 %
7	4	:	:	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	35 %
8	7	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	30 %
9	8	:	:	:	X	-----	:	:	:	:	X	:	:	:	:	:	:	:	:	:	30 %
10	2	:	:	:	X	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	15 %
11	12	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	40 %
12	2	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	20 %
13	10	:	:	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	35 %
14	8	:	:	:	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	35 %
WEIGHTED SUMMARY	78	X	-----	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	31 %

Table 3-9: Histogram of Responses to Question on Cables and Connectors Maintenance Activity.

USAP BASE	NUMBER OF RESPONSES	PERCENTAGE																		CONSENSUS FIGURE
		0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	
1	6	:	:	1	:	1	3	:	:	:	:	1	:	:	:	:	:	:	:	30 %
2	3	:	:	:	:	:	3	:	:	:	:	:	:	:	:	:	:	:	:	30 %
3	3	:	:	:	1	1	:	:	:	:	1	:	:	:	:	:	:	:	:	30 %
4	5	:	:	:	:	:	:	2	1	:	:	:	:	:	1	1	:	:	:	30 %
5	6	1	3	:	:	:	:	:	2	:	:	:	:	:	:	:	:	:	:	10 %
6	2	:	:	:	:	:	:	:	1	1	:	:	:	:	:	:	:	:	:	37 %
7	4	:	:	:	:	1	:	2	1	:	:	:	:	:	:	:	:	:	:	35 %
8	7	:	1	1	1	2	1	:	:	1	:	:	:	:	:	:	:	1	:	30 %
9	8	:	:	:	:	1	4	2	:	:	1	:	:	:	:	:	:	:	:	30 %
10	2	:	:	:	2	:	:	:	:	:	:	:	:	:	:	:	:	:	:	15 %
11	12	1	2	3	1	1	1	1	:	1	3	:	:	:	:	:	:	:	:	40 %
12	2	1	:	:	:	:	1	:	:	:	:	:	:	:	:	:	:	:	:	20 %
13	10	:	:	:	:	3	2	1	:	1	:	:	:	:	1	1	:	:	1	35 %
14	8	:	:	2	1	:	:	1	:	1	:	2	:	:	:	:	1	:	:	35 %

problems perceived at each site by the number of responses at that site, then summing the results across all 14 sites and dividing this by the total number of responses (78 here).

The significance of this result stems from two effects. First, the frequency of cable/connector failure is consistently underestimated by MTTR prediction algorithms, which weight device or unit estimated time to repair by predicted frequency of occurrence to determine a mean. Second, failures in cabling and/or connectors are more difficult to detect than internal device failures. This is because standard fault detection/fault isolation (FD/FI) techniques (including built-in test (BIT)) are not designed to cover these failure modes. This is, in turn, caused both by the (falsely) perceived low failure rates of cabling and connectors, and by restriction of BIT requirements to detecting and isolating faults internal to a device; i.e., responsibility for built-in FD/FI ends at the connector to the unit or item.

The time characteristically expended to diagnose and identify problems relating to cables and connectors was also solicited from the surveyed maintenance technicians. Time values to diagnose and remedy cabling and connector problems range from one hour to a week, with a commonly stated mean value of four hours. This is considerably longer than the characteristic predicted MTTR of 0.5 hours for ground C³I equipment. The predicted MTTR for most electronic systems assumes that cable and connector problems occur extremely

infrequently--an assumption directly at odds with the study findings (which is 31%). Thus, the impact factor value is properly applied directly to the predicted MTTR value to adjust for the real world situation (as shown in section 3.2.1).

The significant percentage of problems attributed to these components contributes to maintenance time in another, less obvious fashion. Recognizing cabling and connector problems as frequent occurrences, maintenance personnel often take the opportunity afforded during other maintenance actions to clean connectors and check them for good contact and firm seating. This is widely considered good practice in the field. The time taken to clean and check connectors is recorded as part of the maintenance action, and thus directly increases reported repair time.

Maintenance personnel stated that an average of 5 minutes is expended during each maintenance action for activity to prevent or forestall future cable and connector problems. Thus, a value of 0.08 hours (5 minutes) should be added to the predicted MTTR to account for these actions.

In summary, two k factors are associated with cable and connector maintenance. Survey results show an average 31 percent of all failures are ultimately identified as due to cables, cabling and/ connectors. This impact is inherent to the equipment and independent of fielding conditions. It must therefore be accounted for by adjusting inherent MTTR to weight the high

percentage of cable, cabling and/or connector problems and the longer repair time (4 hours) associated with them. Thus,

$$P_{CC} = 0.31 \text{ and } MTTR_{CC} = 4 \text{ hours}$$

Secondly, common field practice extends repair actions to check and maintain cables and connectors. Thus a second k factor of 0.08 hours must be added to field repair time to account for this field activity. Thus,:

$$K_{CC} = 0.08 \text{ hours} = k \text{ factor for additive cables and connectors impact.}$$

3.3.6 Base Policies and Practices

This impact subject area accounts for the additional maintenance time caused by policy and/or procedures followed at a particular site or base. It was hypothesized that repair time could be affected by delays in obtaining and using tools and TOs due to spatial separation, paperwork requirements, lighting and space available at the maintenance location, and so forth. The study therefore included in its survey a series of questions addressed to Air Force personnel to ascertain whether policies and practices in force for their units were impacting maintenance times.

Survey results indicated that base policies and procedures have a perceptible, though not severe, impact on field repair times. Physical resources such as

lighting and space at maintenance locations are generally considered adequate and not impacting maintenance activities. Air Force personnel surveyed did perceive modest increases in field repair time due to resource locations and the necessity to document maintenance actions, as shown in Tables 3-10 and 3-11. Since these areas impact each maintenance action to the same extent, they are jointly quantified as an additive k factor for transitioning inherent MTTR to field MTTR.

One element of base policies and practices identified during the surveys and interviews as having an impact on maintenance time is the base layout. The separation between the maintenance personnel area and the equipment location requires time to be spent not only to get to the equipment when needed, but also to record maintenance actions once they were completed. Table 3-11 presents the survey results as to the effects of base maintenance resource location impact on maintenance time. These indicate that field maintenance time is increased by an average of 12.7 minutes per maintenance action due to the spatial separation of resources and equipment to be maintained.

Table 3-10 displays the maintenance time impact ascribed by Air Force personnel to requirements for documenting their actions. In all cases save one, this impact was assessed as between zero and 35 minutes. At Base 6, data terminals for recording maintenance actions were unavailable on base, with the nearest such devices a two-hour round trip away. Thus the associated impact value (2 hours) is the result of an unusual gap in data

Table 3-10: Effects of Maintenance Recording Impact on Maintenance Time

QUESTION: What increase in repair time is attributable to requirements for recording maintenance actions (including location where recording takes place)?

ADDED TIME (MINUTES)

		CONSENSUS												
USAF BASE	FIGURE	0	10	20	30	40	50	60	70	80	90	100	120	
1	N/A	:	:	:	:	:	:	:	:	:	:	:	:	
2	0 min	X	:	:	:	:	:	:	:	:	:	:	:	
3	22.5 min	:	:	X-----X	:	:	:	:	:	:	:	:	:	
4	N/A	:	:	:	:	:	:	:	:	:	:	:	:	
5	12.5 min	:	X-X	:	:	:	:	:	:	:	:	:	:	
6	120 min	:	:	:	:	:	:	:	:	:	:	:	X	
7	17.5 min	:	:	X-X	:	:	:	:	:	:	:	:	:	
8	30 min	:	:	:	X	:	:	:	:	:	:	:	:	
9	15 min	:	:	X---X	:	:	:	:	:	:	:	:	:	
10	0 min	X	:	:	:	:	:	:	:	:	:	:	:	
11	N/A	:	:	:	:	:	:	:	:	:	:	:	:	
12	12.5 min	:	X-X	:	:	:	:	:	:	:	:	:	:	
13	2 min	:X	:	:	:	:	:	:	:	:	:	:	:	
14	15 min	:	X---X	:	:	:	:	:	:	:	:	:	:	
WEIGHTED SUMMARY		22.5 min												
		(16.2 min trimmed mean)												

Table 3-11: Effects of Base Maintenance Resource Location Impact on Maintenance Time

QUESTION: To what extent is repair time affected by the location within the base of resources required to perform maintenance?

ADDED TIME (MINUTES)

USAF BASE	CONSENSUS FIGURE							
		0	5	10	15	20	25	30
1	(no response)	:	:	:	:	:	:	:
2	12.5	:	:	X----	X	:	:	:
3	12.5	:	:	X----	X	:	:	:
4	(no response)	:	:	:	:	:	:	:
5	12.5	:	:	X----	X	:	:	:
6	10	:	:	X	:	:	:	:
7	17.5	:	:	:	X----	X	:	:
8	30	:	:	:	:	:	:	X
9	15	:	:	X-----	X	:	:	:
10	0	X	:	:	:	:	:	:
11	(no response)	:	:	:	:	:	:	:
12	12.5	:	:	X----	X	:	:	:
13	2	:	X	:	:	:	:	:
14	15	:	:	X-----	X	:	:	:
WEIGHTED SUMMARY	12.7	X-----	X	:	:	:	:	X

communication and does not reflect standard Air Force practice. The value from Base 6 was therefore excluded or "trimmed" from the data set as unrepresentative. The weighted average of reported impact from the 13 other bases was then 16.2 minutes per maintenance action.

Other policies and procedures in force at the visited bases had impacts on maintenance time which were more difficult to quantify. There is considerable emphasis on training at several sites. This includes taking advantage of each "training opportunity" which presents itself. Access to the systems maintained at the sites is limited because of operational conditions and the high reliability of the equipment. Many maintenance personnel never see most equipment failures and failure modes. This lack of familiarization with the equipment and the failure modes results in a lack of confidence and skill when confronted with a maintenance problem and causes longer maintenance repair times.

Several bases have remedied this to a limited degree by taking advantage of certain training opportunities. When a system is down for maintenance and there is no extreme urgency to bring it back to operation (such as in redundant systems or when a back-up, less capable, system can perform), training classes are scheduled and held. These impromptu classes enable more maintenance people to receive hands-on access to the equipment for familiarization. While this general practice causes an increase in recorded maintenance time, commanding officers have stated that "they are willing to take a hit in increased maintenance

time in exchange for increased technician skills and confidence so that when those skills are needed in a war-time or other emergency, they are ready." This logic and reasoning cannot be faulted.

Approximately 70 percent of the maintenance actions performed on the systems with redundant capability was found to be conducted with the system in an amber state (not fully down). This is the situation which presents the opportunity for training. In the typical case when this type of training occurs, a half hour was spent bringing an average group of 5 technicians together for the training opportunity. Each of the five technicians sequentially has hands-on access to the equipment for five to ten minutes. Using an average of 7.5 minutes, this adds 37.5 minutes to the maintenance time. Thus, the total time for training opportunities is 67.5 minutes additional maintenance time. This type of training was found to be implemented in approximately half the cases where the opportunity presents itself, or 35 percent of the instances when maintenance is performed. Thus the adjustment to predicted MTTR for training emphasis is:

$$MTTR_F = P_r [(0.35) * [67.5 + MTTR_{IN}] + (0.65) MTTR_{IN}]$$

$$= P_r [MTTR_{IN} + 23.5 \text{ minutes}].$$

where P_r = 1 if system incorporates redundancy

= 0 if system does not incorporate redundancy

Summing the effects of resource location (12.7 minutes per maintenance action for travel), recording time impact (16.2 minutes) and training opportunity impact (23.5 minutes), the addition to predicted MTTR to account for these practices is

$$\begin{aligned}
 k_{\text{bpp}} &= 28.9 + P_r (23.5) \text{ minutes} \\
 &= 0.48 + P_r (0.39) \text{ hours} \\
 &= k \text{ factor for base policy and practices impact.}
 \end{aligned}$$

3.3.7 Cannot Duplicate (CND) K Factor

Personnel at each visited site were surveyed to determine the percent of reported failures result in no specific fault found in the system or equipment. This is classified as a "cannot duplicate" failure. Very few Air Force maintenance personnel felt sufficiently qualified to render a factual response to this question. This held true even for very experienced technicians and maintenance officers. It was generally agreed that the percentage or CND rate was very low. The limited survey data from Air Force sites was augmented with experience data from Westinghouse field engineers who had experience with ground based electronic systems and equipment. The limited data collected is presented in Table 3-12. The consensus value for the CND rate is 6 % after assuming a 2.5 % value for the response of less than 5 %. This CND percentage for ground based electronic systems is dramatically less than the CND rate for much airborne electronic systems and equipments. An experienced CND rate of 30 to 35 percent

is not uncommon for airborne systems. Ground based systems do not appear to have this problem based on the collected data.

Table 3-12 Data for CND Rate on Ground Based Electronic Systems

<u>Number of Responses</u>	<u>CND Rate</u>
1	20 %
3	10 %
8	5 %
5	< 5 %

It is even more difficult to develop an average time required to address or "repair" CND condition. Data on this repair time element varied from a few minutes (to reset computer input/output devices or to reset a printed circuit board) to several hours (to perform extensive diagnosis or track down an intermittent fault.) Rather than state an average repair time for CND failure which may be incorrectly applied to all situations, it is left to the reliability or maintainability specialist to develop this time estimate for the particular system or equipment under analysis.

Thus this study found:

$P_{CND} = 0.06$ and $MTTR_{CND} =$ to be developed for a specific application.

3.4 Application of K Factors

Application of these k factors to transition from a predicted inherent MTTR to the MTTR value expected in a fielded environment is a three step process. First is to adjust the inherent active MTTR to an overall inherent active MTTR. Second to apply the appropriate multiplicative factors. Third to apply the appropriate additive factors. The application consists of both universal k factors and contingent k factors.

3.4.1 Universal K Factors

Universal k factors are those that are applicable at every site or location. These do not vary from site to site. The universal k factors are maintenance induced impact, spares availability impact, cables and connectors impact, base policy and practices impact, and CND impact.

3.4.2 Contingent K Factors

The contingent k factors are those that vary from base to base. These are dependent on the local environment and/or practices at the fielding location. When utilizing the contingent k factors, it must be kept in mind that these factors are functions of conditions in force at specific bases. Caution must therefore be observed when attempting to apply a repair time correction to equipment in service at particular bases. The contingent k factors are climatological impact and NBC gear impact. Estimates of the percent of time these

factors at present or used at the system location is needed before these contingent factors can be applied. It would be extremely misleading, for example, to use the same climatological k factor for an arctic base as for units based in subtropical climates.

Sound application of the k factors analysis should begin with careful examination of the k factor development detailed in Section 3.3 above, in conjunction with an understanding of conditions at the fielding locations under consideration and the type of resultant measure which will prove most useful.

3.4.3 Examples of Application

The examples below illustrate how the survey-based k factors may be applied to adjust the MTTR for a fielded system. The three situations treated serve to illustrate how the rationale behind factor derivation, conditions at the location(s) of interest and the area of interest combine in a straightforward manner.

Example 1: Base X operates a variety of ground C³I equipment under subarctic conditions. For approximately 4 months out of the year, base temperatures are below freezing; for 2 months temperatures are below zero Fahrenheit, but never reach -20 F. The equipment in question has a predicted inherent MTTR of 0.5 hours and incorporates redundancy. How must the MTTRs of the ground electronics equipment be adjusted to reflect actual repair times over the long term under field conditions at this base?

The first step is to adjust the predicted inherent MTTR for the effects of cables and connectors and CND conditions. We use the formula derived in Section 3.2.1:

$$MTTR_{IN} = P_{CC} MTTR_{CC} + P_{CND} MTTR_{CND} + (1 - P_{CC} - P_{CND}) MTTR_{PR}$$

Based upon the current study, cables and connectors account for 31% of all failures, with an associated MTTR of 4 hours. CND conditions account for approximately 6% of all failure reports; although no MTTR for a CND was found, for purposes of illustration it will be assumed to be three times normal repair time, or $3 * 0.5 = 1.5$ hr. Thus the adjusted inherent MTTR would be

$$MTTR_{IN} = (0.31 * 4) + (0.06 * 1.5) + (0.63 * 0.5)$$

$$MTTR_{IN} = (1.24) + (0.09) + (0.32) = 1.65 \text{ hr.}$$

The next step is to apply k factors for field dependent impacts. This is done by substituting k factor values into the following expression:

$$MTTR_F = [MTTR_{IN} * k_{ind} * k_{NBC} * k_{cli}] + [k_{sp} + k_{bpp} + k_{ccm}]$$

From sections 3.3.2, the multiplicative k factor for maintenance induced impact is 1.22. The additive k factors which account for the impacts of spares availability, inspection and cleaning of cables and connectors, and base policy and procedures are 1.3 hours, 0.08 hours, and 0.88 hours from sections 3.3.4,

3.3.5 and 3.3.6 respectively. NBC gear is not normally used at this base, so the k factor for protective gear from section 3.3.3 equals one.

Finally, for a k factor of long term climatological impact, the equation derived in section 3.3.1 is used:

$$k_{cli} = (1.34 * t_1) + t_2 + (1.9 * t_3) + (3.1 * t_4) + (4.7 * t_5)$$

For the conditions described,

$$\begin{aligned} t_1 &= 0, \\ t_2 &= (8 \text{ months}) / (12 \text{ months}) = 0.66, \\ t_3 &= (2 \text{ months}) / (12 \text{ months}) = 0.17, \\ t_4 &= (2 \text{ months}) / (12 \text{ months}) = 0.17, \text{ and} \\ t_5 &= 0. \end{aligned}$$

This yields a composite k factor of

$$\begin{aligned} k_{cli} &= (.66) + (1.9 * .17) + (3.1 * .17) \\ &= .66 + .32 + .53 \\ &= 1.51. \end{aligned}$$

The complete adjustment is then given by:

$$\begin{aligned} MTTR_F &= [(1.22 * 1 * 1.51) * MTTR_{IN}] + 1.3 \text{ hrs} \\ &\quad + 0.08 \text{ hrs} + 0.88 \text{ hrs} \\ &= (1.84 * 1.65) + 2.26 \text{ hr} \\ &= 3.04 + 2.26 = 5.3 \text{ hr.} \end{aligned}$$

Example 2: The maintenance command at Base X (see the example above) wishes to establish a worst-case MTTR for maintaining its ground C³I equipment under the most severe conditions encountered in peacetime.

For this operational scenario, the majority of k factors retain the values used in Example 1. This includes those for CND conditions; cables and connectors (both adjustment to predicted MTTR and additive factors for routine preventive inspection and maintenance); spares availability; policy and practices; NBC gear (again set equal to one); and maintenance induced failures.

The worst-case conditions for Base X essentially reduce to those of severest climatological impact. This occurs during the two months yearly when temperatures range between 0 F and -20 F. Under such conditions the k factor for climate from Section 3.3.2 is

$$k_{cli} = 3.1.$$

Thus the worst-case peacetime adjustment to inherent MTTR is given by

$$\begin{aligned} MTTR_F &= [3.1 * 1.22 * 1 * (1.65 \text{ hr})] + 2.26 \text{ hr} \\ &= 6.24 \text{ hr} + 2.26 \text{ hr} = 8.5 \text{ hr} \end{aligned}$$

Example 3. Base Y operates an equivalent set of ground C³I equipment in a tropical environment where temperatures run over 90 F seven months of the year. The base is located in a geographical region highly

accessible to attack by chemical and/or biological weapons in the initial stages of conflict. Maintenance elements have been asked to estimate their ability to keep the C³I equipment operational should the base go on highest alert and exposed personnel be required to wear NEC gear at all times. In the course of responding to this request, the maintenance command wishes to calculate a worst-case factor for the increase in MTTR under the given conditions.

In this case, adjustment of predicted MTTR to inherent MTTR goes forth as in the first two examples:

$$MTTR_{IN} = 1.65 \text{ hr}$$

The k factors for maintenance induced impact, spares availability, policy and procedures, and cables and connectors will be kept the same for the purposes of the example.

In the worst-case environment, technicians are working in NBC gear in a 90°-plus environment. This implies that k factors appropriate for these impacts will be

$$k_{NBC} = 2.3 \quad \text{and} \quad k_{cli} = 1.34.$$

Combining the k factors above for a predicted MTTR of one half hour yields a worst-case MTTR of

$$\begin{aligned} MTTR_F &= [1.34 * 1.22 * 2.3 * (1.65 \text{ hr})] + 2.26 \text{ hr} \\ &= 6.20 \text{ hr} + 2.26 \text{ hr} = 8.46 \text{ hr}. \end{aligned}$$

Extraordinary measures such as dispensing with cable and connector maintenance, or immediately accessing WRSKs for spares, might substantially lower the expected MTTR. While the present study serves to highlight these impact areas for consideration in the given situation, estimation of the result of such actions is beyond the study scope.

4.0 RELATED OBSERVATIONS

The study team's site visits with Air Force maintenance personnel frequently encompassed discussion of a number of issues important to the global maintenance effort. While not specifically called out in the study contract, the study team believes these discussions shed valuable additional light on the conditions which the study was to address. Pertinent observations based on these discussions are set forth in this section.

4.1 Correlation Between BIT Capability and Induced Failures

There was no correlation between the built-in-test (BIT) capability of the electronic systems surveyed and the incident of maintenance induced failures. Maintenance personnel stated that the induced failures usually resulted from personnel performing an actual repair while the BIT was used to perform diagnosis of the equipment or to find out what specifically was not working within the system or equipment. The BIT capability for the surveyed systems was generally to the system or subsystem level. The BIT monitors system or subsystem performance and signals a fault or failure. The technician would then be required to perform fault diagnosis below the subsystem level to the actual malfunctioning unit. The induced failures were then at or within the unit level.

4.2 Cables and Connectors Problems

This study identified a significant amount of system failures to be attributed to cables and connectors. Ideas on the causes for these failures were solicited from the maintenance personnel. No specific causes were stated. Most experienced technicians stated that cables and connectors have always been a problem and will always continue to be a problem. Among the causes cited at visited sites were the stress at cable connectors which are continually connected and disconnected with mobile systems and which are under constant exposure to the external environment. Sometimes printed circuit board connectors are exposed to high humidity which causes corrosion and eventual failures. However, no specific reason or cause for the high occurrence of cables and connectors failures was given across the visited sites.

4.3 Extended Maintenance Practiced

Experience with long delay times to obtain spares from the depot, along with a need for high availability deemed critical for their equipment and its mission, has encouraged maintenance elements to pursue work around options. These typically include troubleshooting and replacing subassemblies and component beyond that which is stated in the authorized maintenance plan. This is accomplished on a trial and error basis, drawing on the general electronics knowledge of the maintenance personnel, without the supporting schematics and technical data. It is reasonable to hypothesize that

such actions would take longer than those for which proper support was on hand. However, information on the frequency and duration of this practice was insufficient to estimate its impact on field MTTR.

The need for high operational readiness was sufficiently great at one base to encourage obtaining a required spare from the war readiness spares kit (WRSK) if the spare was not available at the local or lateral supply. A requis was then issued to the depot to replenish the WRSK. Thus, there was no direct reliance on the depot for spares to maintain the equipment.

4.4 Preventive Maintenance Requirements

Significant numbers of Air Force personnel believe that preventive maintenance activities cause additional real faults through exposure of the equipment to maintenance technicians. Preventive maintenance accounts for the vast majority of maintenance activity at several of the sites visited. Taken together, these observations indicate that reduction of these preventive maintenance requirements, where feasible, and/or increasing the intervals between successive preventive maintenance actions, would greatly reduce maintenance requirements and man-hours and therefore increase system readiness and availability.

4.5 Effects of Nuclear/Biological/Chemical (NBC) Protective Gear

Air Force maintenance personnel indicate that some maintenance actions cannot be performed by technicians wearing standard nuclear/biological/chemical (NBC) protective gear, and that most if not all maintenance activities require significantly more time to perform when NBC gear is mandated. This information needs to reach systems designers to ensure that equipment intended to be maintained in an NBC environment incorporates features which promote this.

4.6 Real Impact on System Availability and Readiness

It is generally agreed by the maintainers that increased system and equipment reliabilities tend to outweigh increases in their maintenance and repair times. Where redundant capability is built into a system, most maintenance can be performed while the system is still operational (i.e., in an amber state). In such a situation, the impact of increased maintenance time upon the system's operational readiness is significantly reduced.

4.7 Personnel Availability

The availability of maintenance personnel was stated to be adequate for the system and operational requirements at each surveyed base. There was no maintenance delayed for a general lack of maintenance personnel or technicians. It was stated that some

maintenance requirements were delayed until the next shift or until after the weekend due to scheduling priorities only if this did not effect the operational readiness or performance of the equipment. This was possible with many C³I systems because of the redundancy built into the equipment.

4.8 Training Needs

Maintenance officers and enlisted personnel feel that training needs merit greater attention than they presently enjoy. Due to the high reliability of the prime systems, the technician's understanding of a system can degrade significantly in the time between maintenance actions of a specific type. Familiarization of maintenance personnel with failure modes, diagnostic procedures and repair actions is not possible due to the low rate of failure occurrence. To offset this, a number of units take advantage of actual failure occurrences, when these do not cause significant loss of coverage or availability and mission demands permit, to conduct impromptu hands-on training. This, in turn, results in greatly increased repair times, especially when each technician diagnosed the fault and performed the repair action in turn. In these cases, the reported repair time is the sum of the repair times of each technician troubleshooting the same fault.

4.9 Impact of Tools

Data obtained on the impact of tools on repair time is sufficiently diverse to preclude a definitive

statistical analysis. Collected information indicates that tools requirements showed two extreme impacts: either no effect on maintenance, or a very significant lengthening of repair time.

Most maintenance areas and shops are very well stocked with common and special tools, and are well organized to allow convenient access to them. Equipment maintenance generally calls for tools which are readily available and perform the specified functions well. In such cases, tools requirements add no significant time to the duration of a maintenance action. However, upon certain occasions the time required to gather necessary tools adds drastically to the maintenance action duration. This occurs when a special tool is needed which is in extremely short supply.

At one base, a 9/64" allen wrench is needed to obtain access to a particular part in one system. Unfortunately this size wrench is not included in the standard set of allen wrenches! This shop has one 9/64" allen wrench, which the maintenance chief keeps with him, on a key ring, at all times. When a technician needs this size wrench, the appropriate action is to locate the maintenance chief and borrow it. When the chief is nearby, this usually takes no more than 10 to 15 minutes. More often, however, the chief is in a meeting or elsewhere on the base, so that the maintenance action which required access to that particular part is delayed until the chief returns - normally in two to four hours.

Solutions to such situations need to be implemented both in the equipment design phase and as part of subsequent maintenance planning. A sound supportable design should not require a non-standard tool for its repair, except when unavoidable as a result of some design feature which offers overriding compensation to the Air Force. When a non-standard tool is required, maintenance planning must provide for its acquisition by maintenance shops in numbers sufficient to afford timely access a high percentage of the time. In the above case, buying a second 9/64" allen wrench appears to be a logical way to cut down on waiting time.

A number of maintenance personnel are vocal about the quality of common tools entering the USAF inventory. Most comments are negative. They feel that the new tools do not meet the quality standards of older tools. Some of the newer tools actually break when used. While the maintainers appreciate the need to reduce support costs and the concept of buying from the lowest bidder, they feel that more can and should be done in tool acquisitions to ensure a high quality level.

4.10 Technical Training and Technical Orders

Personnel interviewed find the levels of technical training and technical orders (TOs) available at most bases to be appropriate for their work. Very little impact is perceived on basic maintenance time as a result of training of technical personnel and the level of technical documentation presented in the TOs. Less experienced personnel do show a higher incidence of

maintenance induced failures due to lack of familiarization with the equipment; however, this reduces to the average level as their experience increases.

The TOs available do not include data for repair beyond removal and replacement of failed units. In normal day to day maintenance activities, more extensive technical data (e.g. schematics) is not required. Inclusion of more detailed data would be extremely helpful when detailed troubleshooting is performed at the base. Internal troubleshooting and repair of units is not a usual activity at the base level. Maintenance personnel state that it is done, even without schematics, in situations when the logistics delay time involved in obtaining a spare unit is perceived as extremely long. Provisioning of schematics and other detailed technical data for troubleshooting would aid such activities. However, a greater payback could be attained by reducing the logistics delay time for spares through stock level and/or transportation adjustments.

4.11 Common Screwhead Preference

During a site visit to the second surveyed base, the question of a common screwhead type came up in the course of discussions among survey and maintenance personnel. Maintenance personnel explained that additional repair time is spent obtaining the many different screwdrivers and associated tools required to gain access to replaceable subassemblies. Screws and other fasteners which become stripped through age and

use present serious problems and significantly increase active maintenance and repair time. Intrigued by the interest shown by Air Force maintainers, the study team decided to bring up the question in subsequent site visits.

Results of these queries are shown in Table 4-1. Seventy-one of the surveyed maintenance personnel at 13 sites expressed a preference for one of seven screwhead types. As the table shows, the Phillips head screw type was named by over 56% of the personnel who expressed a preference, and was favored by three to one over the next most preferred variety (external hex).

Several reasons can be hypothesized for the recorded preference. The common single-slot screwhead requires a proper size blade for efficient removal, and even then is vulnerable to screwdriver slipping. Proper size is equally important for removal of external or internal hex heads. The latter type requires Allen wrenches which, although smaller and lighter than the equivalent standard screwdriver, may more easily be dropped or misplaced and are not easily differentiated for sizes. Torx (internal star-shaped), Bristol and quick-disconnect screwheads suffer from being comparatively unfamiliar to most technicians. The Phillips head screw does not require an exact size match between blade and screwhead, provides protection against screwdriver slipping, and is common and familiar.

TABLE 4-1

MAINTENANCE PERSONNEL PREFERENCES
FOR COMMON SCREWHEAD TYPES

<u>Base</u>	<u>Screwhead Type</u>						Quick Discon -nect
	<u>Phillips</u>	<u>Single Slot</u>	<u>Internal Hex</u>	<u>External Hex</u>	<u>Torx</u>	<u>Bristol</u>	
2	3						
3	1			2			
4	1			1			
5	6	1					
6	2				1		
7	3		1	2			
8	3	2	1			1	
9	5	2		1			
10	1	1					
11	7	1		2		1	
12	1			2			
13	5			1	1		1
14	2	1	3	2			
TOTALS	40 (56%)	8 (11%)	5 (7%)	13 (18%)	2 (3%)	2 (3%)	1 (2%)

5.0 APPENDICES

APPENDIX A - RECOMMENDATIONS FOR FUTURE EFFORTS

In the course of this study, a number of issues were raised whose detailed investigation and resolution lay beyond the scope of the contract. Some of these issues will affect future efforts to improve field maintainability characteristics of Air Force electronics equipment. Others concern the need for Air Force planners to obtain the clearest possible picture of Air Force maintenance activities, both as a basis for the most efficient allocation of resources and to accurately assess field capabilities. After comparing the outstanding issues for feasibility of resolution and potential benefit to Air Force electronics equipment maintenance, the study team recommends three areas for further investigation.

A natural step beyond the present study would consist of extending its scope and objectives to investigate operational and logistics impacts on airborne avionics in addition to ground C³I systems. Because airborne electronics systems are different in size, density and maintenance design from ground equipment, such a study would help to further confirm the existence and clarify the magnitude of the effects identified as impacting ground C³I systems, as well as provide insight into the critical airborne avionics maintenance activity.

Effects which negatively impact maintenance time for ground electronics systems also bear further

investigation, with a view toward identifying and implementing cost-effective solutions for them. A prime candidate for such investigation is the maintenance problem posed by cables and connectors, which the present study found to be related to a significant percentage of maintenance actions. Future study should concentrate on engineering and scientific investigation to determine the fundamental causes of cables and connector maintenance problems and propose remedies.

Another promising area for future study is the impact of excessive preventive maintenance (PM) on system performance and maintenance. Such an effort would properly include investigation of the impact from reducing present PM requirements and increasing the PM interval (PMI), and would aim to develop guidelines to identify optimal requirements for preventive maintenance early in the design cycle.

A third issue which calls out for investigation is the impact of nuclear/biological/chemical (NBC) protective gear on maintenance. This study would be tasked with determining what percentage of maintenance actions currently in force are impossible in NBC gear, and developing guidelines for future equipment design and/or modification of the NBC ensemble to promote efficient maintenance in the NBC threat environment.

Another area which bears consideration is that of Air Force tool quality and its impact on maintenance performance. Current quality control and required

standards of performance for tools in extreme climates are issues worth examining in some detail.

The present study team encountered numerous difficulties in collecting maintenance data of appropriate detail and quantity for analysis and conclusions. This hints at a possibly severe problem with amassing information for use not only in future maintenance studies, but also for operations planning and resource allocation. What data is needed for maintenance analysis and planning, and how that data would be most efficiently collected and processed, are questions appropriately asked in a future investigation. Such a study should take special note of current Air Force plans to provide portable computer aids for avionics maintainers on the flight line, and consider the potential benefits of doing the same for ground equipment maintenance personnel, as a common vehicle for maintenance data collection and reduction.

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APPENDIX C - LIST OF ACRONYMS AND ABBREVIATIONS

ADCOM	Aerospace Defense Command
AFALD	Air Force Acquisition Logistics Division
AFB	Air Force Base
AFCOLR	Air Force Coordinating Office for Logistics Research
AFM	Air Force Manual
AMS	Avionics Maintenance Squadron
AFSC	Air Force Systems Command
ANG	Air National Guard
BIT	Built-in Test
BIT/FIT	Built-in-Test/Fault-Isolation-Test
CC	Cables and Connectors
CND	Cannot Duplicate
CS	Communications Squadron
DC/SR	Display and Control/Storage and Retrieval
DoD	Department of Defense
ECS	Electronic Combat Squadron
EMT	Elapsed Maintenance Time
ESR	Equipment Status Report
FD/FI	Fault Detection/Fault Isolation
IF	Intermediate Frequency
IFF	Identification - Friend or Foe
ISG	Information System Group
ISS	Information System Squadron
ISW	Information System Wing
JCN	Job Control Number
LRU	Line Replaceable Unit
MAW	Military Airlift Wing
Mct	Corrective Maintenance Action

List of Acronyms and Abbreviations (Cont'd)

MDC	Maintenance Data Collection
MLDT	Mean Logistic Delay Time
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NBC	Nuclear/Biological/Chemical
NMC	Not Mission Capable
NMCM	Not Mission Capable - Maintenance
NMCO	Not Mission Capable - Other
NMCS	Not Mission Capable - Supply
NORAD	North American Aerospace Defense
NRTS	Not Repairable This Station
PC	Personal Computer
PM	Preventive Maintenance
PMI	Preventive Maintenance Interval
POM	Program Objective Memorandum
R&D	Research & Development
R&M	Reliability & Maintainability
RADC	Rome Air Development Center
SRU	Shop Replaceable Unit
SPACECOM	Space Command
TAC	Tactical Air Control
TACW	Tactical Air Control Wing
TAIRCW	TAC Air Control Wing
TAT	Turn Around Time
TCF	Tactical Control Flight
TCG	Tactical Control Group
TCS	Tactical Control Squadron
TFW	Tactical Fighter Wing
TM	Type Maintenance

List of Acronyms and Abbreviations (Cont'd)

TO	Technical Orders
TWT	Traveling Wave Tube
USAF	United States Air Force
WRSK	War Readiness Spares Kit
WUC	Work Unit Code

APPENDIX D - ACTIVITIES RELATED TO THE CONTRACT

Part 1: Site Visits under BLUE-2 Program

Visits were made to Pease AFB, New Hampshire, and Ellsworth AFB, South Dakota, from 18-23 February 1985 to observe operational and intermediate level maintenance activities on site. This trip was arranged by the Air Force Coordinating Office for Logistics Research (AFCOLR) as part of the Blue 2 program. It was conducted just prior to the receipt of this contract. Although oriented to airborne equipment, the observed maintenance activities provided first hand contact to identify operational impacts and to improve the quality of data collected. The aircraft observed were the FB-111 and KC-135 at Pease, and the B-52 and EC-135 at Ellsworth. The extensive reports prepared from these visits provided the following insights:

- o Maximum built in test (BIT) and associated data extraction at the flight line is desired.
- o The notion of locating a maintenance action memory type of device on equipment was supported. Repair/replace history, what was done last time, how long ago, etc. were items of key interest.
- o The T.O. is regarded as an "order from the Commanding General": a technician deviates from it only at great risk to his career.

- o Personnel were very receptive to the concept of electronic maintenance aids to enhance the combination of diagnostic system test and automated technical data into a single integrated system.
- o Most intermediate level shop repairs take 3-4 hours, if spares are available. Turn around time to get a spare from an on-site warehouse averaged around 1-1/2 hours; from the depot it can take months.
- o Equipment failures related to temperature are usually caused by temperature changes, not extremes.

AF bases and operations at Colorado Springs (Peterson AFB and Cheyenne Mountain), at Buckley ANG Base and at Beale AFB were visited 15-19 April 1985. This trip was again arranged by AFCOLR as part of the Blue 2 program. Observed were operation and maintenance of equipment used by the Space Command (SPACECOM), North American Aerospace Defense (NORAD), and Aerospace Defense Command (ADCOM). This included C³I systems similar to those included as target systems in this study. Data processing systems, communications, cryptography and radar (PAVE PAWS) were specifically included. Observations and comments were similar to those recorded on the previous Blue 2 trip and correlate well with the findings of the study. Results in general resembled those from the visits described above, with the following additional insights:

- o Software maintenance is a major problem. Software faults constitute about one-third of the total failures of their systems. Software diagnosis must be included in future design.
- o Substantial degrees of redundancy contribute significantly to fault tolerance, as well as superior equipment performance.

Part 2 : Projections of Future Maintenance Environments

The Air Force is currently developing several computer systems for management of base maintenance data. These systems will be integrated with future computer systems to provide an automated technical data system, adding diagnostic job aids to increase the ability of technicians to troubleshoot and perform a wider range of maintenance actions. Technical data, training, diagnostics, management, scheduling and historical data bases will be linked together. Initial research in this area during 1985 was addressed to methods of manipulating, managing and displaying the data. From 1-3 May 1985, the American Defense Preparedness Association, in conjunction with the Joint Logistics Commanders, provided a combined symposium - workshop. The symposium provided industry with a progress report on DoD planned Logistics R&D for POM-88 (Program Objective Memorandum). The workshop provided the forum to mutually assess these directions for the future. The recommended objectives will guide the long range management of Service programs and will become a

major consideration in the process of developing Service investment strategies. They include:

- o Automation of technical information - Technology areas such as electronic delivery of all technical data from contractor, computer aided training, and portable display for maintenance and on job training are near term candidates. Specific DoD responsible needs include artificial intelligence, flat panel display technology, computing security, and user interface development for portable technical information delivery devices.
- o Innovative maintenance techniques at all echelons - Hardware and technology issues such as design for battle damage repair, incipient fault detection, and "beyond design environment" diagnostics (thermal stress, nuclear exposure, etc.) will be considered for future Logistics R&D funding.

APPENDIX E
SITE VISIT SURVEY SUMMARY
COMPOSITE FORM

SITE LOCATION VISITED:

DATE OF VISIT:

UNIT(S) VISITED:

POINT OF CONTACT:

I. GENERAL

1.1 Base Visited and Date:

1.2 Unit Visited:

1.3 Point of Contact:

1.4 Types of Systems/Equipment:

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

4.2 Percentage of Maintenance Dealing with Cables,
Cabling, and Connectors:

4.3 Percentage of Maintenance Dealing with Power
Supplies and Power Sources:

4.4 Percentage of Maintenance Induced Effect on
Malfunctions:

4.5 Does Temperature Contribute to the Maintenance
Actions:

4.6 Does Humidity Contribute to the Maintenance
Actions:

4.7 Other Impact Areas Identified:

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to
Perform Maintenance:

5.2 Location of the Area to Record Maintenance Actions
and Time:

5.3 Impact of Facilities in Terms of Adequate Space to
Perform Maintenance:

5.4 Lighting Level to Perform Maintenance:

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

6.2 Personnel Surveyed:

APPENDIX F

SITE VISIT SURVEY SUMMARY COMPOSITE FORM

(COMPLETED)

This appendix contains 14 completed composite forms which summarize each site visit and survey. These cover the eleven site surveys used in the analysis phase and the three site surveys conducted for the confirmation phase.

The majority of the recorded survey responses are consensus views. Individual responses are shown with an alphabetic identifier (i.e., A, B, ...) when applicable.

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 1

DATE OF VISIT:

February 11, 1986

UNIT(S) VISITED:

Tactical Air Control Wing

RANK OF POINT OF CONTACT:

Major

I. GENERAL

1.1 Base Visited and Date:

Base 1 - February 11, 1986

1.2 Unit Visited:

Tactical Air Control Wing

1.3 Rank of Point of Contact:

Major

1.4 Types of Systems/Equipment:

Tactical control radar TPS-43; GSQ-120;
and associated systems
Radios

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

No maintenance done at this site. Area of
expertise to supported units at other sites.

2.2 Is Repair Performed On-Equipment or at a Local
Site Facility:

Not applicable. Most maintenance they support
is done on-equipment at other sites. Lots of
experience here to help newer field personnel.

2.3 Is Repair Performed Beyond the General Maintenance
concept Described Above:

Not supported here.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to
Identify and Isolate Malfunctions as Opposed to External
Test Equipment and Manual Methods:

BIT is good for go/no-go and identify some
malfunction symptoms. Use manual methods to
troubleshoot and find problem.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes! Repair while it is still operating if they can get authorized access to the system.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. Double Time in NBC gear.
- B. Double Time in NBC gear.
- C. Double Time in NBC gear.

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

- A. Cables and alignment on the TPS-43. Mis-align and fails in a hurry. Takes a lot of time to get the tools and fix cables.
- B. Supply and Spares availability.
- C. Cable connecting jacks are the biggest problem. Always break where coax goes into the connector.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 25-30%
- B. 50%
- C. 30%
- D. 10%
- E. 25%
- F. 30%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. 25%; High Voltage SF6 Tank is a big maintenance problem.
- B. 60%
- C. 80% of problems are High Voltage related.
- D. 55%
- E. 60%

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- A. 10%; Higher when working on circuit cards.
- B. 10%

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. Double Time when less than 20 degrees Double again when less than 0 degrees (15 minutes out then 15 minutes in)
- B. Double Time when greater than 100 degrees
- C. Cannot work with winds greater than 50 mph. Big problem in Florida Hurricane season.
- D. Ice on external bolts is a big problem in cold. Triple Time for access.
- E. Double Time when less than 20 degrees
- F. Double Time when less than 30 degrees

4.6 Does Humidity Contribute to the Maintenance Actions:

- A. Humidity increases problems with cables and connectors due to corrosion
- B. No impact due to humidity
- C. High humidity increases connector problem

4.7 Other Impact Areas Identified:

Some failures they do not even attempt to fix. Call in civilians from the depot. Work a 40 hour week but responsible for 24 hr/day 7 day/week readiness. Good 2 hours average to diagnose failures in TPS-43.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Maintenance resources are away from the equipment. No equipment here - just maintenance expertise and reporting area.

5.2 Location of the Area to Record Maintenance Actions and Time:

locally in the shop. Form 349 data is not usually reliable. (Maintenance is not done here.)

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

No facilities here.

5.4 Lighting Level to Perform Maintenance:

Not applicable here.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Common TE is good and is used. Special TE (such as the IFF UPM-135 Tester) is down more than it is used. 240 pound tester to test 40 pound box.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Majority of technicians minimally trained. A lot less than that. 3-levels right out of Tech school never saw equipment. Maintainer confidence impacts maintenance activity. Use TOs as a starting point, then use own experience. 50% follow TOs; 50% own knowledge.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Do not have all the tools. Must borrow from other units which adds time.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

- A. Usually do not have a spare in base supply. Either wait up to a month or raid WRSK.
- B. When base supply or lateral supply has a spare, they get it within 48 hours.
- C. Get a spare within 24 hours or raid WRSK.

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

Not asked here.

6.2 Personnel Surveyed:

E-4
E-4
Captain
E-5
E-5
E-7
Captain
Major

SITE VISIT SURVEY SUMMARY
COMPOSITE FORM

SITE LOCATION VISITED:

Base 2

DATE OF VISIT:

February 12, 1986

UNIT(S) VISITED:

Aviation Maintenance Squadron

RANK OF POINT OF CONTACT:

Captain

I. GENERAL

1.1 Base Visited and Date:

Base 2 - February 12, 1986

1.2 Unit Visited:

Aviation Maintenance Squadron

1.3 Rank of Point of Contact:

Captain

1.4 Types of Systems/Equipment:

Radio Equipment ARC-164
Ground beacon TPN-27A
Ground Support Equipment
Simulators

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Mostly R/R black boxes and send to the Depot.
Very limited box and card repair.

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

Both. Mostly on-equipment.

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Not usually.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

Mostly go/no-go BIT. Does not isolate to failure causes. Manual troubleshooting is used.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Most systems do not have this capability.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

No experience

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Low failure rate - hard to keep maintenance proficiency. 20% increase in time.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

30% - repair their own cables and connectors.
Have pin tools; make own harnesses.

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

None.

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

5%

4.5 Does Temperature Contribute to the Maintenance Actions:

20% outside maintenance with increased time due to cold weather (less than 30 degrees).
No increase in hot (greater than 90 degrees) weather.

4.6 Does Humidity Contribute to the Maintenance
Actions:

Not here.

4.7 Other Impact Areas Identified:

None.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to
Perform Maintenance:

Resources are all local. 10-15 minutes to
obtain TOs and tools.

5.2 Location of the Area to Record Maintenance Actions
and Time:

Record locally - no impact.

5.3 Impact of Facilities in Terms of Adequate Space to
Perform Maintenance:

No impact - adequate space for maintenance.

5.4 Lighting Level to Perform Maintenance:

Good lighting and maintenance.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

TE being reduced over time. Required TE is readily available.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Must look up tool and test equipment requirements to perform maintenance due to the low frequency of actions.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Too many special tools for particular uses. Spend a lot of time hunting for the right tool. Must look up in the T.O. Tools are sufficient and easy to get once identified.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

Obtainment of Spares is the biggest time driver.

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

3 - Phillips

6.2 Personnel Surveyed:

Captain
E-7
E-9

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 3

DATE OF VISIT:

March 3, 1986

UNIT(S) VISITED:

Tactical Control Squadron

RANK OF POINT OF CONTACT:

Lieutenant

I. GENERAL

1.1 Base Visited and Date:

Base 3 - March 3, 1986

1.2 Unit Visited:

Tactical Control Squadron

1.3 Rank of Point of Contact:

Lieutenant

1.4 Types of Systems/Equipment:

TPS-43
Radios
Computers

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Generally R/R assemblies and black boxes. R/R cards and modules in computer equipment and some radars.

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

Both -- work on assemblies on-equipment and within assemblies in the shop

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

- A. Yes - do a good bit of repair to components. Don't want to go to depot because response time is so long.
- B. Do some R/R of ICs from boards

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

BIT good for go/no-go indication. Further troubleshooting is a manual operation

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

TPS-43 has good redundancy. Most maintenance done while system is still operational.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. Often have exercises in NBC gear. Time is three times as long with a lot of agony
- B. Some experience -- maintenance time is 3-4 times as long

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

- A. Lot of waveguide problems which we had to diagnose. General diagnosis is the biggest problem.
- B. Typical repair 4-5 days; 80% of that time due to supply problems

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 50% -- a mobile system with a lot of connect/disconnects
- B. 15-20% cables/connector problems in computer equipment
- C. 25% -- flex cable is a big problem

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. Computer memory problem with every power surge
- B. 30% power supply related problems
- C. P.S. are minimal problems - 3%

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- A. 50% -- mostly with newer personnel. Preventive Maintenance causes additional failures. PM done once a week. Should be more selective.
- B. 10% maintenance induced
- C. 5%
- D. 20-25%
- E. 20%

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. Repair time 50% longer in cold weather less than 30 degrees
- B. Wind greater than 20 mph -- wait til it subsides (10-15% more time)
- C. Cold (less than 30 degrees) takes 3-4 times as long

4.6 Does Humidity Contribute to the Maintenance

Actions:

Moisture creates quite a problem in electronic systems. Causes quite a bit of intermittents which are hard to troubleshoot

4.7 Other Impact Areas Identified:

- A. Form 349 into AF 66-1 system is misleading
- B. Reduce PM is possible
- C. Alignment is a problem at times -- align until it works, not to specs
- D. Use manual trial and error troubleshooting

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Resources in shop away from main equipment.
Maybe 10-15 minutes to get

5.2 Location of the Area to Record Maintenance Actions and Time:

Record actions across the street. 15-30 minutes additional time.

- A. Recorded information is misleading!
- B. Record data on 349 as soon as possible

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Little impact -- adequate space available

5.4 Lighting Level to Perform Maintenance:

Good lighting conditions

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

T.E. generally available and works well. When it does go down -- it stays down. Hard to get spares for T.E.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

- A. Most T.O.s are adequate. Some are very poor though and have to use trial and error (maybe 10%). T.O.s kept in shop away from the equipment. Good people coming out of training
- B. Tech Data is atrocious in computer area -- wrong specs; lengthy procedures
- C. High turnover -- big training problem

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

No contribution noted

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

- A. Have some spares but not all. It takes a long time to get a spare.
- B. Bench stock 30%; local supply approximately 1 hour (40%); depot at least a week (30%)
- C. 1-4 days to get spares (radio equipment)

- D. Have no spare cards for some equipment so
R/R components to effect repair

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

- 1 - Phillips
- 1 - External Hex Head

6.2 Personnel Surveyed:

Lieutenant

E-4
E-4
E-6
E-5
E-5
E-6
E-4
E-4
E-6
E-7
E-6
E-8

SITE VISIT SURVEY SUMMARY
COMPOSITE FORM

SITE LOCATION VISITED:

Base 4

DATE OF VISIT:

March 4, 1986

UNIT(S) VISITED:

Tech Training School

RANK OF POINT OF CONTACT:

Civilian

I. GENERAL

1.1 Base Visited and Date:

Base 4 - March 4, 1986

1.2 Unit Visited:

Tech Training School

1.3 Rank of Point of Contact:

Civilian

1.4 Types of Systems/Equipment:

TPS-43	FPS-93
GPN-20	GPN-12
GPN-22	TPN-19
Airport Surveillance Radar (ASR)	
Precision Approach Radar (PAR)	
FPN-62	

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

A Training Site - no equipment maintained on a regular basis. Personnel have many years of experience maintaining fielded systems and equipment.

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

N/A

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

N/A

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

- A. 75% BIT to faults
- B. BIT good for go/no-go; then manual troubleshoot for actual failure.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

- A. Definitely, when the system has the capability.
- B. 70% amber; 30% red failures and maintenance

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. No experience
- B. 2.5 times as long
- C. No experience
- D. 5 times as long -- some jobs are impossible

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

75% of maintenance is troubleshooting. Need better indication of what is wrong. But experience is the only thing which really helps.

TO's could be better -- impossible to have all the information though.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 75%
- B. 70%
- C. 30%
- D. 30%
- E. 35%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. 30%
- B. 10%
- C. 10%

Equipment very sensitive to power. Field generated power much better than commercial power. Newer equipment more susceptible to electro-static discharge (ESD) problems.

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- | | |
|---|--------|
| A. 10% | F. 20% |
| B. 3% | G. 20% |
| C. 5% | |
| D. 35% | |
| E. 30%; Mostly in doing preventive maintenance (PM) | |

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. 2.5 times as long at less than 30 degrees
- B. 3 times as long at less than 30 degrees
- C. 2 times as long at less than 30 degrees
- D. 2 times as long at less than 30 degrees
- E. 4 times as long at less than 30 degrees, at less than -20 degrees, 5 minutes out

and 15 minutes in (factor of 4 just there)

4.6 Does Humidity Contribute to the Maintenance Actions:

- A. Yes -- adds 10% to time when it is hot (greater than 90 degrees) and humid
- B. Average humidity 90% here. Causes corrosion of connectors and components. Harder to perform maintenance and generates more failures

4.7 Other Impact Areas Identified:

None

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

N/A here

5.2 Location of the Area to Record Maintenance Actions and Time:

N/A here

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

N/A here

5.4 Lighting Level to Perform Maintenance:

Need good light to perform electronic maintenance

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

- A. Yes - TE is usually not available when it's needed
- B. CY-6718/UPM-132 IFFSIF Tester is never available. It's always in the shop. Calibration requirement is every 90 days and it takes that long to get one back!

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

- A. Yes -- don't follow the T.O. -- use experience
- B. T.O.s are basically good and used
- C. Count on experience more than the T.O.s
- D. T.O.'s are not adequate -- wrong part numbers, stock numbers and terrible theory of operation

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

No Comment

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

No comment here -- no spares required through this organization. Other groups responsible

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

6 - Phillips
1 - Single Slot

6.2 Personnel Surveyed:

E-6
E-6
E-4
E-7
E-7
2 Others -- did not catch rank

SITE VISIT SURVEY SUMMARY
COMPOSITE FORM

SITE LOCATION VISITED:

Base 5

DATE OF VISIT:

March 5, 1986

UNIT(S) VISITED:

Aviation Maintenance Squadron

RANK OF POINT OF CONTACT:

Captain

I. GENERAL

1.1 Base Visited and Date:

Base 5 - March 5, 1986

1.2 Unit Visited:

Aviation Maintenance Squadron

1.3 Rank of Point of Contact:

Captain

1.4 Types of Systems/Equipment:

Radio ARC-164
Communication
Ground Support Equipment
Satellite communications ARC-171 and others

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Generally R/R black boxes from the system. Do own maintenance on the black boxes.

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

40% on-equipment; 60% shop.

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

- A. Change components if think they have the capability - takes too long to get parts from the depot.
- B. Not authorized to R/R components but they do anyway.
- C. Do replace components if not a multi-layer board.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

- A. BIT is good in some systems; non-existent in others.
- B. BIT records a lot of false readings.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes, when the equipment has it. Most equipment does not!

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. Some are trained in NBC gear to where it has no impact.
- B. No experience.

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

- A. Spares availability
- B. TO content - need more detail and schematics
- C. Need more emphasis on accessibility and removeability.
- D. Too many screws on units and of different types (counted 8 types on one 10" x 8" unit)

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 10% - Coax cables in particular
- B. 3% - very small
- C. 40% - wiring problems

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

(No comment)

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

(No comment)

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. Cold weather (less than 30 degrees) 2 times as long.
- B. 25% increase greater than 100 degrees
- C. Time doubles in cold weather (less than 30 degrees)
- D. below zero - use buddy system and manpower doubles.

4.6 Does Humidity Contribute to the Maintenance
Actions:

- A. Yes it does - significantly
- B. High humidity adds 50%
- C. Humidity causes corrosion and shorting.
Adds 10-15% in time.

4.7 Other Impact Areas Identified:

- A. CY6718-UPM-137 IFFSIF Tester is a big
maintenance problem.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to
Perform Maintenance:

Shop within 10-15 minutes of equipment.

5.2 Location of the Area to Record Maintenance Actions
and Time:

Record maintenance locally.

5.3 Impact of Facilities in Terms of Adequate Space to
Perform Maintenance:

Adequate space - no impact

5.4 Lighting Level to Perform Maintenance:

Good lighting level.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Generally good and available; New Fluke meter 8025A will not work under 32 degrees Fahrenheit - a big problem.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

- A. TO's in the next shop 10-15 min. to get.
- B. TO's need schematics to be good.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

- A. 9/64" allen wrench not in standard set. Kept with crew chief (one only!). He's usually in meetings.
- B. Too many different types of fasteners (screws) on the same unit.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

- A. Yes - lack of spares causes more component troubleshooting and replacement.
- B. destroy 1 in 10 cards is worth the cost of delay for a spare.

30 minutes to obtain spares across the building

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

- 1 - High Torque
- 2 - Phillips

6.2 Personnel Surveyed:

E-5
E-8
E-4
E-7
E-6
E-4
E-4
E-4

SITE VISIT SURVEY SUMMARY
COMPOSITE FORM

SITE LOCATION VISITED:

Base 6

DATE OF VISIT:

March 6, 1986

UNIT(S) VISITED:

Information System Squadron

RANK OF POINT OF CONTACT:

Chief Master Sargent

I. GENERAL

1.1 Base Visited and Date:

Base 6 - March 6, 1986

1.2 Unit Visited:

Information System Squadron

1.3 Rank of Point of Contact:

Chief Master Sargent

1.4 Types of Systems/Equipment:

AFSATCOM - GSE-44, TSE-88 (small 44)
ARC-171 Radios
AN/FPS-77 Weather Radar

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Perform O & I level maintenance

2.2 Is Repair: Performed On-Equipment or at a Local Site Facility:

On-equipment R/R box
Locally R/R component 50%

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Average frequency of maintenance 10 times a month. Mostly minor -- R/R lamp and fuses

Perform O and I level maintenance activities.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Compared to External Test Equipment and Manual Methods:

Fairly good BIT; less than 30 minutes on GSE-44 to isolate failures. ARC-171 radio is 20-year old technology; takes 10 hours to bench check

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes for GSE-44
No for radios

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

None

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

- Not enough spares
- Lot of PM actions -- too much!
- Reduce paperwork. Forms 264 (ESR) & 349 (66-1) are redundant
- 65% PM actions on the FPS-77
- Massive # of screws which are never needed

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

35-40% -- multi-pin connectors are too easy to pull out. BIT does not cover cables -- big time user

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

10-20%

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

Minimal - about 5%

4.5 Does Temperature Contribute to the Maintenance Actions:

- 95% maintenance in sheltered area
- 5% outside, twice as long outside with wind chill below zero
- Weather radar 65% inside, 35% outside
- 2 times as long at greater than 100 degrees

1.5 times at less than 30 degrees

4.6 Does Humidity Contribute to the Maintenance
Actions:

2 times as long when greater than 100 degrees.
Humidity and moisture cause a lot of problems.
About 15% of problems

4.7 Other Impact Areas Identified:

Redundancy in equipment. Red downtime is approximately 30%. Average downtime is 6 hours. Lot of pride in work, "any moron can R/R it." Rely too much on BIT/FIT. Won't go to wires/cables. Weather changes cause an increase in maintenance frequency.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Maintenance personnel and tool area 10 minutes away from equipment site.

5.2 Location of the Area to Record Maintenance Actions and Time:

Paperwork is a problem; 5 hour job takes 3 hours in paperwork; job control application; form 349; ESR form; AFCC Form 56; input to MIMIX; order a part; research/order; look up T.O., supply forms, etc. Paperwork adds about 2 hours to task time.

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Lack of adequate facilities and space. Very crowded conditions. Little tabletop area.

5.4 Lighting Level to Perform Maintenance:

Poor lighting level to do electronic maintenance

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Common TE is at equipment site. Some TE is 10 minutes away

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Basically good -- T.O.s used often

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Most tools are at equipment site. Others are 10 minutes away

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

If On Base - 1/2 hour to obtain
Not On Base - lateral support, average 3-1/2 hours; if not, goto Depot support at Hill AFB - 1 week to obtain

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

- 1 - Phillips
- 2 - Hex

6.2 Personnel Surveyed:

- E-5
- E-6
- E-4
- E-8

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 7

DATE OF VISIT:

March 10, 1986

UNIT(S) VISITED:

Tactical Air Control Wing
Electronic Combat Squadron

RANK OF POINT OF CONTACT:

Captain (TACW)
Chief Master Sargent (ECS)

I. GENERAL

1.1 Base Visited and Date:

Base 7 - March 10, 1986

1.2 Unit Visited:

Tactical Air Control Wing
Electronic Combat Squadron

1.3 Rank of Point of Contact:

Captain (TACW)
Chief Master Sargent (ECS)

1.4 Types of Systems/Equipment:

TPS-43
Communications Systems
Radios (ARC-164 and others)

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Remove and replace (R&R) black boxes

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

On-equipment, little locally

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

At times when can't readily get a spare and have a red condition

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

Not impressed with present BIT capability.
Relies on experienced judgement. BIT good for go/no-go indications.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes, when the system has the capability.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. Used overseas - 20% added time
- B. Great loss of mobility, bulky gloves -- some maintenance is impossible (small components and knobs)
- C. Doubles time -- some things are impossible

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Cables and connectors.
Lot of PM together with maintenance induced problems.
T.O. accuracy and depth.
Spares availability and turn-around time.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 25%
- B. 40%
- C. 35%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. Power spikes cause multiple maintenance problems
- B. 10%-15% of maintenance results from power supplies and sources
- C. 10% after adding protective devices to the computers

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- A. 15% -- most of it unavoidable
- B. 70%
- C. 35%
- D. 5%
- E. 40%

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. 25% of maintenance exposed to the elements. Varies by system; adds 25% time at less than 30 degrees
- B. Wind chill less than 0 degrees -- adds another 20%
- C. 10% increase in time due to hot weather greater than 90 degrees
- D. 80% effectiveness in hot weather
- E. 40% more time in cold (less than 30 degrees); 2 times as long with wind chill less than -10 degrees

F. 25% increase in heat greater than 90 degrees

4.6 Does Humidity Contribute to the Maintenance Actions:

- A. High humidity (greater than 90 degrees) creates problems, even in "controlled" rooms and shelters. 10% increase in time
- B. 5% increase in time due to humidity
- C. 20%
- D. 20%

4.7 Other Impact Areas Identified:

None

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Resources in the shop. Takes time to move them to the equipment (15 - 20 minutes)

5.2 Location of the Area to Record Maintenance Actions and Time:

Locally in the shop

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Good space. No impact.

5.4 Lighting Level to Perform Maintenance:

Low lighting level

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

T.E. is adequate and easy to get

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Adequate -- some T.O.s need more accuracy

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

No comment-- so assume good tools and no impact

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

Definitely. Lack of spares is a reason to do more maintenance on the unit

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

3 - Phillips
1 - Allen
2 - Hex

6.2 Personnel Surveyed:

Major
E-6
E-5
E-9
E-8
E-8

SITE VISIT SURVEY SUMMARYCOMPOSITE FORMSITE LOCATION VISITED:

Base 8

DATE OF VISIT:

March 11, 1986

UNIT(S) VISITED:

Information Systems Group

RANK OF POINT OF CONTACT:

Major

I. GENERAL

1.1 Base Visited and Date:

Base 8 - March 11, 1986

1.2 Unit Visited:

Informatin Systems Group

1.3 Rank of Point of Contact:

Major

1.4 Types of Systems/Equipment:

Satelite Communications - AN/GSE-44
GPN-12; GPN-22;
NPN-14 (mobile antenna)
Weather Radar
Nav Aids Radios

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Satelite Equipment - can do all maintenance
99.5% of Depot capability
All: Do not work on antennas; Call for Tech
assist from Norton AFB - (Local)
Radar/Radio - R/R black boxes.

2.2 Is Repair Performed On-Equipment or at a Local
Site Facility:

Mostly on-equipment lot of redundancy in
systems 95-98%
Radar/Radio - do go to component level at
times
Satelitte Communication Systems - lot of
redundancy.

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

R/R some tubes and components at times.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

Good BIT capability on most newer equipments.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes - often on radars and satellite communications.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. Once a quarter
10% of maintenance actions are impossible
factor of 3 increase in time due to heat,
sight impairment, physical exhaustion.
2 input of impossible to do some maintenance
factor of 3-4 times as long.

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Troubleshooting to find the cause of a malfunction. Much more time spent in diagnostic than actual repair; Must think the systems approach in troubleshooting. Bent pin on a cannon plug is hardest to straighten and repair.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 20% of system outages due to wires/cables
10% due to pin/connectors opens & shorts
30% total
- B. 35%
- C. 80-85%
- D. 50%
- E. 10%
- F. 20%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. Power surge takes out crypto - equipment everytime. Built own P/S protectors for some equipment.
- B. 40% of maintenance due to P/S problems. Some chips are destroyed when touched with fingers.
- C. No experience with power problems.
- D. None
- E. Own stable P/S for computers.

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- A. 10% - varies depending upon system
- B. 3-4%
- C. 50%
- D. less than 10%
- E. 25-35%
- F. 5%
- G. 1-2%

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. Most satellite systems maintenance done in protected shelter 4-5% exposed to element
- B. Some systems 0% exposed; some 100% 110-115 degrees in the summer with low humidity 10-15% increase in time due to heat
- C. Windchill less than 20 degrees with snow takes 9 times as long "Hell" of a time with cables.
- D. Ave. cold is 3-4 times as long. Greater than 95 degrees - repair time is one and one half times.
- E. 1/8 of maintenance done outside. Two times as long at less than 32 degrees; greater than 95 degrees - 1.25 times as long.
- F. N/A

4.6 Does Humidity Contribute to the Maintenance

Actions:

- A. Low humidity - must add humidity in the computer. Still 8-10% faults and maintenance time due to moisture.
- B. 5% problem dealing with moisture - can corrode cable connectors.
- C. None

4.7 Other Impact Areas Identified:

- A. Ave. 50 min. to diagnose
Ave. 2 hours to repair
- B. Ave. 30 min. to diagnose
Ave. 1 hour to repair

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

- A. 50% of the times it takes half an hour to get a technician to the problem
- B. Radio receivers are 5 miles from the base on a mountain.

5.2 Location of the Area to Record Maintenance Actions and Time:

Away from main equipment (Ave 1/2 hr to record)

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Good facilities

5.4 Lighting Level to Perform Maintenance:

Generally good. Poor lighting to perform some maintenance internal to the systems.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Mostly use common TE - works good and generally available.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

- A. Tech data is mostly good but could be updated more often; Not enough data to go to component level.
- B. Training is good. Lot of problems with TOs of newer equipment. Spend a lot of time completing AFTO 22s.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

No.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

- A. Spares ordered from Depot take a couple of days if ordered on priority
Log Air - called "lost air".

- B. If supply problem - repair takes a month;
no supply problem - repair takes a day;
80% of maintenance have supply problems.

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

3 - Phillips
1 - Bristol - Spline
1 - Allen
2 - Slotted

6.2 Personnel Surveyed:

Lieutenant
Major
E-7
E-8
E-5
E-6
E-9

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 9

DATE OF VISIT:

March 12, 1986

UNIT(S) VISITED:

Information Systems Group

RANK OF POINT OF CONTACT:

Lieutenant

I. GENERAL

1.1 Base Visited and Date:

Base 9 - March 12, 1986

1.2 Unit Visited:

Information Systems Group

1.3 Rank of Point of Contact:

Lieutenant

1.4 Types of Systems/Equipment:

Radars:	GPN-12	GPN-22
	FPN-63	
Radios		
IFF		

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

R/R boxes on the equipment -- usually

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

Both -- R/R on-equipment; maintenance on the equipment in the shops

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Yes -- will repair locally if feel they won't get timely service from the depot (about 50%)

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

Most newer equipment has extensive BIT but cannot always rely on it.
No BIT in radios -- use manual techniques and troubleshooting only

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Definitely -- most these systems have redundant capability. One side goes down and the other picks up. Perform maintenance in place.
Uptime rate is greater than 95%; more than 75% of maintenance is during amber conditions.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. No experience
- B. 3-4 times longer. About 60% of maintenance is impossible
- C. Double time easily -- impossible to R/R components
- D. Doubles the time -- some maintenance is impossible
- E. 3-1/2 times longer

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Delay of maintenance until allowed to get access to the equipment (90% of the time delays)
Cables and connectors. Especially loose or bent pins
25% CND rate
Lack of technical data on internal workings of the equipment

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 20-25%
- B. 45% -- GPN-22 is a connector nightmare
- C. 30%
- D. 30%
- E. 35%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. 60% of faults due to power related problems (with the computers)
- B. 70%
- C. 5% in radios

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- A. 50% of actions result in additional maintenance
- B. 50%
- C. 25%
- D. 10%

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. 75% longer at wind chill less than 0 degrees
- B. 2-1/2 times longer. With GPN-20, a 10 minute action took 1 hour
- C. 3 times longer at less than 30 degrees
- D. twice as long at less than 30 degrees
- E. 1 1/2 times longer at greater than 100 degrees

4.6 Does Humidity Contribute to the Maintenance
Actions:

- A. 20% of problems due to humidity. (50% of waveguide problems are caused by humidity)
- B. 25%. Corrosion is the biggest problem.

4.7 Other Impact Areas Identified:

Can't get access of the tools to the components. Usually guess about applying correct torque.
Pressurized waveguides would cut down on the humidity problem
Average 2-1/2 hours MTTR -- ranges from 1 to 4 hours

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Shops are close but away from the systems.
10-20 minutes to get there

5.2 Location of the Area to Record Maintenance Actions and Time:

Record actions back at the shop area

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Adequate shop facilities

5.4 Lighting Level to Perform Maintenance:

Good lighting for general maintenance. Not sufficient for detailed internal repair

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Most TE is manual. Readily available. Little time impact

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Training is good. Every T.O. is different. You must get use to each one. Takes time to figure out how each one is put together and where the information is.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Have problem getting correct tools. Often have to make do and use a substitute

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

Problem with spares is the reason they perform maintenance below the box or assembly level

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

5 - Phillips
2 - Single Slot
1 External Hex

6.2 Personnel Surveyed:

Lieutenant

E-6

E-6

E-5

E-5

E-3

E-3

E-6

E-5

E-3

SITE VISIT SURVEY SUMMARY
COMPOSITE FORM

SITE LOCATION VISITED:

Base 10

DATE OF VISIT:

March 21, 1986

UNIT(S) VISITED:

Aviation Maintenance Squadron

RANK OF POINT OF CONTACT:

Chief Master Sargent
Chief Master Sargent

I. GENERAL

1.1 Base Visited and Date:

Base 10 - March 21, 1986

1.2 Unit Visited:

Aviation Maintenance Squadron

1.3 Rank of Point of Contact:

Chief Master Sargent
Chief Master Sargent

1.4 Types of Systems/Equipment:

Ground communications and ground ATE
ARC-164
Collins Radio

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Perform Org and Intermediate type tasks.
Would perform depot tasks if trained!

2.2 Is Repair Performed On-Equipment or at a Local
Site Facility:

Both

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Do a lot of repair themselves due to a problem getting spares. Do not feel comfortable going to 2-level maintenance because of this.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

Newer equipment has go/no-go BIT. Will not isolate to failed units.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Most do not have this capability

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

No experience

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Not enough training and tech data to actually accomplish repairs.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

15% - worst is connector repair in the cold! Make their own cables and harnesses. Save and re-use connectors.

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

Negligible (3 - 5 %)

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

Very low; 3-5%

4.5 Does Temperature Contribute to the Maintenance Actions:

Note an increase of maintenance activity and time at change of seasons. More failures and harder to track and isolate.

Antenna work is outside. Time doubles at less than 30 degrees; doubles again in wind chill below -20 degrees. Warm inside every 15-20 min.

4.6 Does Humidity Contribute to the Maintenance
Actions:

Humidity problems with older equipment. Not
so much with newer equipment. 10-15% increase
in time in general.

4.7 Other Impact Areas Identified:

Hard to get spares and component parts and
must NRTS out. More new units going
commercially supported - not by blue-suiters.
"Every AFTO 349 is a lie!" 5% increase in
time because of insect problem.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to
Perform Maintenance:

Everything local and handy. Very near to the
equipment. Little impact on time.

5.2 Location of the Area to Record Maintenance Actions
and Time:

Record actions locally - little impact on
time.

5.3 Impact of Facilities in Terms of Adequate Space to
Perform Maintenance:

Good area to perform repair; lots of cleared space.

5.4 Lighting Level to Perform Maintenance:

Good lighting.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Have mostly special TE. Hard to maintain, calibrate, and repair.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Training and documentation not to depth wanted. They perform maintenance beyond with a significant impact on time due to trial and error methods.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Quality of tools is poor. They often break when in use. 20% increase in maintenance time

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

Yes! Hard to get most spare items. 1 hour for local supply; 2 days lateral; Up to 2 years to get ATE spare parts. Lengthy time to get spares from depot. (3 months)

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

- 1 - Phillips
- 1 - Common slot

6.2 Personnel Surveyed:

E-9
E-9

Most of other technicians away on short notice

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 11 (part 1 of 2)

DATE OF VISIT:

March 24-25, 1986

UNIT(S) VISITED:

Electronic Combat Squadron
Tactical Control Group

RANK OF POINT OF CONTACT:

Civilian (ECS)
Lieutenant

I. GENERAL

1.1 Base Visited and Date:

Base 11 - March 24-25, 1986

1.2 Unit Visited:

Electronic Combat Squadron
Tactical Control Group

1.3 Rank of Point of Contact:

Civilian (ECS)
Lieutenant (TCG)

1.4 Types of Systems/Equipment:

Ground radars and communications
Seek Igloo systems - FPS-117, FPS-93
ARSR-3 (FAA system).

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

New Maintenance concept - all contractor
maintenance. RCA has the contract. AF must
give 7 days notice to visit the sites.

2.2 Is Repair Performed On-Equipment or at a Local
Site Facility:

On-equipment. Do not know much beyond this
because contractor performs all maintenance.

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Unknown for contractor performed maintenance.
Thought so though.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

High level of BIT speced in newer systems.
Limited history has proven it to be good.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

No redundancy generally in communication gear supported by the AF.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. No NBC gear practiced here.
- B. Yes it is practiced. 50% is impossible;
3 times longer on average.

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

No blue suit maintenance of ground radar.
Some blue suit maintenance of communication gear. Now do more contract management than maintenance.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. Cables a problem in communications gear - especially small coax. It breaks in the cold.
- B. 5%
- C. 10%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. 20%
- B. 5%
- C. 15%

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- A. 10%
- B. 10%
- C. 20%

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. Even though most work is done in the radomes, the cold still gets through. Must wear gloves and protective gear. Two to three times longer. Some to - 70 in radomes.
- B. Double time at less than 30 degrees
- C. Triple time at less than 30 degrees

4.6 Does Humidity Contribute to the Maintenance
Actions:

Humidity contributes to the cable/connector problem. Also 1-2% of problems of its own. 30% of maintenance time devoted to humidity and moisture.

4.7 Other Impact Areas Identified:

80% schedules maintenance - 20% unscheduled.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Did not visit remote sites.

5.2 Location of the Area to Record Maintenance Actions and Time:

Did not visit remote sites.

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Did not visit remote sites.

5.4 Lighting Level to Perform Maintenance:

Did not visit remote sites.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Mostly standard (common) TE. No real impact to maintenance time.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

- A. Validity and accuracy of TOs is very bad. Rely on own experience and judgement.
- B. Base actions on experience and use the TO for guidance only.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Poor quality. Seems many tools shatter in the cold. 10-15 minutes to get a new tool. (good excuse for a break.)

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

Spares supply point is local. Most critical spares are stored at the operating sites. Other spares are flown out as needed. Bad weather delays flight and arrival of the spare. (1 - 2 days)

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

3 - Phillips

6.2 Personnel Surveyed:

Civilian
E-8
Lieutenant
E-7
E-7

SITE VISIT SURVEY SUMMARY
COMPOSITE FORM

SITE LOCATION VISITED:

Base 11 (part 2 of 2)

DATE OF VISIT:

March 24-25, 1986

UNIT(S) VISITED:

Information System Wing
Information System Squadron

RANK OF POINT OF CONTACT:

Captain (ISW)
Major (ISS)

I. GENERAL

1.1 Base Visited and Date:

Base 11 - March 24-25, 1986

1.2 Unit Visited:

Information System Wing
Information System Squadron

1.3 Rank of Point of Contact:

Captain (ISW)
Major (ISS)

1.4 Types of Systems/Equipment:

FPN-22; GPN-20; FPN-62
ASR and PAR Radars
Radios - GRC 171; GRC-212
ROCC AN/FYQ-93

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

Moving toward a new concept - R/R black box only. No component or internal work. (Not being accepted very well)

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

All done on-equipment. Still doing some internal work as new maintenance concept is being phased in.

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Yes, in transition.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

BIT good for newer systems. Also good for older systems as a go/no-go test. Then use manual troubleshooting.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes, when the system has redundant capability.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

- A. 10% is impossible. Other takes 10 times as long.
- B. 2 to 3 times as long in good conditions. (after adjusting for the cold)

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

The cold makes everything brittle. Cables and tools the biggest problems.

50% corrective; 50% preventive.

75% preventive; 25% corrective.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- | | | | |
|----|--------|----|-----------------|
| A. | 25-30% | F. | 10-20% |
| B. | 20% | G. | 25% |
| C. | 20% | H. | 50%-ROCC System |
| D. | 40% | I. | 50%-ROCC System |
| E. | 10% | J. | 50%-ROCC System |

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- | | | | |
|----|----------------------------------|--------|---|
| A. | 50% | F. | 15% |
| B. | 40% | G.H.I. | No pwr problems in ROCC |
| C. | 60% | | |
| D. | 10% | | Add power protection circuitry to critical systems. |
| E. | 30% when using commercial power. | | |

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- | | | | |
|----|-----------------------|----|------------|
| A. | 10% | F. | 25% |
| B. | 10% | G. | 15% |
| C. | 5% | H. | 10% - ROCC |
| D. | 40% - even during PM. | I. | 20% - ROCC |
| E. | 20% - even during PM. | J. | 25% - ROCC |

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. 50% of maintenance is out in the elements.
- B. Cannot work below -40 degrees; -20 is considered good weather at some sites. At least 5 times longer at -20. About 2 and 1/2 times as long between 0 and -20.
- C. 2 to 3 times longer when wind chill less than 0.

D. Wind chill less than -20, 2 to 3 times longer; at -35 degrees, 4 to 5 times longer.

E. 2 times as long at -20 degrees

4.6 Does Humidity Contribute to the Maintenance Actions:

A. 5%

B. not much - 0%

C. 35% - mostly due to corrosion.

4.7 Other Impact Areas Identified:

Seems solid state getting more sensitive to power problems. Especially computer equipments.

Finding a good ground is really difficult in the perma-frost. Poor grounds present faults. Not much frostbite - people quickly learn to look for it.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Response time to get to the failure is a lot longer in the extreme cold when less than 0 degrees. Send people out from Elmendorf if necessary to assist in maintenance with 1 to 2 days delay time.

5.2 Location of the Area to Record Maintenance Actions and Time:

locally in the ROCC

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Not taken to maintenance area.

5.4 Lighting Level to Perform Maintenance:

Not taken to maintenance area.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Most TE is common or standard. Little impact on maintenance time. Used only in sheltered area.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

TOs are always questionable. Use them for guidance only. Not enough information for detailed maintenance performance. Emphasis on training. Willing to have lower readiness in exchange for well trained personnel. Not uncommon to add 30-40 min. for training.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Tools not built for the artic cold. Shatter a lot of tools. 10-15 minutes to get a new tool. Do not like going with the lowest bidder. 9/64" allen wrench is not in the standard allen set! Maintenance chief keeps it on his key ring.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

Commercial Manuals do not have AF part numbers so must use a cross reference.

Spares are still a problem here. Have to special supply by air to the remote sites with 1 to 2 day delay.

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

- 4 - Phillips
- 1 - Bristol
- 2 - external hex.
- 1 - single slot

6.2 Personnel Surveyed:

- Captain
- E-8
- Civilian
- Major
- E-7
- E-5
- E-3
- E-6
- E-9
- E-7
- E-7

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 12

DATE OF VISIT:

October 28-29, 1986

UNIT(S) VISITED:

Information Systems Squadron

RANK OF POINT OF CONTACT:

Captain

I. GENERAL

1.1 Base Visited and Date:

Base 12 - October 28-29, 1986

1.2 Unit Visited:

Information Systems Squadron or Communication Squadron

1.3 Rank of Point of Contact:

Captain

1.4 Types of Systems/Equipment:

GPN-20 Airport Surveillance Radar
FPN-62 Precision Approach Radar
Various Radios - GRC-211 and others

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

R/R black boxes; limited internal maintenance. Send failed units to the depot.

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

Mostly on-equipment. Radio repair and some radar assembly repair in the local shop area.

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Yes when spare items are not readily available.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

BIT is poor in most equipment. The newer systems have better BIT. Cables are never included. BIT does not include fault isolation - a go/no-go indication only.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes, when enabled to get access to the equipment.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

Definitely increases time (at least double) but not a whole lot of experience.

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Lack of Spares; lengthy diagnostic time; CND rates.

Downtime of the radios was reduced significantly when PM was reduced.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

- A. 5-10%
- B. 30%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

- A. 20%
- B. 20%

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

- A. 10-15%
- B. 20%

4.5 Does Temperature Contribute to the Maintenance Actions:

Not much of an impact noted. They are accustomed to the cold.

4.6 Does Humidity Contribute to the Maintenance Actions:

High level of corrosion due to humidity.

4.7 Other Impact Areas Identified:

Too much P.M. actions. Don't handle it unless it's broke.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Resources 10-15 minutes from the system. Adds this time to each maintenance action.

5.2 Location of the Area to Record Maintenance Actions and Time:

Record actions in the shop area 10-15 minutes away from the system.

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Very crowded conditions. Little table top area for work. Increases maintenance time and induced problems.

5.4 Lighting Level to Perform Maintenance:

Poor lighting for electronic maintenance.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

TE is available but takes 10-20 minutes to set up for use.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Additional maintenance time is used for training opportunities.

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Tools generally in good condition. No impact.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

50% of the time - 2 hours to get spare from local supply.
35% go lateral - use Federal Express takes 1 and 1/2 to 2 days.
15% go to depot - 1 to 2 weeks minimum.

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

2 - External hex
1 - Phillips

6.2 Personnel Surveyed:

Captain
E-7
2 others in the shop

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 13

DATE OF VISIT:

November 25, 1986

UNIT(S) VISITED:

Communications Squadron (old ISS)
Aviation Maintenance Squadron

RANK OF POINT OF CONTACT:

Captain (CS)
Captain (AMS)

I. GENERAL

1.1 Base Visited and Date:

Base 13 - November 25, 1986

1.2 Unit Visited:

Communications Squadron (old ISS)
Aviation Maintenance Squadron

1.3 Rank of Point of Contact:

Captain (CS)
Captain (AMS)

1.4 Types of Systems/Equipment:

Ground Radars - GPN-20 ASR;
FPN-62 PAR
Radios - GRC-211 and others
Ground Support Equipment

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

R/R black boxes and PC boards; Some PC board
test and repair.

2.2 Is Repair Performed On-Equipment or at a Local
Site Facility:

Both on-equipment and in the local shop
facility.

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Performs maintenance on both black boxes and boards. Sends problems to the depot but tries hard to limit this.

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

BIT is better on newer equipment but trusted for go/no-go indication only. Manual procedures for fault isolation. Need more test points in some systems. The systems rely too much on BIT which does not always work well.

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Yes when the system has this capability and access to the equipment is authorized.

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

NBC gear slows down the process. Limited experience - doubles the time.

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Obtainment of Spares; Cable and connector problems; PC board seating.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

A.	20-30%	F.	30%
B.	20-30%	G.	25%
C.	30%	H.	90%
D.	25%	I.	75%
E.	35-40%	J.	70%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

A.	50%
B.	10% with radios
C.	30%
D.	5%
E.	5%
F.	10%

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

A.	50%	E.	40%
B.	15-20%	F.	50%
C.	30%	G.	50%
D.	25%	H.	5%

4.5 Does Temperature Contribute to the Maintenance Actions:

- A. Wind chill less than -35 is impossible.
- B. Doubles time between 0 and 32 degrees.
- C. Do some standard maintenance actions at first cold weather (eg. re-connect all cables).
- D. 15% increase in workload in the cold.

4.6 Does Humidity Contribute to the Maintenance
Actions:

Humidity causes problems in seating of PC boards. 20% of actions is re-seating of boards. Problem with ocean salt in the air here.

4.7 Other Impact Areas Identified:

Cycling the systems (bring it down and then back up) always seems to create a fault. Additional failures and maintenance actions noted at each change of season.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Right outside the system locations. A short time (2 minutes) to get to the equipment.

5.2 Location of the Area to Record Maintenance Actions and Time:

Record actions in maintenance area close to the equipment. Minimal impact on time.

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Good facilities and adequate table top work space.

5.4 Lighting Level to Perform Maintenance:

Good general lighting level. Could be better for detailed electronic board troubleshooting and repair.

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Most of the TE is available and easy to get to. Some TE is a bear to work. One PC board tester needs 24 hours to warm up and stabilize. Most of their TE requires time to warm up but not this much.

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

New people know the basics pretty well but need more practical exposure to equipment. Most diagnostics are based on experience. Take time to show new people how it's done (20% increase in time).

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

Tools are in good condition. Minimal impact. Takes a few minutes to get a tool you forgot. 5% increase in time.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

- A. Big time consumer. 10% of the time spares are available on base and takes 30 minutes to obtain. Most of the time (70%) go to lateral base supply. This takes 2 days in a Red condition and 4-5 days in amber condition. 20% of the time use the depot at Sacramento and it takes a week (7 days).
- B. Base supply building 1/4 mile away and takes one hour to get a spare if there is a priority need.

- C. 20% local spares take 30 minutes; 60% lateral supply take 2-3 days; 20% go to depot and take anywhere from 1 week to 1 year.

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

- 5 - Phillips
- 1 - Quick Disconnect
- 1 - External hex
- 1 - Torx (star shaped)

6.2 Personnel Surveyed:

1916 CS

- Captain
- E-6
- E-7
- E-8
- Lieutenant Colonel
- E-5

509 AMS

- Captain
- E-5
- E-5
- E-3
- E-7
- E-7
- E-7

SITE VISIT SURVEY SUMMARY

COMPOSITE FORM

SITE LOCATION VISITED:

Base 14

DATE OF VISIT:

March 3, 1987

UNIT(S) VISITED:

Communications Squadron
Tactical Fighter Wing

RANK OF POINT OF CONTACT:

Captain (CS)
Chief Master Sargent (TFW)

I. GENERAL

1.1 Base Visited and Date:

Base 14 - March 3, 1987

1.2 Unit Visited:

Communications Squadron
Tactical Fighter Wing

1.3 Rank of Point of Contact:

Captain (CS)
Chief Master Sargent (TFW)

1.4 Types of Systems/Equipment:

ASR/PAR -- GPN-22
TPS-43
Radios

II. MAINTENANCE POLICY

2.1 General Maintenance Concept Followed at the Site:

R/R assemblies and black boxes

2.2 Is Repair Performed On-Equipment or at a Local Site Facility:

Mostly on-equipment. Some maintenance on the black boxes at the shop area

2.3 Is Repair Performed Beyond the General Maintenance Concept Described Above:

Will perform maintenance in the black box if a red condition exists and a spare is not readily available

III. DIAGNOSTIC TECHNIQUES AND OPERATIONAL IMPACTS

3.1 Amount of Time Built-In-Test (BIT) is Used to Identify and Isolate Malfunctions as Opposed to External Test Equipment and Manual Methods:

Good go/no-go BIT in equipment but most problems in the interfaces between boxes and to the outside world -- not internal to the box

3.2 Is Maintenance Performed While the System is Still Operational in a Redundant or Degraded Capability:

Definitely. Most of the systems/equipment have redundant capability

3.3 Amount of Time Spent Performing Maintenance in NBC Gear and the Impact on Maintenance Performance:

No experience here. Not practiced.

IV. MAINTENANCE AREAS AND CONCERNS

4.1 Most Common Maintenance Problems:

Cable and connector problems. They are hard to find and require quite a bit of maintenance time. Reasons for problems include expansion/contraction due to hot and cold weather and aging of the equipment. Too much PM actions.

4.2 Percentage of Maintenance Dealing with Cables, Cabling, and Connectors:

A.	60%	E.	10%
B.	80%	F.	10%
C.	15%	G.	60% -- Everyone agrees; twice as long to diagnose and fix
D.	30%	H.	45%

4.3 Percentage of Maintenance Dealing with Power Supplies and Power Sources:

A.	90%	E.	33%
B.	50%	F.	25%
C.	20%	G.	25% -- Bad commercial power in Florida
D.	20%		

4.4 Percentage of Maintenance Induced Effect on Malfunctions:

A.	5%
B.	1%
C.	15%
D.	5%

4.5 Does Temperature Contribute to the Maintenance Actions:

Temperature does not vary that much here

4.6 Does Humidity Contribute to the Maintenance
Actions:

Not a big impact here. Some corrosion due to humidity but not a whole lot. However, failure rate doubles in the rainy season

4.7 Other Impact Areas Identified:

A lot of preventive maintenance. Agreement of 10 hours PM to 1 (one) hour corrective maintenance. If it works, don't fix it. Accessibility to connectors and components is a big problem.

V. LOGISTICS IMPACTS

5.1 Impact of Base Layout - Location of Resources to Perform Maintenance:

Maintenance location away from the system site. 10-20 minutes to get there

5.2 Location of the Area to Record Maintenance Actions and Time:

Record maintenance actions back at the maintenance shop area

5.3 Impact of Facilities in Terms of Adequate Space to Perform Maintenance:

Facilities are adequate

5.4 Lighting Level to Perform Maintenance:

Good general purpose lighting. Poor for detailed electronics work

5.5 Does the Availability of Test Equipment Contribute to the Maintenance Action Time:

Most TE is common. Usually available and working. Not too much of a maintenance problem

5.6 Does the Adequacy of Training and Technical Documentation Contribute to the Maintenance Action Time:

Not too much impact. On-the-job experience is better than technical school once you have the basic knowledge

5.7 Does the Availability and Condition of Tools Contribute to the Maintenance Action Time:

A significant number of tools are not of sufficient quality (soft wrenches, poor heat treatment, etc.) Declining quality in the last 8 years. Tool warranty program is helping somewhat but not achieving best goal.

5.8 Does the Availability of Spares Contribute to the Maintenance Action Time:

Definitely! Average delay time several (3-4) hours from base supply; 3 to 7 days from lateral; months from the depot (not usually used). Bench stock is fuses, light bulbs, knobs. Spares sufficiency is a big problem.

VI. OTHER DATA COLLECTED

6.1 Responses to the Common Screw-head Question:

- 2 - Phillips
- 1 - Single Slot
- 3 - Allen
- 2 - External Hex

6.2 Personnel Surveyed:

CS

Captain

E-7

E-5

E-6

E-4

E-4

E-4

E-4

TFW

E-9

E-7

E-5

E-5

E-5

APPENDIX G SAMPLE DATA FROM AIR FORCE MAINTENANCE
DATA COLLECTION SYSTEMS

Sample data from Air Force maintenance data collection systems is on file with Project File - 2338022J.