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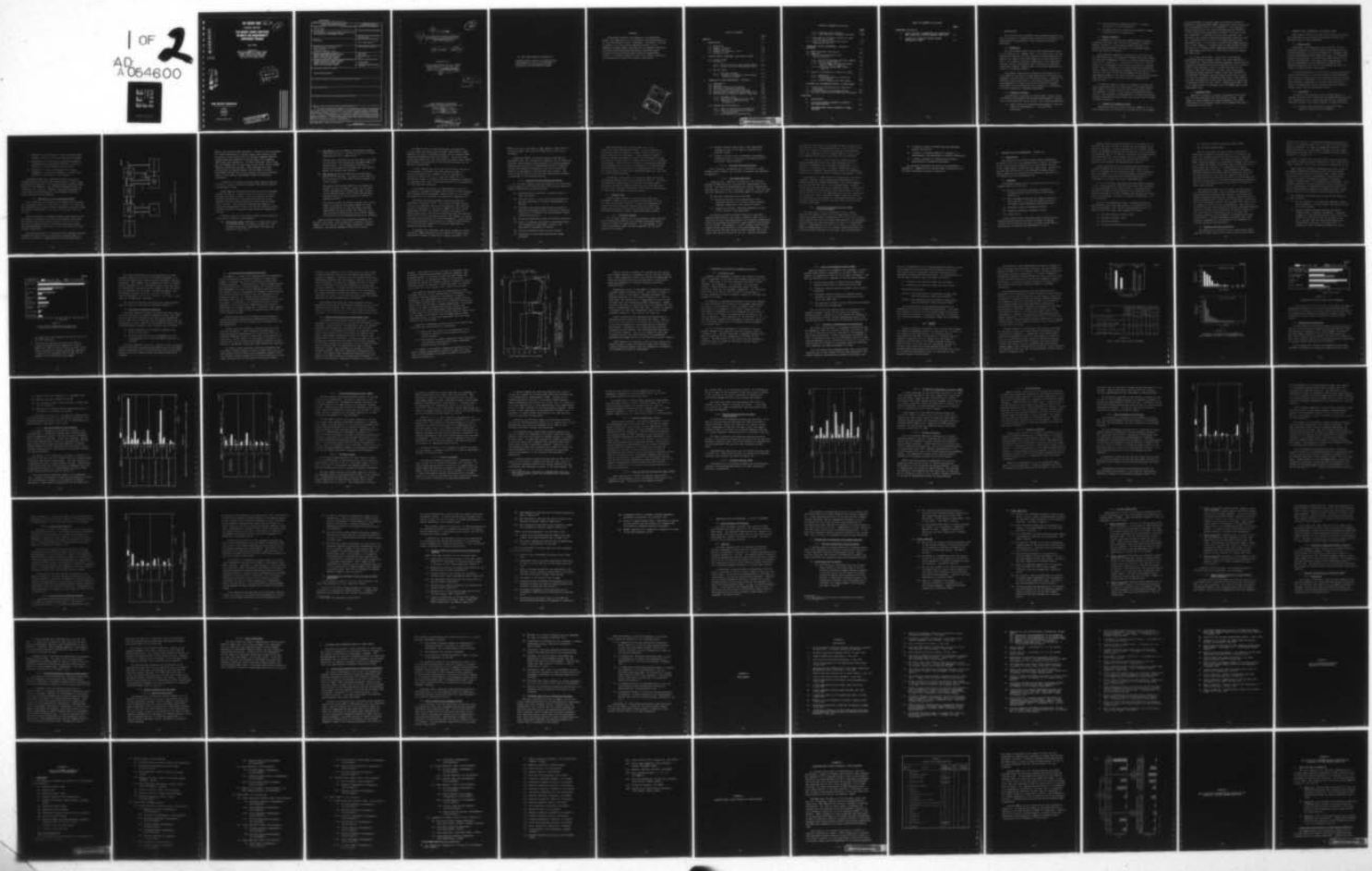

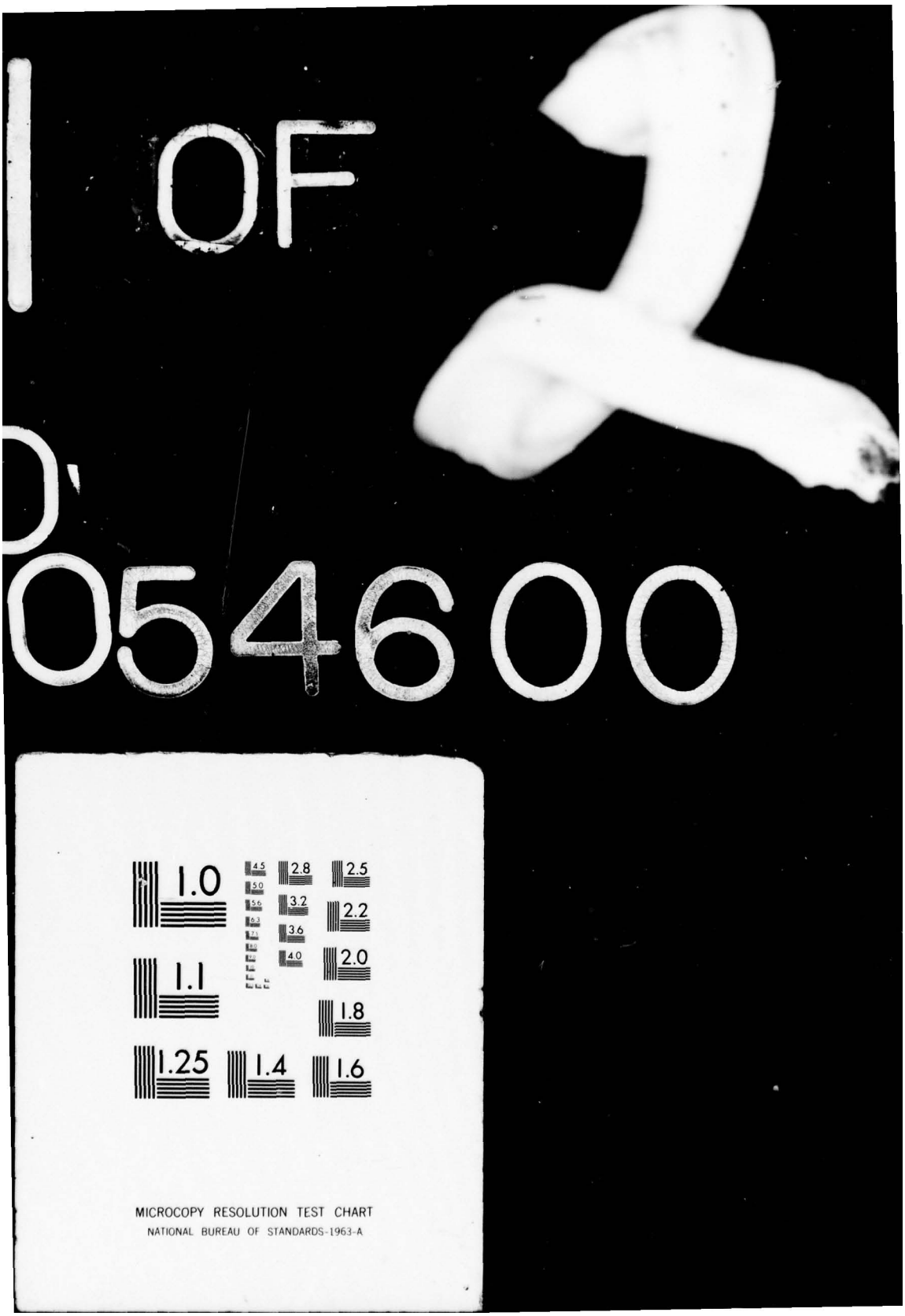
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INTERIM REPORT

B-58 AIRCRAFT AVIONIC SUBSYSTEMS RELIABILITY AND MAINTAINABILITY IMPROVEMENT PROGRAM

June 1965

Prepared for
SERVICE ENGINEERING DIVISION (WRNE)
WARNER ROBINS AIR MATERIEL AREA
ROBINS AIR FORCE BASE, GEORGIA
under Contract AF 09(603)-46796

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This report presents the progress of an engineering project for improvement of the reliability and maintainability of the B-58 aircraft avionic subsystems. The report, covering 15 months of a 2-year effort expended primarily on the AN/APN-113 Doppler Radar subsystem and the AN/ALQ-16 Defensive Electronics Countermeasures equipment, identifies major sources of failure and describes corrective engineering actions. It further identifies areas that require corrective action which are outside the scope of this project.

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ABSTRACT

This report presents the progress of an engineering project for improvement of the reliability and maintainability of the B-58 aircraft avionic subsystems. The report, covering 15 months of a 2-year effort expended primarily on the AN/APN-113 Doppler Radar subsystem and the AN/ALQ-16 Defensive Electronics Countermeasures equipment, identifies major sources of failure and describes corrective engineering actions. It further identifies areas that require corrective action which are outside the scope of this project.

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1. INTRODUCTION

This interim report documents the progress made during the first 15 months of a planned 2-year project for reliability and maintainability improvement of the B-58 aircraft avionic subsystems.

1.1 Background

The B-58 weapons system is the newest operational bomber in the Strategic Air Command (SAC). It is also one of the most advanced SAC weapons, and its performance characteristics are superior to those of any other bomber in the SAC ready-alert force. The complex electronic subsystems of this supersonic aircraft allow a three-member crew to perform the necessary navigation, bombing, communication, and aircraft defense functions of the bombing mission.

Of paramount importance to mission effectiveness of the B-58 bomber is reliable in-flight operation of the electronic equipment, and the ability of SAC ground crews to complete the necessary ground maintenance in the shortest possible time. This dependence of mission success on electronic equipment reliability and maintainability has resulted in a continuous Air Force program for equipment improvement.

1.2 Purpose of Project

As specified in Contract AF 09(603)-46796, Warner Robins Air Materiel Area (WRAMA) has retained ARINC Research Corporation to perform, within certain areas, the following assignments:

(1) Apply reliability engineering principles to identify areas for improvement in the B-58 avionic subsystems.

(2) Provide special engineering effort to improve reliability and maintainability.

(3) Recommend specific subsystem improvements through corrective-action engineering.

1.3 General Approach

In carrying out this project, ARINC Research utilizes procedures that have been successfully applied in similar efforts on other U. S. Navy and Air Force aircraft. In essence, these procedures are based on a detailed failure study and reporting technique.

ARINC Research engineers, located with the aircraft at the Bomb Wings and at the equipment-repair facilities, report all details of equipment failure by a coding system especially prepared for computer use. Appropriate failure and logistic details on the equipment under study are recorded on punched cards. When a representative failure sampling is completed, special computer programming techniques are utilized to reduce the data, in order to determine equipment faults and the improvements required for better reliability and maintainability. This also provides an efficient means for supplementing AFM 66-1 data.

In addition, special reports, in support of corrective-action engineering efforts coordinated by the ARINC Research main office, are being written on the engineering details not amenable to coding. Flight testing of prototype modifications, test procedure investigations, and other engineering liaison activities are also carried out in the field to assist Air Force personnel.

1.4 Summary of Progress to Date

Theoretical mean time between failure (MTBF) value has been computed for all subsystems, as required by the contract,

including AN/APN-113 Doppler Radar and AN/ALQ-16 Defensive Electronic Countermeasures (DECM) equipment on which corrective-action engineering effort is in progress.[36] The sampling of observed failures and the computer programming for reduction of the observed data regarding this phase of the project have been completed.[61] Observed data have been evaluated continuously, and selected engineering-improvement tasks are under way. Reference should be made to the WRAMA Doppler Radar Improvement Plan -- it has been initiated under WRAMA auspices, and is based largely on findings made by ARINC Research during execution of the Doppler Radar Temperature Measurement Plan.[6] The improvement plan serves to consolidate efforts on Doppler set improvement.

As of this report date, 1 final and 10 preliminary Engineering Change Proposals (ECP's) have been formulated on the AN/APN-113. Engineering analyses regarding various test and alignment procedures affecting the reliability of the airborne Doppler Radar equipment, but not within the scope of the contract, have been submitted. To date, eight Preliminary Engineering Change Proposals (PECP's) have been submitted on the AN/ALQ-16 equipment, and prototype modifications on three of these are presently undergoing flight tests. Other PECP's have been incorporated, or are being considered for fleet-wide incorporation without flight tests. Doppler Radar PECP's are to be flight tested in accordance with the WRAMA Doppler Radar Improvement Plan.

1.5 Documented Work

Appendix A contains a listing of documented work effort that has been submitted under the contract to date. Highlights of these documents are given throughout this report. References to the documents listed in the appendix are made by a superscript in the text.

2. PROJECT SCOPE, PROCEDURES, AND SPECIAL TASKS

This section defines the scope of the project, discusses the reliability data collection and analysis effort, and describes special tasks undertaken.

2.1 Project Scope

Subsystems, Line Replaceable Units (LRU's), and subassemblies assigned for ARINC Research investigation by the contracting agency are listed in Appendix B. Assigned tasks include determining observed MTBF values for the subsystems; observed and predicted, or theoretical, MTBF values for the LRU and subassemblies; corrective action engineering on the LRU and subassemblies of the AN/APN-113 subsystem and AN/ALQ-16 equipment; and study of the problem of AN/APN-113 "unlock at high altitude, over water".

Field Engineering and liaison services have been provided. Special tasks related to other projects have been performed: collection and reduction of data to assist with Project "Fly-Rod" evaluation; measurement of Search Radar Indicator Console (ICU) operating temperatures; and reliability modeling to assist in determining the most fruitful areas for ASQ-42(V) Weapons Control System improvement efforts.

2.2 Procedures

In general, the procedures used by ARINC Research to improve B-58 electronic reliability and maintainability include the consideration of all conditions pertaining to equipment operation, repair, and logistic support, as indicated below:

(1) Technical data required for repair and other logistical support of the equipment

(2) Component specifications in those instances where present reliability is below acceptable standards

(3) Performance of electrical or mechanical assembly redesign where a desirable reliability cannot be achieved by simple component substitution

(4) Evaluation of testing procedures and testing equipment to the extent necessary to assure full reliability potential of the equipment

As problem areas were identified through use of the reliability data collection and analysis effort, PECP's were developed and submitted. The change proposals submitted were limited to the AN/APN-113 and AN/ALQ-16 equipments only, as outlined in the contract. However, engineering analyses on other items and recommendations for extending corrective actions have also been submitted.

2.2.1 Reliability Data and Analysis Effort

Data collection and analysis is an essential and necessarily continuous activity in this type of project. To keep the data collection and analysis effort responsive to project needs, the nature of the effort is reviewed and modified from time to time.

Since all phases of equipment handling and operation must be studied to determine true failure and support conditions, each phase of the B-58 avionic equipment flow cycle within the Air Force was monitored in the data-collection program. The general equipment flow cycle for the B-58 bomber is illustrated in Figure 2-1.

To avoid duplication of effort and effect maximum economies, available Air Force failure information generated under the direction of AFM 66-1, Organizational and Field Maintenance

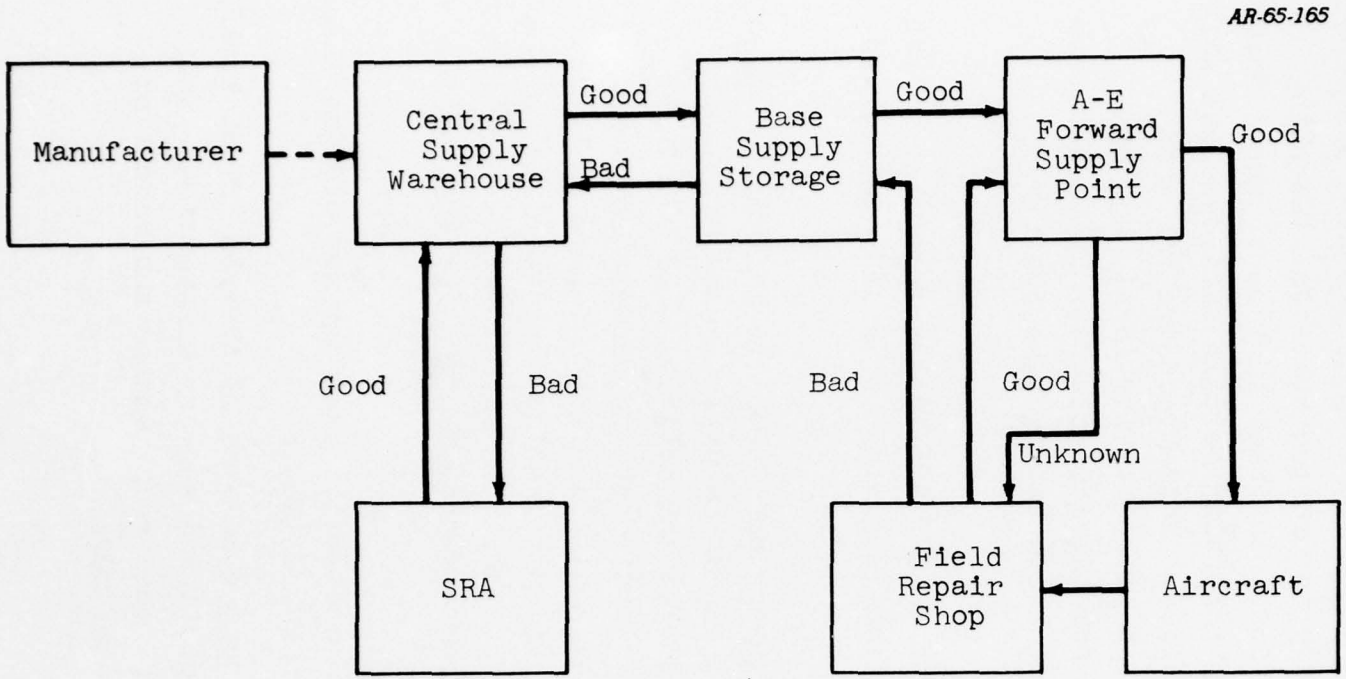


FIGURE 2-1

B-58 AVIONIC EQUIPMENT FLOW CYCLE

Manual, was utilized where possible. Because of the requirement for close correlation of cycling times, particularly in the recovery of the aircraft after the flight, standard AFTO-200 series forms were modified to provide space for inserting additional time information. In other instances, where there was no standard form for reporting certain data, special ARINC Research forms were provided. This procedure was used particularly for Special Repair Activity (SRA) equipment maintenance actions and for the logistic flow-cycle documentation, so that support requirements might be positively identified.

Information recorded on SAC-126 flight-report forms was utilized to augment information gained from AFTO-200 series failure-report forms.

ARINC Research engineers monitored the flow of equipment through the SRA and documented the relationship of reported failures and repair actions. The activities of all ARINC Research engineers were coordinated and directed by the company's central office; analysis of data inputs provided task direction. The detailed investigations required to satisfy the established criteria of the data-collection effort provided excellent in-progress cross-checks for engineering actions.

The data collection and analysis effort was divided into three distinct levels of surveillance:

(1) The Pretest Phase consisted of a rapid "first look" at existing detail and summary information. The findings established requirements and reporting methods for later work.

(2) Test Phase I was the general surveillance program, covering a period of 7 months and about 1315 flights (approximately 8227 flight hours).

Detailed data collected during Test Phase I provided the information for determining equipment MTBF and failure modes. The relationship of failure to operational procedure was established, and logistic support information was obtained.

(3) Test Phase II was the modification surveillance portion of the program. It began at each base with the installation of the first modified assembly for flight testing.

The general surveillance method in this phase is similar to that for Phase I, except for the additional requirements of knowing the exact location of all modified items at all times and providing detailed reports for each instance of failure or suspected failure.

The scope of Phase II is much narrower than that of Phase I, because of the smaller number of items under surveillance; but the precision reporting requirements are much greater for Phase II, since more detailed information for use in direct support of corrective-action engineering efforts is necessary.

Special monthly reports were prepared throughout the period of the Phase I data collection to provide a periodic summary of B-58 aircraft flight times, frequency of system complaints, and general equipment condition or status.

The AFM 66-1 Data Collection System, as augmented by special format and reporting procedures instituted by ARINC Research, was used to provide raw data for all observed MTBF computations required under the contract. These data were obtained at Bunker Hill and Little Rock Air Force Bases (AFB's) and represent the operation of the entire B-58 fleet for the period of observation.

Initial computations were made from failures reported by the aircrews -- airframe hours were used as a base. (A failure is defined as a complaint that is followed by corrective action; that is, it does not result in a "No Malfunction Found".) Airframe hours were adjusted by subsystem to compensate for those flights initiated with the subsystem not in fully operable condition.

To increase the accuracy of observations in the B-58 environment, a sample of elapsed time indicator (ETI) readings was obtained from 19 subsystem timers in each of 49 aircraft. The results of this analysis are presented in Appendix C.[61]

Predicted (theoretical) MTBF's were determined and submitted in November 1964.[36] The utility of these figures can be fully realized only when the method by which they are derived is understood. Theoretical MTBF's for the selected subsystems and LRU's of the B-58 avionics were based on a simple parts count; part failure rates were used which provide them with "built in" averaging factors, with respect to stress and operating conditions in a field environment. These failure rates were extracted from studies on a weapons system similar to the B-58 and are judged to be the most applicable of currently available data.

In general, the confidence that may be placed in a given theoretical MTBF determined by this method is related to the complexity in terms of quantities of parts contained. The

MTBF's for units containing a large number of parts tend to be more accurate than those for simple units with only a few parts.

Theoretical MTBF's can provide gross guidelines for performance that can reasonably be expected; but in deficiency analysis, since detailed identification is required, greater emphasis must be placed on engineering analysis of specific circuit and component performance, and strict statistical analysis of part-removal data becomes less valuable. The value of the theoretical analysis and engineering assessment is described in the following section.

2.2.2 Corrective-Action Engineering Effort

In this work, emphasis has been placed on the "scientific method" approach, which establishes the following ordering of steps to facilitate a problem solution:

(1) Identification of problems in general terms of cause and effect

(2) Detailed study to collect and relate appropriate data and determine all factors contributing to a problem

(3) Performance of engineering analysis by means of practical experiments and/or theoretical study and computation to determine the relationships between contributing factors

(4) Proposing appropriate action for problem correction

(5) Trials of proposed solutions on a prototype basis with appropriate observation, records, and quantitative assessment of results

(6) Further refinements based on trial results

(7) Formulation of fleet-wide engineering change proposals

The reliability-data effort points the way for corrective-action engineering effort. In the beginning the reliability data are especially useful through step (1) and part of step (2) as given above. Then corrective action involves concern for intimate detail that is beyond the scope of practical accomplishment in terms of failure data collection and analysis. When detailed solutions to engineering problems are developed, the collection and analysis of reliability and maintainability data can assist with quantitative evaluation of success during the test and observation steps (5), (6), and (7), as previously defined.

Information found useful in assisting corrective-action engineering effort covers a wide variety of sources. Air Force documentation, ARINC Research field and laboratory experimentation, reports by other contractors, and interviews with Air Force and contractor personnel, both civilian and military, at bomb wings and depots have proven useful.

2.3 Special Tasks

Special tasks related to other projects have been performed. These include collection and reduction of data to assist with Project "Fly-Rod" evaluation; measurement of Search Radar ICU operating temperatures; and reliability modeling to assist in determining the most fruitful areas for ASQ-42(V) Weapons Control System improvement efforts.

2.3.1 "Fly-Rod" Program

The "Fly-Rod" program was an environmental study conducted by San Antonio Air Materiel Area (SAAMA) during Test Phase I study of the B-58 by ARINC Research. At the request of the contracting agency, ARINC Research supported the "Fly-Rod" program in two areas:

(1) Maintain separate Test Phase I data acquisition programs on each of the special "Fly-Rod" test aircraft groups.

(2) Conduct a special test to determine environmental conditions within a particular high-failure LRU of the Search Radar Subsystem.

2.3.1.1 "Fly-Rod" Reliability Data

Basic "Fly-Rod" information and a tabulation of ARINC Research data on MTBF's for "Fly-Rod" equipments are presented in Appendix D.

2.3.1.2 ICU Temperature Test

A special test, conducted in support of the "Fly-Rod" program by ARINC Research, monitored the temperatures within the ICU. This LRU was instrumented with special temperature-sensing tapes at 40 selected component locations. The resulting data were delivered to the contracting agency in November 1964.

The ICU test objectives were as follows:

(1) Determine whether or not temperatures at the locations monitored in the units tested exceeded component temperature rating specifications.

(2) Compare the internal operating temperature levels of the "Fly-Rod" test group ICU's.

No specific overheat problems relative to applicable component specification were found. However, since it is in the nature of such tape measurements that component temperatures cannot be determined specifically, some components were singled out for further investigation. On the average, using rounded numbers within the resolution of the tape measurements, it was found that the "Fly-Rod" Group "A" ICU's operated 15F to 20F cooler than those in Groups "B" and "C". Several individual

locations in the Group "A" units were actually hotter (by as much as 25F) than corresponding places in ICU's for the other groups as a result of variation in cooling characteristics. In no case, however, were the temperatures at a level that would degrade the long-term stability of the components.

Since any amount of heat above the standard nominal ambient temperature does have a deteriorating effect on electronic components, any decrease in temperature can be expected to be beneficial. At higher temperature levels (relative to component rating) smaller values of temperature reduction will produce relatively greater improvement in MTBF.

Conversely, at lower level's of temperature (relative to component rating), larger temperature reductions result in smaller increments of MTBF improvement. The latter appears to be the case with the ICU's, on an average basis. However, individual units may have an air passage blocked, or variations in air passage flow-resistance, which could result in over-stress due to heat of some components that are not overstressed in other units. Also, secondary failure caused by overheat can continue to occur through air conditioner failures, unless automatic shutoff of the ICU coincident with air conditioner failure is provided.

2.3.2 AN/ASQ-42(V) Weapons Control System Reliability Model

The importance of the various parts of the complex AN/ASQ-42(V) weapons system, and the significance of its diverse problems, makes it imperative that a method be utilized which assures that available engineering manpower and engineering facilities will be most efficiently utilized in an improvement effort. ARINC Research has used as its method a mathematical model to demonstrate that by an ordered, definitive means, the following items, pertinent to the above, can be established:

(1) A realistic basis for predicting and assessing mission reliability

(2) A method to determine effects of proposed, or demonstrated, LRU improvement on mission reliability

(3) A common language for communications between engineering and operations personnel

The modeling procedures and results are presented in Appendix E. Suggestions for further areas of application of the model technique are given in Section 5.

3. CORRECTIVE ACTION ENGINEERING - AN/APN-113

3.1 Description

The function of the APN-113 Doppler Radar subsystem on the B-58 is that of a true ground-velocity sensor; it develops three voltage outputs proportional to the aircraft velocity in the longitudinal, transverse, and normal axes. The velocity data are fed continuously to the ASQ-42(V) Weapons Control System computer, which performs the necessary computations on the Doppler data for navigational use.

3.2 Approach

The general approach used in connection with work on the assigned tasks is as follows:

(1) Review all available historical information, including failure data collected in Test Phase I (Section 2).

(2) Check equipment operating and support conditions. (This was done in conjunction with execution of the Doppler Radar Temperature Measurement Plan.)

(3) Determine causes of equipment failures.

(4) Establish necessary corrective actions.

(5) Submit ECP's.

Certain APN-113 LRU's were specifically cited for reliability and maintainability effort; however, the general latitude of the task was such that all areas of the APN-113 were subject to analysis and improvement, or both.

During a period of familiarization with the APN-113, all available data were studied to obtain an understanding of the long-term problems. The data prepared by the aircraft vendor during the production period, and the results of the qualifying environmental test of the APN-113, indicated that many problems were associated with test equipment and test procedures. Interviews with the navigators and technicians using and repairing the equipment substantiated this opinion.

A more exact definition of problem areas was obtained by a careful research of all failure and repair data on ten APN-113 subsystems for a four-month period. This information, which was supplied to the contracting agency, indicated the general failure conditions and possible deficiencies in environment and testing for future investigations.[9]

A study of Material Improvement Packages (MIP's) supplied by the contracting agency indicated that excessive maintenance was being performed on the APN-113 LRU's. The technicians repairing the APN-113 at the SRA were interviewed so that a detailed analysis of initial findings could be made and materiel handling procedures, as related to material improvement, could be established.

Based on the foregoing actions, a general priority of investigative action was established in conference with the contracting agency. The order of investigative action, in terms of work unit items, was arranged as follows:

(1) Klystron Frequency Control (LRU)

(2) Frequency Tracker (LRU)

(3) Klystron Assembly

(4) IF Amplifier-Frequency Converter Subassembly

(5) Power and Signal Distribution Panel (LRU)

(6) HV Power Supply (LRU)

Since in all cases the level of data used was not sufficient to define the problem exactly, the items on the above list essentially stand for the functional loops with which they are associated. The Klystron Frequency Control (KFC), Klystron Assembly, the frequency reference cavity portion of the Power and Signal Distribution Panel (PSDP), and the HV Power Supply are included in the Transmitter Automatic Frequency Control (AFC) Loop. The Intermediate Frequency Amplifier-Frequency Converter (IFFC) subassembly constitutes the major portion of the receiver. However, some of the receiver-related functions are included in the AF-IF Amplifier LRU (circuits related to the ferrite single-sideband generator) and in the PSDP (primary power control and d-c vacuum tube heater power supply).

The Klystron Assembly is, of course, the major part of the transmitter function. Only the Frequency Trackers are essentially self-contained, functionally, in providing for signal acquisition and tracking. However, these functions are related intimately with the Waveform Converter in connection with data processing, and with the Coherency Test Unit in terms of judging the quality level of performance. Thus, when the possible influence of secondary failures and secondary degrading effects on a given LRU is thoroughly considered, relative to the other LRU in its functional loop, it is clear that attention cannot be limited simply to considering the above-listed LRU's. A similar statement can be made, with equal validity, regarding ground maintenance test equipment and airborne equipment and procedures.

3.3 Equipment Operating Statistics

The APN-113 is in operation at all times during flight and should supply correct data except during certain extreme

maneuvers of the B-58. During severe banking maneuvers, the offset of the APN-113 beams, due to the use of a fixed antenna, would be sufficient to cause an inoperable condition. (For specific details on the operational concept and the various operational profiles, see Air Force Technical Orders listed in the LOAP T.O. 1B-58A-01.)

A study of operational data and flight reports indicated that APN-113 failures usually resulted in a total loss of the Doppler function, rather than in partially degraded operation.

Eight types of complaint expressions were used in 94% of the Doppler complaints recorded at Little Rock and Bunker Hill AFB's during the period of this study. These include: "broke lock" (or unlock), "inoperative", "self-test bad", "broke lock dirty", "erroneous velocities", "erroneous voltage", "intermittent", and "inoperative at altitude". The relative importance of each complaint is shown in Figure 3-1, which is based upon 177 maintenance reports from Little Rock AFB and 184 maintenance reports from Bunker Hill AFB. These reports were filed in accordance with SAC Regulation 66-7.

The following conclusions were reached on the basis of the above reports:

(1) Of all complaints, the broke-lock complaint occurs most frequently: 52.5% at Bunker Hill AFB and 25.0% at Little Rock AFB.

(2) Marginal Doppler systems represent the second largest group of complaint categories. (Marginal systems are those which supposedly operate well when tested on the ground but do not function in the air.) Usually they are reported as inoperative, inoperative at altitude, or intermittent. A grouping of these categories accounts for 21% of

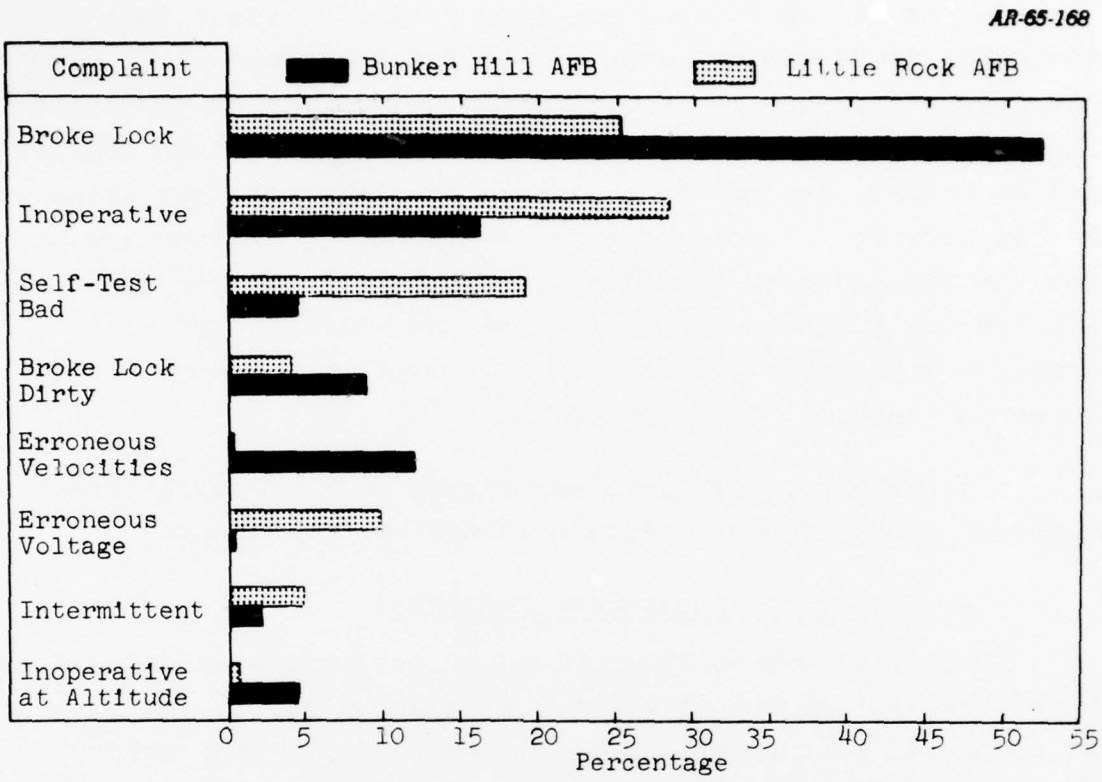


FIGURE 3-1

MAJOR IN-FLIGHT COMPLAINTS FOR THE APN-113 AT LITTLE ROCK AND BUNKER HILL AIR FORCE BASES

the Bunker Hill AFB complaints and 31% of the Little Rock AFB complaints.

(3) Dirty-unlock complaints are about one-sixth as frequent as simple-unlock complaints: 8.5% at Bunker Hill AFB and 4.9% at Little Rock AFB. These values include the erroneous-velocities complaint, a condition that precedes "dirty unlock" if the Doppler is not deactivated soon enough.

The above conclusions are only estimates since each navigator gives his own view of the failure symptoms; i.e., one failure symptom may generate several different complaint categories. For example, one navigator who finds his Doppler system inoperative at the beginning of the flight may issue an "inoperative" complaint and not attempt to use the system for the remainder of the flight. Another navigator, upon discovering the same condition, may test his system sometime afterward. If it then operates, as it may, he may issue an "intermittent" complaint.

The variety of problems associated with these failures made the study of other related subsystems mandatory.

3.4 Electrical Subsystem Conditions

Electrical system tolerances and deviations were found to have been the subject of several detailed studies, the latest of which had been conducted by the Operational Engineering Section (OES) of the 43rd Bomb Wing at Carswell AFB during the latter part of 1962. Results of this study were made available to ARINC Research engineers; they indicated the following:

(1) Minor deviations from assigned tolerances were noted in many tests

(2) No particular deviation was considered to be of such magnitude as to cause the APN-113 failures in evidence.

Although exceptions may occur, a review of the conclusions of various Air Force groups who evaluated the study (and ARINC Research experience) does not indicate any direct relationship between electrical system problems and Doppler performance problems.

3.5 Air Conditioner Subsystem Conditions

The APN-113, located in the unpressurized aft compartment of the B-58 aircraft, requires no internal cooling fans or blowers -- cooling fans would be ineffective during high-altitude operation. Cooling airflow is supplied under pressure by aircraft electronic cooling equipment and circulated over heat exchangers into each of the components requiring cooling. The design of the heat exchangers is arranged to avoid circulation of the cooling air directly over the components of the electronic circuits. It thereby avoids contaminating the assemblies with any dirt or loose particles present in the cool air supply. The design of the aircraft electronic cooling equipment is such that airflow temperatures are inversely proportional to aircraft engine rpm. Therefore, these temperatures vary over a range of 130F, as experienced by the APN-113 in the typical aircraft.

Forward cabin areas of the aircraft are maintained at relatively constant pressures and temperatures by complex regulating devices, but aft equipment must necessarily be more self-regulating.

Airflow levels are generally controlled by one or two means in the APN-113. Some components are maintained at a selected operating temperature by a flow-control valve and component temperature sensor; others have a less specific airflow level. In the latter, the only means of control is an orifice plate with an opening that permits sufficient cooling airflow to accommodate worst-case (high-temperature) operation.

The APN-113 major components (Klystron Transmitter and Electronic Package) mounted in the aft radome area have an airflow control, but the APN-113 major components (Ripple Filter and Receiver Antenna) mounted in the forward radome do not have them; they must rely on the maximum flow-control orifice.

Therefore, the diameter of the orifice must be large enough to permit equipment cooling at the highest temperature of cooling air applied, coincident with the highest ambient air temperature condition that can prevail. Because of this fixed orifice diameter, the operating temperatures for the Ripple Filter and Receiver Antenna are extremely low during high-altitude operation. Although similar conditions exist in both the filter and antenna, primary concern is for the antenna. The antenna circuits are much more sensitive to temperature variation than those of the filter and are thought to perform marginally in the low-temperature environment.

The Ferrite Modulators and their associated driver amplifiers (both part of the Receiver Antenna), as well as the critical radio frequency (RF) tuning of microwave detector mounts and intermeditate frequency (IF) interstage amplifier components, have been proposed as subjects for further study.

3.6 Doppler Radar Temperature Measurement Plan

Interviews with maintenance people indicated a lack of confidence in the capability of the aircraft electronic cooling equipment. Because of the low-confidence level, the Weapons System Manager established a program entitled "Fly-Rod" (Section 2.3.1) to determine the effects of increased cooling airflow rate changes on the reliability, in terms of mean flight time between maintenance actions, of selected high-failure LRU's of the ASQ-42(V). Although the APN-113 electronic package was included for study under the "Fly-Rod" program, all available history data indicated a lack of detailed knowledge of internal APN-113 temperatures at high altitudes. Therefore, because this knowledge was essential to ensure accurate analysis, additional temperature information was sought. The Doppler Radar Temperature Measurement Plan was submitted by ARINC Research, and permission was granted to install a multi-channel temperature recorder in a group of test

aircraft. The objective of the plan was to determine actual on-aircraft operating temperature conditions properly. The recording device, a 12-channel Century Recorder, Model 409, was installed in the pressurized cabin of the B-58 and connected by cabling to thermistor sensors attached to selected locations within the APN-113.[6] Tests were made on 4 aircraft for a total of 16 test flights, or 4 flights per aircraft.

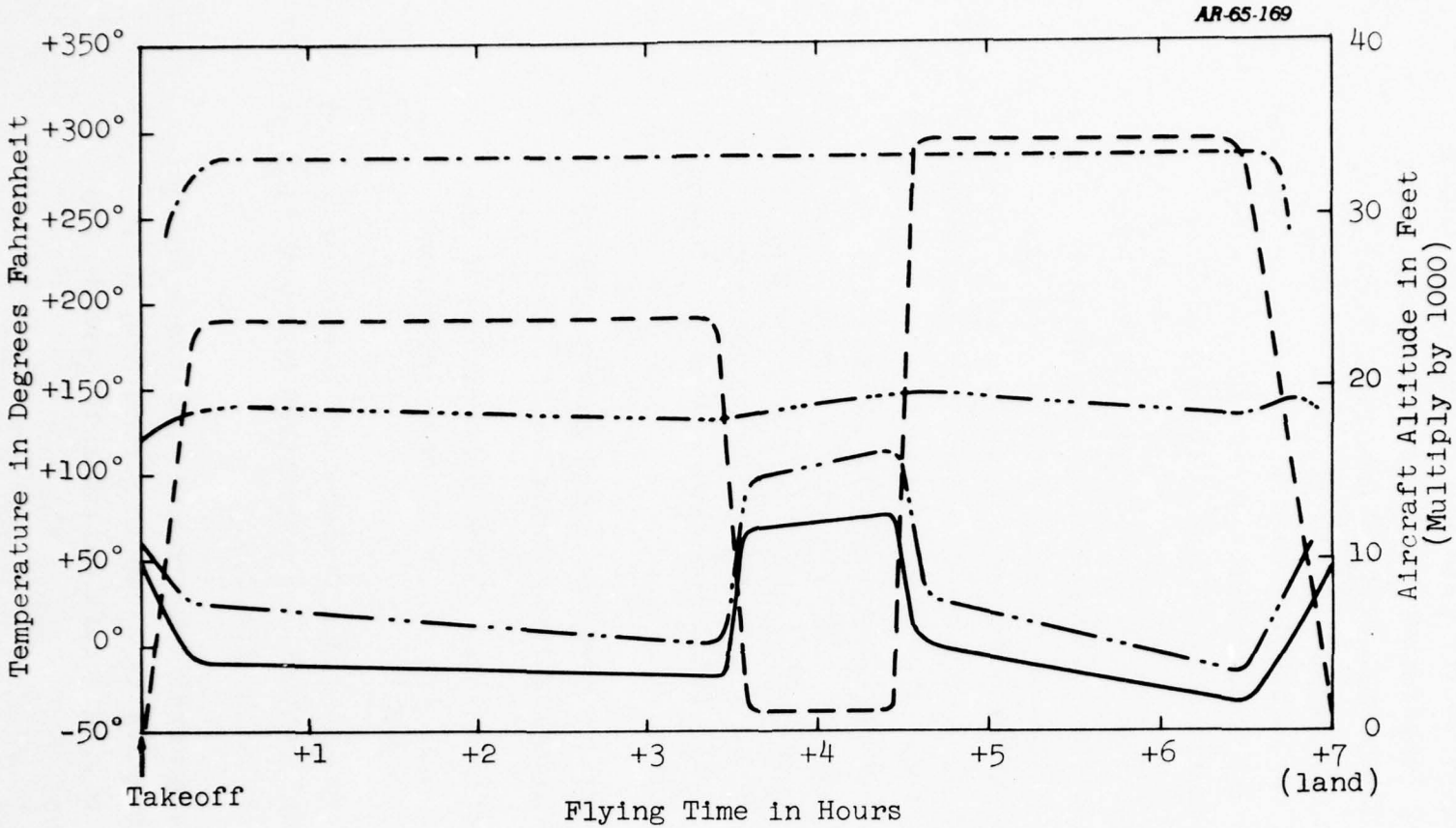
Test results indicated that the temperatures at high altitudes were too low for optimum APN-113 performance. Also, in cases of marginal alignment or adjustment of APN-113 components, the temperature deficiency would probably result in in-flight failures that could not be verified during ground tests, which are performed at higher temperatures. An interim report on the APN-113 temperature-recorder project was delivered to the contracting agency during December 1964.[38] A final report on this subject is planned after the flight tests are completed, in accordance with the WRAMA Doppler Radar Improvement Plan, in order that temperature data from these tests may also be included.

Generally, temperature problems noted in the APN-113 may be divided into the following two categories:

(1) Those directly related to the temperature of the cooling air supplied by the aircraft electronic cooling equipment

(2) Those related to higher temperature levels controlled by electrical heaters and associated thermostatic controls within the APN-113

A summary of the general temperature conditions in the APN-113 radome compartments is given in Figure 3-2, which shows the relationship of aircraft altitude to certain LRU operating temperatures.



Legend: ——— Cooling air temperature
— · — Klystron tube body temperature
—···— Component temperature in electronic package
—·—·— Component temperature in receiver and ripple filter
— — — Aircraft altitude

FIGURE 3-2

TEMPERATURE CHART FOR APN-113 RADOME COMPARTMENTS

Certain critical components of the APN-113 must operate with extreme stability to generate accurate velocity information. These components control the critical RF generating and detection processes and must be stabilized at a particular operating temperature to maintain required electrical characteristics.

Temperature control is performed by thermostatic-switch-actuated heaters in several places. This kind of control is used in a total of five LRU's: Frequency Trackers (3), Waveform Converter (1), and Ferrite Modulator (1). Four of these LRU's are maintained at a temperature that will always be higher than the surrounding ambient temperature. Temperature for the fifth is controlled only to the extent that will ensure a temperature no lower than +46F. A heater is required to maintain at least this temperature level in all flight instances, except for very-low-altitude operation.

Study of failure rates indicated high removal and no-malfunction-found rates for the above five LRU's. This, in turn, led to an analytical evaluation which showed that all of the five thermostatic control switches are relatively short-lived. Analysis of the failing switches revealed bimetallic active elements that performed switching action in an erratic fashion. The rate of closure for this type of switch is such that contact arcing is of undesirable magnitude and causes failure of the electrical contact elements.

ARINC Research has prepared a PECP that will replace the defective switch types with positive snap-action devices of a more satisfactory design from the standpoint of reliability and documented reliability performance.

3.7 Maintenance and Materiel Support Conditions

3.7.1 Wing/Base Level

Automatic test equipment is used in the testing of failed APN-113 components at the wing level Armament-Electronics (A-E) Shop. Flight-line or aircraft testing is performed by semi-automatic test equipment. In each case, the technician follows a fixed procedure and performs a group of tests planned to check out the equipment completely. The technician has little or no control over the test to be performed; in many instances, he has no specific concept of the depth and purpose of the test.

The approach to equipment performance testing was designed to lower the skill level necessary for equipment maintenance. One result of this approach is that the skill level of the technician is not upgraded by the normal testing routine; improvement is dependent on the willingness and initiative of the technician to explore the implications and depth of the testing operation. (The complexity of the ASQ-42(V) is such that the time period required for developing a high-skill level in both the primary system and the automatic testing equipment is extremely long.)

Lack of a thorough knowledge of the automatic testing concept becomes truly important when the testing concept is inadequate for a complete diagnosis of equipment malfunctions. There is evidence of such inadequacy in the APN-113 test program. The particulars of such conditions are discussed in connection with the detailed analysis of APN-113 failure modes in Section 3.8.

3.7.2 Specialized Repair Activity (SRA)

Manually operated or programmed test equipment is used in testing failed APN-113 components at the depot (SRA) level. (There is no appreciable quantity of automatic equipment.) The SRA test installation is composed of the following equipment:

(1) Rack-mounted groups of specialized and general-purpose tester units to test a particular LRU

(2) Commerical general-purpose equipment (used whenever possible)

(3) "Marriage" panels designed for original system production (used for interconnection and control of the LRU under test)

(4) One functional station to test group-level performance of Electronic Package LRU's

Many of the SRA test stations were constructed by the original equipment vendor for use during the equipment production phase. Because all of the production equipment is not installed at the SRA, certain inadequacies exist in the testing capability. Particulars are discussed in Section 3.8.

3.7.3 Influence of Maintenance on Reliability

The effect of maintenance on equipment unreliability may be assessed in terms of so-called "inherent" reliability; that is, the reliability that may be observed if the equipment is given ideal maintenance. Perfect maintenance environment is still an idealistic goal, but the detrimental effect of inadequate maintenance can be quantitatively stated on the basis of observations of the degree of successful operation exhibited by an equipment following maintenance activity.

If it is assumed that equipments which have successfully completed one or more flights are free from malfunction and possess typically representative inherent reliability, the

success of maintenance can be quantitatively estimated by using next-flight data on malfunction-free equipment and related next-flight data on equipments upon which maintenance was performed following the previous flight. Two probabilities of success may be written using conditions as follows:

A = condition that previous flight was successful

B = condition that previous flight was unsuccessful

The probabilities are:

P(S/A) = the probability of a successful flight given that the previous flight was successful

P(S/B) = the probability of a successful flight given that the previous flight was unsuccessful

It is implied that any discrepancy between the two probabilities is due to ineffective maintenance. (The term maintenance is used here in its broadest sense and includes some aspects of materiel and materiel handling.) Therefore, the relative efficiency of maintenance (REM) can be expressed by

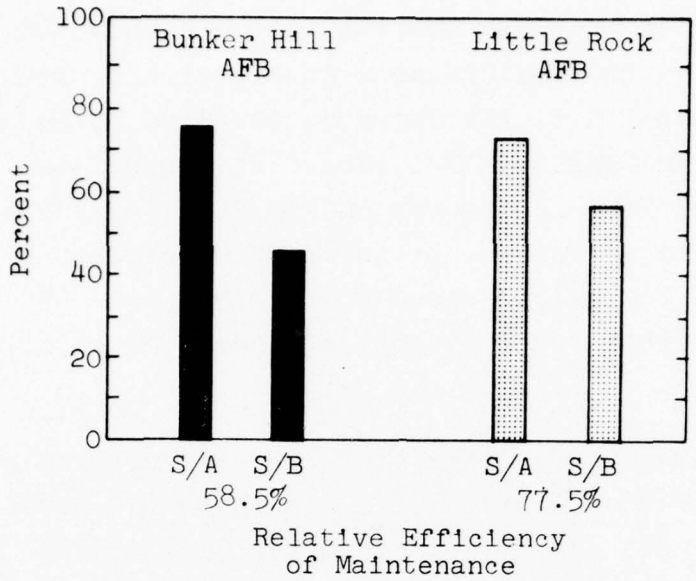
$$REM = \frac{P(S/B)}{P(S/A)}$$

Doppler reliability information was collected and arranged for evaluation regarding whether the operation was successful or unsuccessful on the next flight. The criterion for an unsuccessful flight was the existence of a verified operator complaint, regardless of the severity of a malfunction. Slightly more than 10% of all flights observed during the period of data collection were not considered, because the aircraft were flown with a known Doppler malfunction, secondary ground maintenance activity had disturbed the status of the previous maintenance action, or they were the last observed flights in this period.

The results of these observations are shown in Figure 3-3, which indicates that maintenance personnel are often unable to restore the APN-113 to its expected level of flight reliability following an in-flight malfunction. It further indicates a substantial difference between Bunker Hill and Little Rock AFB's in the relative efficiency of their first attempt to repair a malfunction. Following successful flights, the APN-113's at both bases exhibit nearly identical levels of in-flight reliability.

The maintenance problem is further identified by an examination of the quantity of LRU's involved in repair actions. (Figure 3-4 shows the distribution for each base.) There are a maximum of 19 separate items, including 3 Frequency Trackers per subsystem, which are identified as LRU's in the APN-113. In a complex system that has extraordinary interface or harmonization ("marriage") problems, an average of three LRU's per functional loop with a maximum of six LRU's per loop, involvement of three or four LRU's per repair action is not unreasonable. However, the records of both bases show that nearly one-fourth of all events involve from 4 to 16 LRU's per repair action. This indicates recurring difficulty in locating defective LRU's at the flight-line level or use of faulty LRU's as replacements, or both.

Further evidence of maintenance difficulties is provided by the data in Figure 3-5, which gives a distribution of LRU major-action categories. At least 20% of all APN-113 LRU's involved in maintenance events are found <u>not</u> to be defective. This is an optimistic figure, since this particular display includes LRU adjustments and/or repairs that were completed without LRU removal, and the no-malfunction-found category applied <u>only</u> to LRU's removed from an aircraft. Also, according to Figure 3-5, more than 30% of all LRU actions involve adjustments or alignments only.



AR-65-170

Flights	Bunker Hill AFB		Little Rock AFB	
	Number of Flights	Percent	Number of Flights	Percent
All Successful Flights	313	100.0	456	100.0
Next Flight Successful (S/A)	237	75.7	331	72.6
Next Flight Unsuccessful	76	24.3	125	27.4
All Unsuccessful Flights	192	100.0	199	100.0
Next Flight Successful (S/B)	85	44.3	112	56.3
Next Flight Unsuccessful	107	55.7	87	43.7

FIGURE 3-3

DOPPLER "NEXT-FLIGHT SUCCESS" ESTIMATES

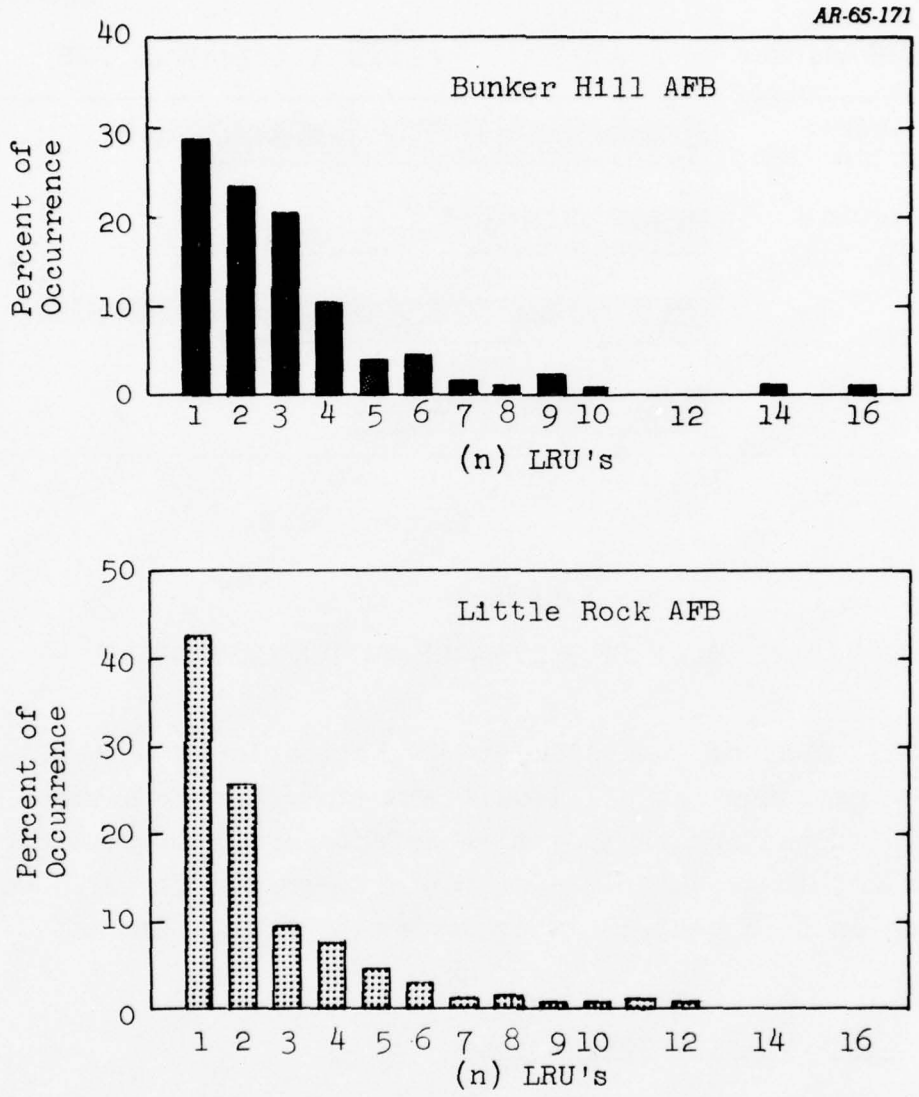


FIGURE 3-4

FREQUENCY DISTRIBUTION OF THE NUMBER OF LRU'S INVOLVED PER APN-113 MAINTENANCE ACTION

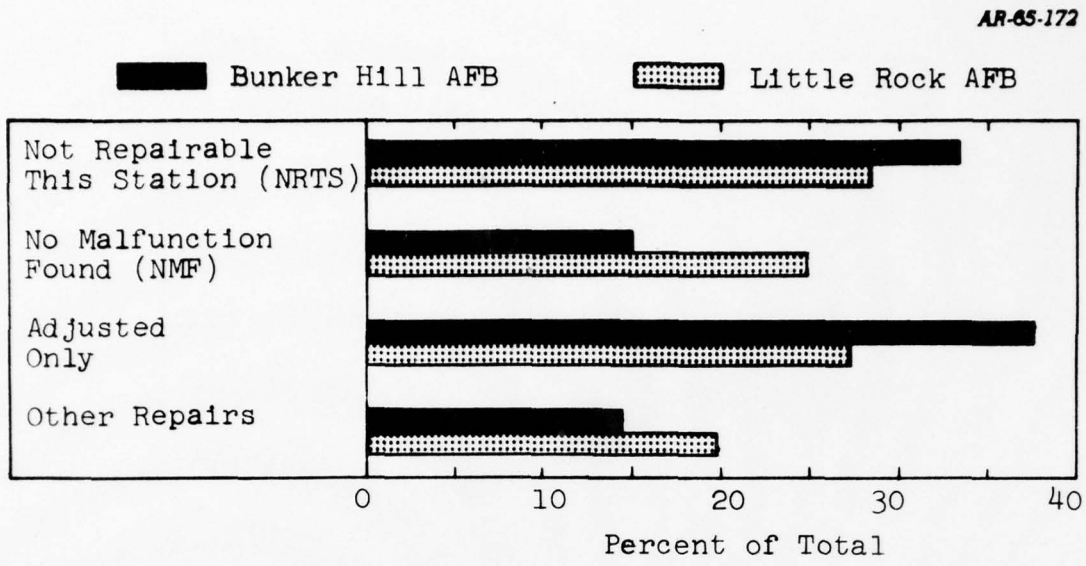


FIGURE 3-5

DISTRIBUTION OF LRU MAJOR ACTION CATEGORIES

At this level of analysis, it may be concluded that APN-113 maintenance personnel at all levels are experiencing extreme difficulty in locating or isolating defects and in maintaining the system within acceptable electronic tolerance limits. More information on this subject is presented in the following section.

3.8 Engineering Investigation

To facilitate the laboratory studies and ensure conclusive analysis of the failures, Government-furnished equipment (GFE) was requested in September 1964. The equipment for analysis and study began arriving in late October 1964, during the Test Phase I data-collection period; but the lack of important LRU's and a complete APN-113 in the laboratory delayed completing an analysis during that portion of the project.

The following data analyses and experimental work were performed to determine the reasons for APN-113 failure modes:

(1) Gross failure data analyses on a wing/base level

(2) LRU part failure analyses at the SRA

(3) On a current-interest basis, analysis of failed part in the laboratory

(4) Measurements of Doppler Radar temperatures while in all phases of operation on aircraft

As discussed in Section 3.2, the approach toward solution of failure problems has been on a functional loop basis. The following paragraphs contain discussions of investigations and change proposals arranged in this manner.

3.8.1 APN-113 Transmitter Loop Function

The APN-113 Transmitter Loop Function consists of the following LRU's: Transmitter Antenna, KFC, HV Power Supply, Klystron Temperature Control, and the AFC portion (Reference Cavity Assembly) of the PSDP. These LRU's generate, control, and radiate approximately 4 watts of continuous wave (CW) RF power, which, after losses have been deducted, is evenly divided between the three radiating reflector dishes. Also, the LRU's supply power to the Receiver to facilitate detection of reflected signals.

The nature of the transmitter loop makes it difficult to isolate its failures, and as a result there is a high percentage of multiple LRU actions during repair. The loop accounts for a substantial portion of APN-113 repair actions. Distribution of LRU actions per 1000 flight hours for transmitter functions is described in Figure 3-6. PSDP removals related to Transmitter Loop Functions are shown in Figure 3-7.

The study revealed deficient areas in the transmitter loop. However, the majority of them can be corrected by slight, but very effective, changes to the equipment or testing procedures. These areas are discussed on an LRU basis below.

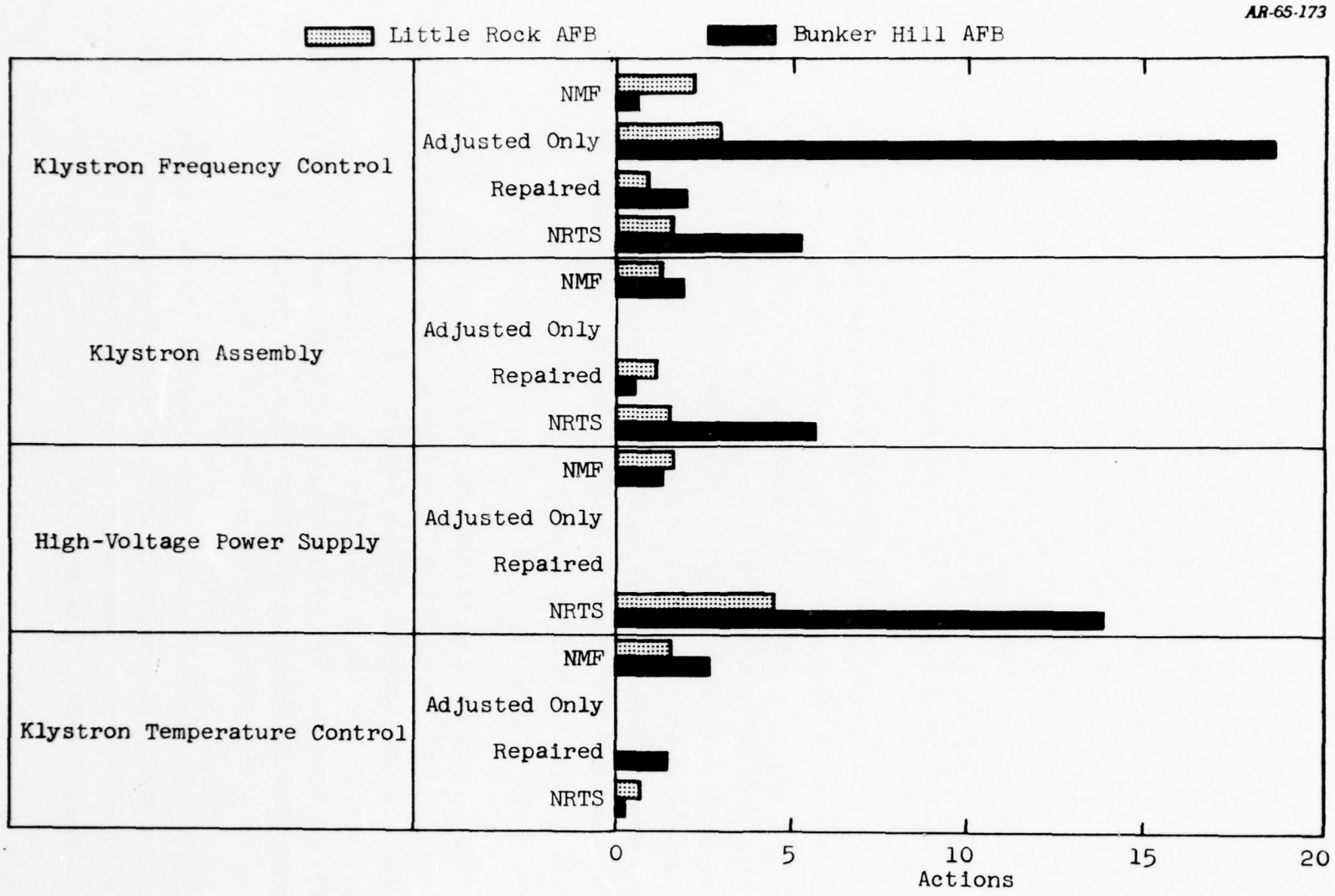


FIGURE 3-6

TRANSMITTER LOOP FUNCTION - DISTRIBUTION OF LRU ACTIONS PER 1000 FLIGHT HOURS

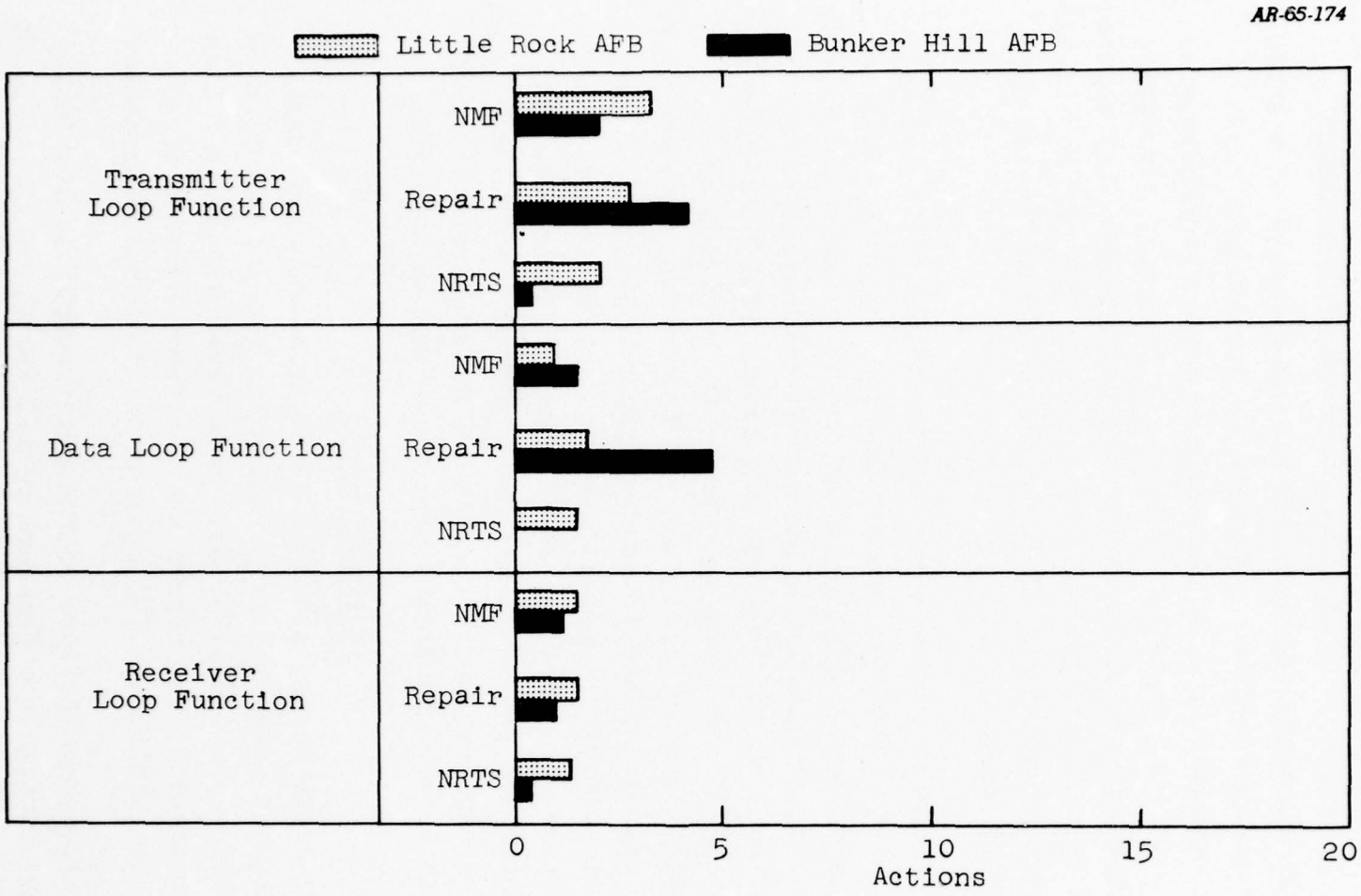


FIGURE 3-7

POWER AND SIGNAL DISTRIBUTION PANEL -
DISTRIBUTION OF UNIT ACTIONS PER 1000 FLIGHT HOURS
RELATED TO APN-113 FUNCTIONS

3.8.1.1 Klystron Frequency Control (KFC)

The KFC contains the decision-making elements of the AFC system for the transmitter. The AFC is basically a Pound System; it operates on a 30-megacycle sensing frequency, with the tuned cavity of the PSDP acting as a frequency standard element. Because the cavity phase shift determines the control locus, and this information is acted upon by the KFC to initiate control action, adjustment of the phase reference in the KFC determines the adequacy of loop performance.

The KFC output controls the series regulator in the HV Power Supply and, thereby, transmitter frequency by changing power supply voltages applied to the klystron transmitter tube. Present testing procedures do not permit refinement of the phase adjustment to the required accuracy. PECP-5(APN-113)[52], prepared by ARINC Research, recommends the addition of a simple tip-jack test point to the KFC to provide accurate phase-adjustment capability and to ensure proper adjustment of the KFC phase discriminator operating points. This is essential in order to secure good results over the entire environmental range to which the equipment may be subjected. More importantly, the PECP contains suggested changes to the required technical data so that proper adjustment procedures can be employed.

3.8.1.2 HV Power Supply

The HV Power Supply provides d-c tube element voltages and a-c filament power to the Klystron tube, and its output is approximately -2200 vdc at 50 ma. This power supply is filled with a silicone oil that serves the combined function of (1) dielectric insulation and (2) cooling the internal components.

The most common failure in the power supply is leaking, or discharge through the pressure relief valve, of the silicone oil. Investigation proved some of the oil leaks to be the outward indication of a more serious failure that causes severe overheating of the unit. The overheating is usually

the result of excessive current drain and is, therefore, not readily detectable under normal load circumstances. Many instances of klystron connector-plug short circuits, which cause power supply overload, have been revealed through ARINC Research Field Engineering investigation. A probable result of overheating is a considerable reduction in the life of this LRU.[37] Further difficulties with the HV Power Supply will arise if stringent baking, evacuating, and oil-filling procedures are not followed during LRU repair at the SRA.

PECP's 2, 3, 4, 6, and 8 (APN-113), prepared for the contracting agency, define corrective measures for (1) overload protection,[50] (2) redesign of internal hardware to correct deficient electron-tube mountings,[43] (3) improvement of the pressure relief valve,[49] (4) improved sealing techniques;[47] and (5) rectifier tube installation and mount modification.[63] However, procedure and test-station adequacy is essential for improved performance, even after these modifications have been incorporated. Internal arcs caused by improper filling procedures will not be less catastrophic than before, and will still result in undesirable repair action.

Corrective action on test equipment is beyond the scope of this contract. However, assistance in terms of engineering analysis is being provided.

3.8.1.3 Klystron Assembly

The Klystron Assembly is made up of a transmitter tube, which is part of the Transmitter Antenna, and a harness. The tube receives approximately 100 watts of d-c power from the power supply and generates a minimum of 4 watts of output RF power. Low efficiency of the tube is inherent in its design in order that maximum frequency stability can be attained. Control of the tube is achieved not only by electrical regulation, but also by regulation of operating temperature.

A special temperature controller regulates the flow of cooling air through the klystron anode block and maintains the block temperature at approximately +300F. Testing of the temperature-control function in the special ARINC Research Doppler Temperature Measurement Plan showed that the transmitter loop would perform well at room ambient, with block temperatures as low as +260F, provided the AFC was properly adjusted. Nevertheless, closer regulation, as specified for the APN-113, is necessary to assure proper functioning of the AFC apparatus under all specified circumstances.

Generally, the RF power output of the Klystron Assembly can provide sufficient ground return for all operational altitude requirements, providing the remainder of the APN-113 also performs according to design specifications.

The wing/base-level power-output testing equipment has been the subject of considerable criticism, since the voltage readout of the test sets cannot be readily related to a specific RF power level. An additional problem is a special attenuator on the flight-line test equipment that cannot be fully calibrated with available secondary standards. Generally, the knowledgeable flight-line technician has learned to accept the power measurement for the relative quantity it is and base klystron replacement on other factors affecting APN-113 performance.

A serious Klystron Assembly failure mode has been that of arcing in the P-1241-1 connector of the tube power cable.*[40] An important secondary effect of the arcing condition was the overloading, and consequent failure, of the power supply. The

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* This condition was discussed in correspondence with the contracting agency, along with procedures for eliminating the problem.

initial arcing condition usually appeared only at low atmospheric pressures of high-altitude flight; thus it was not readily detected during ground tests.

The ARINC Research Doppler Radar Temperature Measurement Plan data show a delay of some 10 minutes between the time the typical Klystron Assembly is turned on and the time its operating temperature approaches the required value. A change proposal designed to allow the tube to remain at a near-nominal temperature at all times during flight is being prepared.

3.8.1.4 Klystron Temperature Control

When properly adjusted, the Klystron Temperature Control has demonstrated good reliability and, in the special temperature recorder test, good control of the temperature in the Klystron Assembly. Present testing procedures do not provide capability for such adjustment. New procedures and apparatus are being proposed by ARINC Research for the Doppler cart to allow klystron temperature monitoring during adjustment on the flight line. Field tests with wiring external to the Doppler cart have been made with satisfactory results. This method is briefly described in PECP-5(APN-113), but further elaboration on this subject is required to determine its accuracy and limitations. However, it has the capability of reliably providing the test operator with two absolutely essential minimal items of information which the present equipment does not do; that is, it would tell the operator that the Doppler Klystron tube is within nominal temperature control range and that it is stable in temperature before he begins the test procedure. Refined accuracy may be considered of secondary importance to these considerations.

3.8.1.5 Power and Signal Distribution Panel (PSDP)

Only a portion of the PSDP, the special high-Q-tuned resonant cavity assembly, can be considered a basic part of the transmitter loop. The cavity is the reference element

for klystron AFC. As a continuation effort, an investigation should be made of the influence on this cavity and the effect on AFC accuracy of the routine practice of operating the electronics package without a cover during maintenance.

The field shop Radar Line Replaceable Units Test Set (RLRUTS) is not capable of testing the cavity. A test that would reduce the overall transmitter loop maintenance effort is being investigated.

3.8.2 Receiver and Frequency Tracking Loop Functions

The Receiver and Frequency Tracking Loop Functions of the APN-113 must receive and heterodyne the APN-113 microwave Doppler spectrum; amplify the spectrum to a fairly constant level, regardless of aircraft altitude; detect the Doppler frequency shift; and convert the received frequency spectrum to a single frequency representative of the aircraft velocity.

The APN-113 Receiver and Frequency Tracking Functions consist of the Receiver Antenna LRU [including the IF Amplifier-Frequency Converter (IFFC) and Ferrite Modulator subassemblies], the AF-IF Amplifier LRU, and the three Frequency Tracker LRU's.

Representative LRU actions per 1000 flight hours are shown on Figure 3-8. PSDP actions related to receiver and frequency tracking loop functions are shown on Figure 3-7.

3.8.2.1 Receiver Antenna (LRU)

Investigation of the Receiver Antenna has been primarily concerned with problems generated by the IFFC and Ferrite Modulator subassemblies.

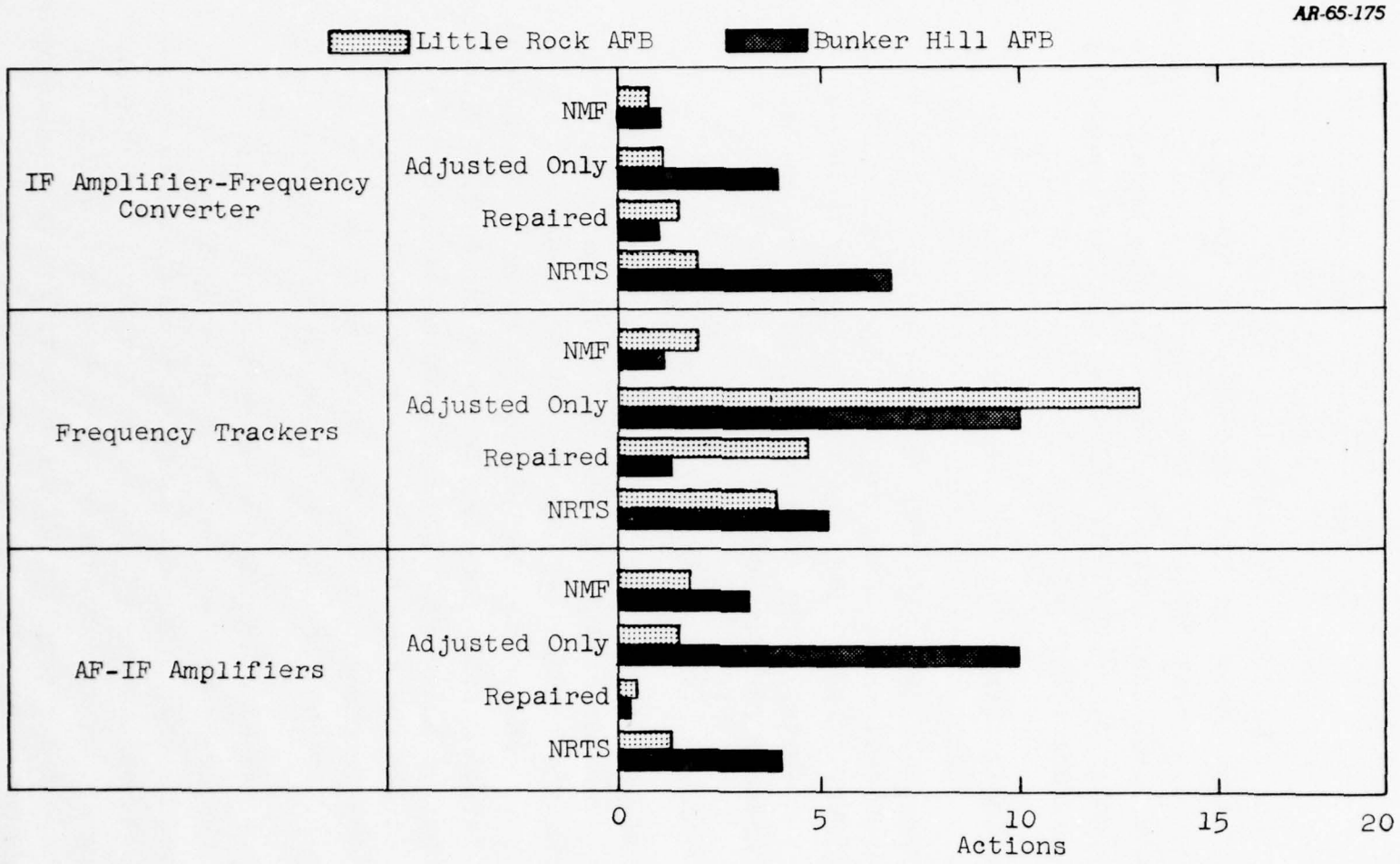

FIGURE 3-8

RECEIVER LOOP FUNCTION - DISTRIBUTION OF LRU ACTIONS PER 1000 FLIGHT HOURS

3.8.2.2 IF Amplifier-Frequency Converter (IFFC)

A large percentage of the functional failures in the IFFC occur for short periods of time only, especially during high-altitude flight. These periodic failures are not readily detectable with normal ground-testing equipment and procedures. As a result, practical repair decisions must be made by the repair technician, or the maintenance action must terminate in a "no malfunction found" type of report.

Some insight into the periodic-failure problem was gained as a result of ARINC Research's on-aircraft Doppler temperature tests, which proved the IFFC was operating at temperatures well below those required for normal stability. A revised PECP-1(APN-113)[46], submitted by ARINC Research, proposes the installation of thermostatically controlled electric heaters for the IFFC.

3.8.2.3 Ferrite Modulator

Use of the Ferrite Modulator components in a single-sideband generator circuit to generate the local oscillator signal from the transmitter signal provides the necessary system signal coherency. Vendor specification indicates that loss of operating efficiency may occur in the Ferrite Modulator at temperatures below +46F. Special thermostatically controlled heaters are a part of the Ferrite Modulator subassembly; however, the temperature recorder tests indicated erratic operation of the heaters during high-altitude flights.

PECP-7 has been prepared recommending the use of an improved heater-control switch.[62] Further problems are encountered in that the ground-testing environment is seldom at temperatures low enough for switch testing. The problems of testing at the wing/base and SRA levels must be resolved. This is beyond the scope of this contract; however, assistance in the way of engineering analyses is being provided.

3.8.2.4 AF-IF Amplifier

Present testing operations do not provide for making an accurate and independent adjustment of the phase and amplitude of the driver signal applied to the Ferrite Modulators, nor do they meet the requirement for alignment of the Receiver AF-IF Amplifier. These problems are under study. A similar testing problem relates to the automatic gain control (AGC) of the Receiver AF-IF Amplifier. The requirement for control of AF-IF amplifier gain to a level generating a fairly constant signal amplitude at the Frequency Tracker's input may be related to certain high-altitude APN-113 unlock problems. The problem must be properly identified to be eliminated by a workable procedure for AGC tracking tests and adjustment. A plan for this investigation should be made and carried out as part of the follow-on effort.

3.8.2.5 Frequency Trackers

Initial problem study of the APN-113 indicated that the Frequency Trackers were erratic in performance and required numerous adjustments by maintenance technicians. The temperature recorder tests proved that the erratic performance was due partially to the inconsistent cycling of the mixer heater switch in the Frequency Trackers. (The mixer function, which contributes to the determination of the Doppler signal-spectrum center frequency, requires extreme accuracy. The accuracy is achieved by closely controlling component temperatures within the mixer through use of a thermostatic switch and heater arrangement.)

PECP-10, recommending the use of an improved heater switch, has been prepared.[65] There is presently no means of testing the proper operation of the switch. Such a test

procedure must be developed if proper heater operation is to be assured. (This is not within the scope of this contract, although engineering analysis assistance is being provided.)

The excessive adjustment of the Frequency Trackers is due, in part, to the stringent operational tolerances required of a phantastron sweep generator within the unit. Correction of the mixer heater-switch problem may allow the use of a more suitable phantastron tolerance. A study of this problem should be carried out as part of a follow-on effort.

3.8.3 Data Conversion Loop Function

Data conversion is performed by the Waveform Converter LRU, the Velocity Computer LRU, and portions of the PSDP LRU. Thus far, the investigation has been centered on the Waveform Converter.

The Data Conversion Loop Function (1) receives the single Doppler frequency information from the Frequency Trackers, (2) counts the oscillations to determine the frequency, and (3) positions a motor-driven potentiometer to a setting representing the ground-velocity information. The potentiometer is excited by the ASQ-42(V) computer precision voltage source, and its output is routed to the Doppler inertial mixer in the ASQ-42(V) computer. There are three identical channels in the data-conversion function, one for each ground-velocity component.

Distribution of LRU actions per 1000 flight hours related to this Data Conversion Loop Function are shown in Figure 3-9. PSDP LRU actions related to this function are shown in Figure 3-7.

Investigation revealed some deficiencies within the Data Conversion Loop Function. The output of the Frequency Trackers is coupled to the Waveform Converter, where it is

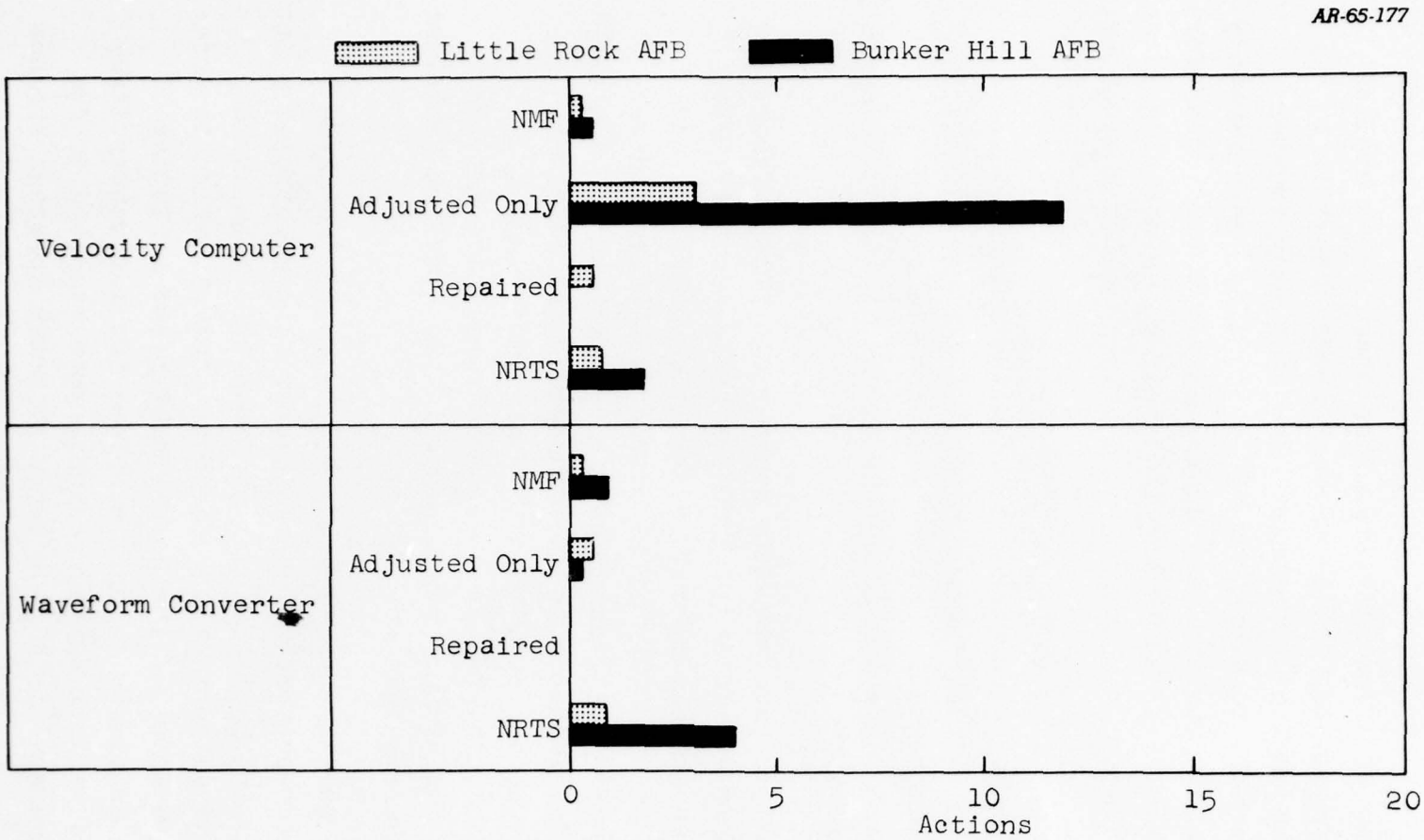

FIGURE 3-9

DATA CONVERSION LOOP FUNCTION - DISTRIBUTION OF LRU ACTIONS PER 1000 FLIGHT HOURS

first processed by a squaring amplifier stage, then applied to a frequency-counting device whose voltage output is a function of the applied frequency. The frequency counter subassembly is held to extremely close counting (approximately 0.1%) and linearity tolerances (approximately 0.01%); therefore, the required accuracy can be obtained only by maintaining close control of operating temperature of the semiconductor counting elements.

The in-flight temperature recorder tests indicated erratic operation of the counter heater control. Further testing revealed the thermostatic control switch to be at fault. PECP-9, recommending a suitable replacement thermostatic switch, has been prepared.[64]

The output of the frequency counter controls a feedback-stabilized servo amplifier in the Waveform Converter. The servo amplifier drives, through a magnetic amplifier, the APN-113 servo in the PSDP. The servo output potentiometer supplies ground-velocity component a-c signals to the ASQ-42(V) computer and d-c feedback to the counter in the Waveform Converter. A tachometer within the servo-motor assembly generates feedback signals for control of relative driving motor speed. Adjustments can be made to the Waveform Converter for setting precise feedback ratios.

The most frequent and important failure of the servo assembly is wear-out of the potentiometer at a particular point. A major factor in the "wear-out" problems is thought to be the improper adjustment of the feedback control, which is under study. Failure modes of the potentiometer and a listing of configuration problems, as well as plans for laboratory life-testing of the various configurations, were reported to the contracting agency.[17,21,27] A group of potentiometers are now

being life-tested to identify the most reliable potentiometer configuration of those now used; however, a sufficient quantity of potentiometers has not been made available for testing.

3.8.4 Coherency Test Function

Basically, one LRU, the Coherency Test Unit, evaluates all APN-113 LRU's when in use. The coherency test may be performed in-flight by the operator when an APN-113 malfunction is suspected. During the test, a special 200-cycle modulation of the APN-113 transmitter determines the quality of the APN-113 lock. Relative distribution of Coherency Test Unit repair actions is indicated in Figure 3-10.

The present coherency testing method does not allow determining in which APN-113 channel failure has occurred. The desirability of providing such a feature was studied by ARINC Research on special request by WRAMA, in connection with evaluating a GD/FW letter of recommendation on this subject. A reply to WRAMA was given as affirmative with respect to the desirability, but negative with respect to method of accomplishment. An alternate method was suggested, one which involved changes in wiring only, rather than addition of parts.

Three APN-113 LRU's have general application to all APN-113 functions. The PSDP LRU may be related to all the various functions. Relative distribution of actions per 1000 flight hours pertaining to the functions is shown in Figure 3-7. The Ripple Filter LRU and Coherency Test Set LRU are generally applicable to all of the APN-113 functions. Distribution of LRU actions per 1000 flight hours for these two LRU's is shown in Figure 3-10.

3.8.5 Other Mechanical Hardware Problems

Some mechanical hardware problems (which had been solved according to historical data prior to this project) actually still exist. In the Receiver and Frequency Loop

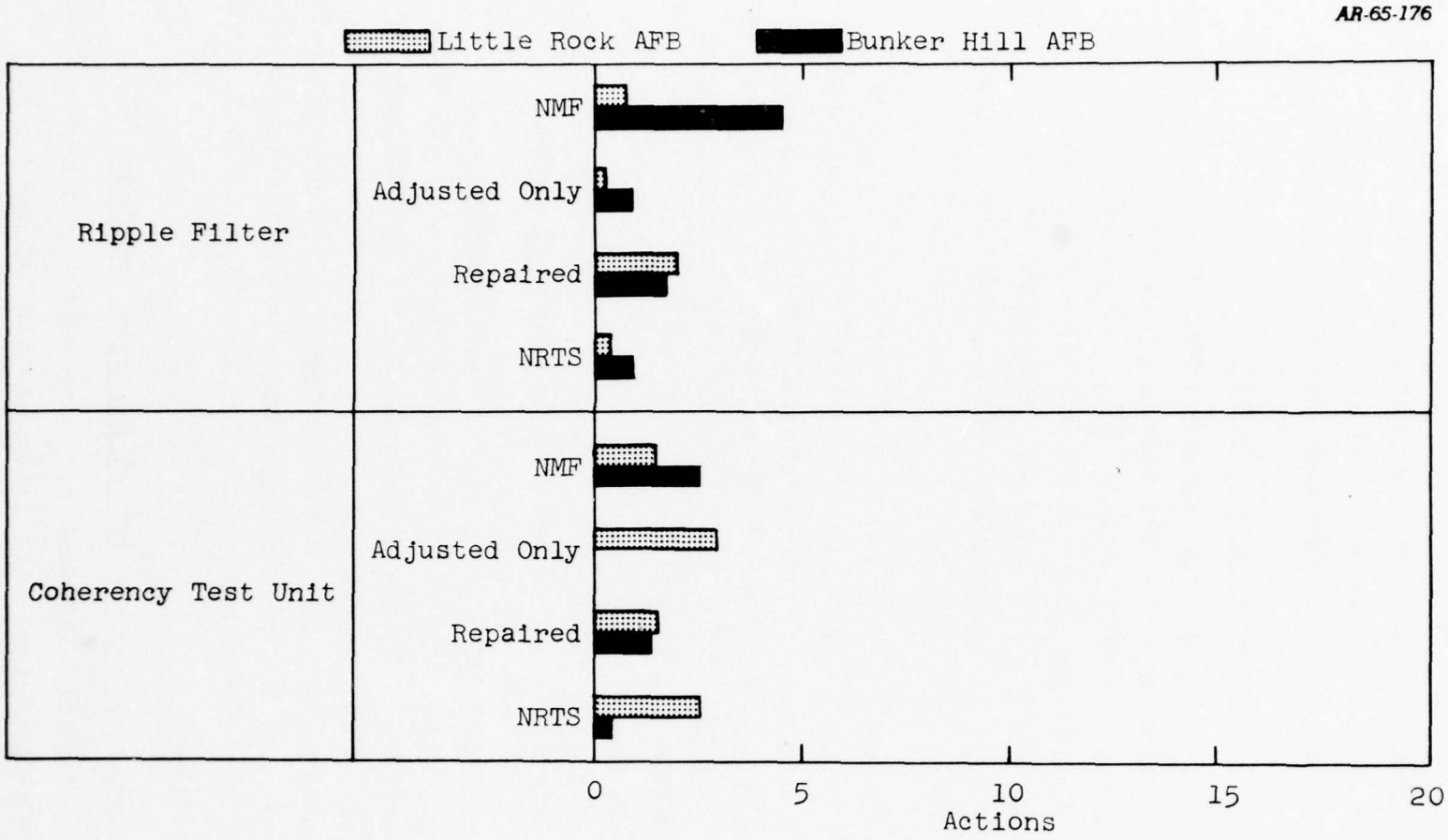

FIGURE 3-10

GENERAL SYSTEM FUNCTIONS - DISTRIBUTION OF LRU ACTIONS
PER 1000 FLIGHT HOURS

Function one such problem is the lack of the latest configuration of the Teflon vibration damping inserts in the crystal detector mounts of many of the Frequency Converters in use. Vibration of the detector crystal mounts, which was the subject of a study during the aircraft's production period, required correction. Consequently, a special Teflon collar was placed around the female contact in the mount. Observation of operating equipments in the Bomb Wing has shown many equipments not fitted with the special collar.

Another problem noted in early equipment histories was that of the load spring holding the APN-113 transmitter dummy load switch in the normal operating position, except when it was manually engaged for ground testing. Correction of this problem was not completely successful -- many instances of improperly attached springs have been noted during flight-line work on the APN-113 test tasks.

The majority of adjustment problems caused by vibration were eliminated in the production phase of the weapons system prime contract. Initially, on this project, a study of failure data indicated a need for frequent adjustments of the APN-113, supposedly because of vibration problems in some Electronic Package components. Further study by ARINC Research and WRAMA engineers on the problems of these LRU's, and the Frequency Tracker in particular, showed that the need for frequent adjustment was due to erratic operation of a thermostatic heater control switch. A better adjustment-locking compound was recommended by WRAMA engineers for locking of adjustment screws.

Other mechanical problem areas which have been observed during the course of this project and recommended for further study or fleet-wide corrective action are discussed below:

(1) In view of the method of mechanical support of the ferrite rod,. which is encased in a Teflon sleeve, and the criticalness of rod alignment in the magnetic field of the device, a study of vibration and temperature effects on the Ferrite Modulator should be considered.

(2) The use of poorly mated diamond waveguide flanges in the Receiver Antenna LRU is a problem compounded by the lack of voltage/standing wave ratio test equipment at field level.

(3) The low-noise figure requirement of the Receiver and Frequency Tracking Loop Function necessitates the use of d-c filament voltages in some vacuum tubes. The d-c filament voltage power supply in the PSDP is a high-failure item. Two problems -- (a) damage to the semiconductor rectifiers by poor handling and (b) intermittent connection of the power transformer -- have been investigated. ECP-1 (APN-113) was submitted for correction of the transformer problem.[41] (It is understood that WRAMA engineers have designed a protector plate that will be installed to prevent physical damage to the rectifiers.)

3.9 Investigation of Doppler "Unlock at High Altitude Over Water"

Investigation of Doppler "unlock at high altitude, over water" was assigned as a task under the contract.

Failure of the APN-113 Doppler Radar set through unlock can result in unsuccessful bombing missions. A report* was submitted which defines the term "unlock" and describes

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* This report was submitted in May 1965.[54]

the unlock problems which occur within the range of specified performance limits. It shows that the major problems attributed to unlock are not the result of inherent performance, or design limitations of the Doppler Radar.

The probable causes of unlock are: (1) design deficiencies, (2) improper adjustment or alignment procedures, (3) improper repair procedures, (4) catastrophic part failure, and (5) lack of sufficient return signal.

A reduction in the frequency of unlock will necessitate (1) correcting minor design deficiencies, (2) establishing better alignment and adjustment procedures, and (3) developing better techniques for locating failed parts.

3.10 Status of APN-113 Corrective-Action Engineering Efforts

PECP's have been submitted on the following items:

(1) Temperature-controlled heaters for the IFFC, PECP-1 (APN-113).[46] (This PECP is currently being revised to account for the latest flight-test results.)

(2) Engineering analysis of alignment procedures for the Receiver and the AF-IF Amplifiers [51]

(3) Revised terminal board wiring for the PSDP d-c filament power supply transformer, ECP-1 (APN-113)[41]

(4) New adjustment procedures and a new test point on the KFC, PECP-5 (APN-113)[52]

(5) Provision for overload protection for the HV Power Supply, PECP-6 (APN-113) [50]

(6) Modification of the pressure-relief valve on the HV Power Supply, PECP-4 (APN-113)[49]

(7) Internal modification of the HV Power Supply to reduce mechanical failures, PECP-2 (APN-113)[47], PECP-3 (APN-113)[48], and PECP-8 (APN-113)[63]

(8) New thermostatic switches for the Ferrite Modulators, PECP-7 (APN-113)[62]

(9) New thermostatic switches for the Z-1 mixer in the Frequency Trackers, PECP-10 (APN-113)[65]

(10) New thermostatic switches for the frequency counter in the Waveform Converter, PECP-9 (APN-113)[64]

PECP's are being prepared on the following items:

(1) A means of maintaining klystron temperatures near nominal value when klystron high voltage is off

(2) Life tests engineering analysis and recommendations on servo potentiometers in the PSDP

The following APN-113 problem areas have been suggested for a follow-on study:

(1) Klystron power measurement problems on the flight line

(2) Programming APN-113 klystron temperature information so that it can be read out on the flight-line test cart

(3) Effect of making transmitter loop adjustments with the PSDP cavity at ambient temperature on the ground with the Electronics Package cover removed

(4) Adjustment of the receiver AGC voltages

(5) Eliminating some adjustment potentiometers from the Frequency Trackers and study of design adequacy and updating of components and circuits

(6) Performance degradation resulting from lack of adjustment of APN-113 servo sensitivity at wing/base level

(7) Environmental performance study of the IFFC and single-sideband generator and updating of components

(8) Integrated effort on testers, airborne equipment, maintenance procedures, and technical data

(9) Study of "Doppler breaks dirty" complaints and aspects of this problem that may extend into computer and stabilization equipment subsystem components

(10) RLRUTS capability for transmitter alignment as related to the PSDP reference cavity

4. CORRECTIVE ACTION ENGINEERING - AN/ALQ-16 EQUIPMENT

4.1 Brief Equipment Description

The ALQ-16 equipment includes three models of Radar Track Breaker sets which operate in two microwave frequency radar bands. The equipment makes use of low-, medium-, and high-powered traveling wave tubes (TWT's) with high-voltage power supplies, crystal video-pulse receivers, electronic control, and programming circuits.

4.2 Approach

The basic approach used to investigate problems on AN/ALQ-16 equipment differed from the one used for the APN-113, as discussed in Section 3.2. These investigations were conducted primarily at the SRA. The identification of specific problem subassemblies required less detailed historical research than that for the APN-113 investigation, because the subassemblies requiring corrective action were more easily identified by the detailed examples available at the SRA work stations.

To establish a logical course of engineering corrective action, there was an initial review of AFM 66-1 data and technical orders. This review was supplemented by interviews with technicians at the SRA and various operating bases. Together, the two efforts generated sufficient information to permit identification of gross failure modes of the equipment and more than enough detailed tasks to occupy the available project group. In the specific LRU subassemblies involved, most of the mechanical and circuitry problems were evident from the SRA reports that had been initiated by ARINC Research to supplement the AFM 66-1 data.

The sequence of engineering actions for the various LRU's was established by the order listed in the contract (Appendix B). A more detailed definition of the problems was obtained through individual LRU and subassembly analyses at the SRA. In conjunction with these analyses, test procedures and techniques also were observed to determine if related deficiencies arose from these sources. Suggestions for their correction have been made in the form of procedure-change ECP's. It was found that supposed component problems associated with certain TWT's were the result of improperly conducted test procedures.

4.3 Engineering Investigation and Change Proposals

4.3.1 LRU and Subassembly Analysis Summary

A detailed study of selected LRU's and of modules within these units identified the specific failure modes upon which to base immediate corrective engineering actions. Those problems that have been resolved by submission of PECP's and those identified for corrective action are enumerated below:*

(1) Locked Oscillator Receiver

(a) The 400-cps hum introduced from the filament power circuit to the first stage of the AD receiver, preventing proper receiver alignment at the SRA, is due to the layout of receiver wiring and ground loop conditions in the test station. Correction of receiver wiring is not economically feasible, but the problem can be corrected by a simple change in the receiver. See PECP-1 (ALQ-16).

* Each PECP noted in this section is described in Sections 4.3.2 through 4.3.4.

(b) The hand-selection-of-diodes problem, in connection with obtaining proper operation of the trapezoidal generator circuit, was identified. Certain diodes caused pulse jitter at the output. See PECP-2 (ALQ-16).

(c) An undefined failure mode in the delay programmer causes "out of adjustment" complaints against the unit. Complete analysis and correction has been proposed as a follow-on effort.[23]

(2) Driver Amplifier

(a) The burnout of resistor R14600 and network Z1505 in the voltage regulator (P/N 89-136554-2 and -3) is caused by transient voltages on the aircraft's three-phase system. See PECP-4 (ALQ-16).

(b) The damage to transformer T-1501 and reactor L-1504 in the HV Power Supply for the Aft T-4 Driver Amplifier is caused by mechanical shock and vibration. See PECP-5 (ALQ-16).

(c) The overheat damage to the tube (P/N JAN 4X150A) is caused while the tube is being soldered to the socket (P/N 72-129319-1) in the electron tube and network assembly. Correction has been proposed as a follow-on effort.

(d) There is a leakage of the gasket (P/N 86-1-129550-1) in the electron tube and network assembly. Correction has been proposed as a follow-on effort.

(3) Power Amplifier

(a) There is an inadequate transistor current gain, which, in turn, fails to ensure proper operation of the power output indicator in the Generator-Receiver. See PECP-3 (ALQ-16).

(b) There are power losses due to unnecessary d-c return in the Power Amplifiers that use TWT's. See PECP-6 (ALQ-16).

(c) The 1-4dS TWT's had high rejection rates caused by improperly conducted test procedures. See PECP-7 (ALQ-16).

(d) The arrestor (Z1900) in the Aft T-4 subsystem changes value on TWT failure when fault-current overloads occur. Correction has been proposed as a follow-on effort.

(e) The mounting brackets for the resistors (P/N 35-128944-1 and P/N 35-128945-1) in the HV Power Supply are bent and broken. Correction has been proposed as a follow-on effort.

(f) There is inadequate support for the capacitor (P/N 45-17088-1) in the HV Power Supply. Correction has been proposed as a follow-on effort.

(g) The retainer rings (P/N 5131-021) for mounting the power supply subassembly (P/N 89-128937-1) in the HV Power Supply are loose. Correction has been proposed as a follow-on effort.

(h) Arcing problems are experienced on the terminal lug (P/N 2104-06-00) of the capacitor assembly (P/N 45-136913-1) in the HV Power Supply. Correction has been proposed as a follow-on effort.

4.3.2 Circuit Design ECP's

Modifications to correct the circuitry problems outlined in the foregoing section have been designed and submitted for consideration to WRAMA. These recommended changes, in order of submission, are as follows:

(1) PECP-1 (ALQ-16)[13] corrects the 400-cps hum problem in the AD Receiver of the Receiver Locked Oscillator LRU. Correction is effected by changing the value of resistor R-1108 from 100 to 15 Kohms. The modification was performed on 10 AD Receivers, 5 for each operating base. Over 800 flying hours, without failure, have been accrued on these test units to date. DECM training mission score records are now being analyzed to show that operational performance has not degraded. SRA records that show unit-test worktime will also provide assessment data. The preparation of a final ECP is in process.

(2) PECP-2 (ALQ-16)[28] eliminates the necessity for hand-selection of diodes and, thereby, prevents pulse jitter in the trapezoidal generator circuit of the Locked Oscillator Receiver. The addition of two diodes and a resistor in the circuit will correct the problem. The modification has been performed on 10 units, 5 for each wing, and is presently being flight-tested. Analysis of performance score records and failure data will be used to assess the effectiveness of the modification.

(3) PECP-3 (AIQ-16)[31] provides proper operation of the power output indicator in the Generator-Receiver. A change in transistor type, from 2N339 to 2N343, proved successful in correcting this problem. Ten flight-test units have been prepared to test the modification.

(4) PECP-4 (ALQ-16)[32] prevents burnout caused by power-line transients through resistor R14600 and network Z1505 in the voltage regulator. Correction consists of relocating resistor R14519, changing its rating from 2 to 5 watts, and changing the resistance of resistor R14600 from 47 to 10 ohms. These changes should prove to be effective in eliminating the damage done by the transients prevalent in the power system. A proposal to test this modification is pending decision by WRAMA Service Engineering.

(5) PECP-6 (ALQ-16)[58] eliminates the d-c return (Z1895) and its associated cable assembly from the Power Amplifiers that use TWT types 1-4dG, 1-4dJ, and 1-4dS. Investigation of the power losses in these LRU's led to the discovery that a d-c return is not required for TWT's of the type listed. It was suggested that this modification be instituted, without further testing, on a fleet-wide basis.

(6) PECP-8 (ALQ-16)[59] provides for an RF adapter connector to correct a problem on the Power Amplifier TWT assembly caused by a vendor changing the type of the connector.

Analyses of known problems, and the identification of additional areas for improvement, are continuing.

4.3.3 Test Equipment and Test Procedure PECP's, PECP-7 (ALQ-16)[60]

The high rejection rate experienced during testing of the 1-4dS TWT's led to a detailed study of this tube, test equipment, and test procedures. As a result of this investigation, recommended changes in the technical orders used in testing, and changes in the external accessories of the test equipment,

were proposed in PECP-7(ALQ-16). These new procedures will greatly reduce the probability of good tubes being rejected. Also, it will be possible to reject bad tubes earlier in the test procedure. Thus the overall rejection rate for 1-4dS TWT's should be greatly reduced, and AN/ALQ-16 performance would improve because of the increased reliability and availability of these components.

In an early test case, twenty-six 1-4dS tubes, which previously had been rejected, were retested by the suggested test procedures. Eleven tubes were reclassified as good tubes. Since each tube is worth approximately $4,000, the new procedures resulted in a net savings of $44,000 in this instance alone. Savings of this kind are continuing through education of test personnel by ARINC Research representatives.

4.3.4 Mechanical Design PECP, PECP-5 (ALQ-16) [39]

The purpose of PECP-5 (ALQ-16) is to prevent mechanical shock and vibration damage to transformer T-1501 (P/N 55-119410-1) and reactor L-1504 (P/N 56-121594-1). (These are parts of the transformer assembly used in the HV Power Supply of the Aft T-4 Driver Amplifier.) The modification has been accepted by WRAMA Service Engineering without a service test. The modification will be installed fleet-wide upon receipt of Command Decision and Modification Review Board approval.

4.4 Special Investigation of Type 6111 Tubes [55]

4.4.1 Background

The initial interviews of shop and depot personnel concerning problems in the Locked Oscillator Receiver indicated that the type 6111 tube might have a fundamental deficiency. Although a formal tube study was beyond the scope of the contract, the tube was evaluated to the extent possible in conjunction with the program effort.

Two basic problems were identified with the type 6111 tube: (1) high rate of failure at base level and (2) hand-selection procedures required to meet requirements of the AD Receiver. Initially, these findings appeared to lend support to the deficiency opinions concerning the tube, but a later investigation discounted them.

A complete report outlining the observations and analyses was made in April 1965. The report did not make specific recommendations regarding usage of type 6111 tubes, since the conclusions reached concerned only Sylvania tubes and were based on a limited sample size. Highlights of this report are contained in Sections 4.3.2 through 4.3.3.2.

4.4.2 Concluding Remarks of Type 6111 Tube Report [55]

The type 6111 tubes collected and laboratory tested were, with the exception of one Raytheon tube, manufactured by Sylvania. Therefore, conclusions reached in this investigation on tube deficiencies are limited to the Sylvania type 6111 tube.

It is apparent from the laboratory tests that the Sylvania tubes in this group failed primarily because of heater-to-cathode leakage. However, the seriousness of the problem at Bunker Hill AFB was amplified by the maintenance procedure of checking all tubes in a Locked Oscillator Receiver, using a Cardomatic 123A tube tester, each time the receiver was brought into the DECM shop for maintenance. DECM personnel used the Cardomatic 123A tester to determine if a tube of this sample group should be replaced. Forty-nine percent of the tubes in this group of rejects checked "good" in a subsequent ARINC Research laboratory test. It can be concluded that the Cardomatic is not satisfactory for this preventive type of maintenance. The indications are that the Cardomatic 123A is over sensitive on the "short" test. Because the "short"

indication was taken as a sufficient cause for rejecting a tube, the failure rate at Bunker Hill AFB greatly exceeded the failure rate at Little Rock AFB.

The design of the Sylvania heater will produce a more extensive magnetic field than a tube with another type of heater construction. The electric field around the heater can modulate the space current of both triode sections. However, there is no indication that the design of the Sylvania heater is causing a problem in the Locked Oscillator Receiver.

The 400-cycle hum problem in the AD Receiver is not related to any deficiency of the type 6111 tube, but results from V1101 (a 5718 type tube) picking up the 400-cycle hum from two principal sources: the video input test lead to J-1102 via ground-loop coupling in the SRA test station, and the heater circuit conduction within the chassis. The adverse effects this problem has on the performance of the receiver-gain characteristics crossover test can be eliminated by incorporating ARINC Research PECP-1 (ALQ-16).[13]

4.4.3 Related Programs and Tube Types

4.4.3.1 SGME Tube Study Plans

The Engineering and Technical Division (SGME) is in the process of contracting for an overall subminiature tube reliability improvement program. The end result of this program will be specifications that reflect end-usage conditions to which subminiature tubes are subjected in operational environments. The type 6111 tube would be one of the tubes studied. For this reason, it was not the purpose of this report to make specific recommendations regarding the usage of type 6111 tubes. Such recommendations will be made when appropriate, in connection with individual circuit reliability or maintainability problems.

4.4.3.2 Type 6111WA Tubes

The type 6111WA tube built to specification MIL-E-1/1270A, dated 20 August 1963, has a more stringent test requirement than the type 6111 tube regarding heater-cathode leakage, insulation of electrodes, heater current, and post shock-and-fatigue-test end points. Economic as well as engineering factors should be considered before use is made of the tube as a type 6111 replacement on an overall basis. Individual problem areas may be evaluated on the basis of failure data analysis, electrical circuit detailed stress analysis, and controlled-end usage tests to determine substitution feasibility where extensive failures in large populations have not occurred.

5. PROJECTED AND RECOMMENDED EFFORT IN OTHER AREAS

This section provides a brief discussion of those areas that should be designated for full-scale efforts in support of the current B-58 Reliability Improvement Programs. The recommendations for corrective engineering action on additional subsystems, test procedures and test equipment, and increased application of modeling techniques could all be implemented within the organizational framework currently provided.

5.1 Correctional Engineering for Additional Subsystems

The limits established by the contract and engineering manpower limitations imposed by budgeting requirements have precluded analysis and correction of reliability problems within the electronic subsystems of the B-58 aircraft, other than the Doppler Radar and DECM subsystems. Some of these deficient areas, as identified by the Data Collection Program, would benefit by the same engineering analysis and investigation methods that were applied to the APN-113 and ALQ-16 DECM subsystems. Since much of the preliminary work -- that is, data collection -- has been accomplished, an ambitious program should bring rapid improvement.

Analysis of available data on the Search Radar subsystem indicates a current MTBF of approximately half the theoretical value. Further, application of the reliability model in which this subsystem was used identified three LRU's that limit the reliability of the Search Radar significantly -- the ICU, the Receiver-Transmitter Modulator (RTM), and the Antenna Assembly. The WRAMA projects to improve the Search Radar will eliminate most of the defects in the Antenna Assembly; however, the following problems in the other two

LRU's should be investigated and corrected as part of an overall subsystem improvement program:

(1) ICU overheat problems related to individual unit internal problems, to general air conditioner performance, and to semiconductor device failures

(2) ICU adjustment and testing procedures

(3) Interrelation of waveguide pressure leaks to failure of the magnetron on the RTM

The reliability model for the AN/ASQ-42(V) shows that a major overall redesign effort would be necessary to improve sufficiently the reliability of the computer and stabilization equipment functions most important to mission reliability. However, on the basis of data reviewed to date, updating of certain major parts used in those LRU's for which redesign is not essential would improve the performance significantly. This would also reduce many "no malfunctions found" types of maintenance actions and accrue the benefits of decreased equipment handling.

Increased effort, directed toward detailed analysis of available data in the ARINC Research files for additional subsystem problems, can provide similarly oriented guidance for corrective engineering action.

5.2 Test Procedures and Equipment Review

To be realistic and truly effective, a reliability and maintainability study must encompass related test equipment, procedures, and conditions of use. In the B-58 project to date, such studies have not been within the scope of contract effort, although many observations and suggestions in this area have been made. Observations by company field engineers in this area indicate that such a course of action is necessary. The investigation should cover the following general task outline:

(1) Evaluate the utility of flight-line test equipment in terms of available turnaround time.

(2) Investigate the adequacy of test equipment to analyze consistently known, frequently experienced failure modes.

(3) Investigate test-tape sequence optimization and examine the applicability of test specifications.

(4) Determine the extent to which environment was considered in test equipment design, and what effect this may have on maintenance. (The two Bomb Wings work under radically different climatic conditions at times.)

(5) Determine to what extent the environment in which the aircraft equipment is used is duplicated by test equipment, and define the instances where this is necessary.

(6) Determine what effect omission of certain equipments and tests would have on the quality of maintenance.

(7) Evaluate the technical accuracy and efficiency of the technical data governing use and repair of test equipment.

5.3 Increased Application of Modeling Techniques

Thus far, modeling activities in support of the B-58 Avionic Subsystems Reliability and Maintainability Improvement Program have been extremely limited. Modeling has been demonstrated to be a useful tool for further guiding the direction and priorities of the engineering work effort. Such an approach could be expected to provide information that would show exactly where funds for B-58 improvement will yield the greatest benefit in terms of system effectiveness, operational readiness, maintenance workload, and overall cost of ownership for the system.

Modeling studies to provide information, as outlined above, should be conducted in the following areas:

(1) A complete B-58 Avionics Functional Reliability Model related to actual war plan mission profiles to show the relationship between overall B-58 avionic reliability and the reliability of each of the avionic subsystems

(2) An AN/ASQ-42(V) Operational Readiness Model to show the probability of flight-line readiness of the AN/ASQ-42(V) as a function of available turnaround time

(3) An AN/ASQ-42(V) System Effectiveness Model to consider the capability of the AN/ASQ-42(V) in its two principal operating modes, its reliability in these modes, and its flight-line readiness. (The combined effect would yield a probability of satisfactory mission performance.)

(4) An AN/ASQ-42(V) Cost-of-Ownership Model to show the relationship between AN/ASQ-42(V) reliability, maintainability, and maintenance cost

(5) Optimization Models to utilize the preceding studies, as required, to define explicitly the relationships between such factors as effectiveness, reliability, and cost

Development of these models would permit rapid determination of the effect, in terms of the several model outputs, of achieving improvement program goals, in addition to the current status of each of the model parameters.

APPENDIX A

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APPENDIX A

BIBLIOGRAPHY

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24. LRU Condition-on-Arrival Report (Reference SAT-43) (Final Copy), 6 August 1964.(Attached to Fifth Status Letter)

25. Report on Trip to San Antonio Air Materiel Area (SAAMA) on TWT and Klystron Problems, 20-21 August 1964 (ED 64-056); 8 September 1964.(Attached to Sixth Status Letter)

26. Report on Trip to San Antonio Air Materiel Area (SAAMA) on APN-113 Temperature Recorder Installation and Doppler Radar System Failure Modes, 23-27 August (LRAFB 64-07); 28 August 1964. (Attached to Sixth Status Letter)

27. Analysis of Mechanical Failure of the Motor-Driven Data Converter Assembly, P/N U-204244, used in the AN/APN-113 Doppler Radar, ED 64-042; 9 September 1964. (Attached to Sixth Status Letter)

28. PECP-2 (ALQ-16) - Modification of Trapezoidal Generator Circuit/Generator Programmer Assembly/Receiver Locked Oscillator/ASQ-16, 31 August 1964. (Attached to Sixth Status Letter)

29. LRU Monthly Condition Report for August 1964, Kelly Air Force Base, 8 September 1964. (Attached to Sixth Status Letter)

30. Handouts for the B-58 Reliability Conferences, October 1964:
    (a) Theoretical Curve-Reliability of the AN/ASQ-42
    (b) Theoretical Curve-Reliability of the Search Radar
    (c) Theoretical Curve-Reliability of the Doppler Radar
    (d) Summary of the Project Fly-Rod ICU data
    (e) MTBF LRU Comparison Chart. (Attachment No. 1 to the Seventh Status Letter)

31. PECP-3 (ALQ-16) - (Attachment No. 2 to the Seventh Status Letter)

32. PECP-4 (ALQ-16) - (Attachment No. 3 to the Seventh Status Letter)

33. ARINC Research Corporation Memorandum (Reference SAT-64-52). Subject: Periodic Maintenance of the PNSU. (Attachment No. 4 to the Seventh Status Letter).

34. ICU Temperature Test Report (Rough draft submitted informally 14 October 1964; final draft in process.)

35. Copy of flip chart used at the B-58 Reliability Conference, Barksdale AFB, Louisiana; 14-15 October 1964. (Attachment No. 1 to Eighth Status Letter)

36. Values of Theoretical MTBF as required by contract, Part I, paragraph 1-b(2). (Attachment No. 2 to Eighth Status Letter)

37. Preliminary Engineering Analysis on Improved Overload Performance of High-Voltage Power Supply/APN-113. (Attachment No. 3 to Eighth Status Letter)

38. Interim Report on Doppler Temperature Recorder Task (Preliminary Data). Reference ARINC Research file, LRAFB 64-47; 13 November 1964. Submitted to WRAMA 27 November 1964.

39. PECP-5 (ALQ-16) - Mounting Brackets (Stiffners) for Transformer T-1501, P/N 55-119410-1; Part of Driver Amplifier High-Voltage Power Supply Assembly, P/N 89-136553-1/AFT-T4 (ALQ-16). (Attachment No. 1 to Ninth Status Letter)

40. Klystron Assembly Tests/APN-113 Performed by the SRA, Kelly Air Force Base, October-November 1964. (Attachment No. 2 to Ninth Status Letter)

41. ECP-1 (APN-113)-Modification of Terminal Boards on Filament Transformer, T-3/Power, and Signal Distribution Panel/(AN/APN-113, Doppler Radar). (Attachment No. 3 to Ninth Status Letter)

42. Trip Report to Canadian Marconi Company. (Attachment No. 4 to Ninth Status Letter)

43. Proposed Group of Doppler Fixes. (Attachment No. 1 to Tenth Status Letter)

44. Analysis of Depot Repair Report Data on AN/APN-113 Doppler Radar Subsystem. (Attachment No. 2 to Tenth Status Letter)

45. Trip Report to Bendix Corporation. (Attachment No. 3 to Tenth Status Letter)

46. PECP-1 (APN-113)-IF Amplifier-Frequency Converter Temperature Controller, 9 February 1965

47. PECP-2 (APN-113)-Change in High-Voltage Power Supply Depot Maintenance Procedures to Add a Diaphragm Sealant Compound, 22 March 1965

48. PECP-3 (APN-113)-Doppler Radar Set AN/APN-113, Modification of the Regulator Tube Subassembly in the High-Voltage Power Supply Doppler Radar/APN-113; 18 March 1965

49. PECP-4 (APN-113)-Doppler Radar Set AN/APN-113, Modification of the Safety Relief Valve of the High-Voltage Power Supply; 18 March 1965

50 Field Engineering Notes Concerning the Carrier and Lower Sideband Suppression Tests on an IFFC LRU on the RLRUTS Unit at the SRA, 19-21 March 1965. (Attachment No. 1 to Thirteenth Status Letter)

51. Notes on HVPS/APN-113 Oil-Filling Station Operation by ARINC Research Corporation Field Engineers, 18 March 1965. (Attachment No. 2 to Thirteenth Status Letter)

52. PECP-5 (APN-113)-Additional Test Point for the Klystron Frequency Control LRU and New Flight-Line Test Procedures, 20 April 1965

53. PECP-6 (APN-113)-Overload Capability Unit for the High-Voltage Power Supply, 6 May 1965

54. On-Aircraft Temperature Tests on the Indicator Console Unit (ICU) AN/ASQ-42 Weapon Control System (Final Report), 27 November 1964

55. Type 6111 Tube Problem Investigations Report, 2 April 1965

56. Analysis of the AN/APN-113 Doppler Radar Set Unlock Problem (Final Report), May 1965

57. Engineering Analysis ALQ-16 Power Amplifier High-Voltage Power Supply. (Attachment No. 1 to Fourteenth Status Letter)

58. PECP-6 (ALQ-16)-Elimination of D-C Return in ALQ-16 Power Amplifiers LH-T4 and AFT-T4, 3 February 1965

59. PECP-8 (ALQ-16)-RF Connector Adapter in the Power Amplifier/ALQ-16 AFT-T4, 2 March 1965

60. PECP-7 (ALQ-16)-Proposed Changes to T.O 12P3-4-3-103 on TWT V1892 (Overhaul Manual AN/ALQ-16 Power Amplifier), 3 February 1965

61. *Observed Operational* MTBF Values and Failure Data for B-58 Avionic Subsystems, July 1965

62. PECP-7 (APN-113) - Change of Thermostatic Switches on the Ferrite Modulators, 29 June 1965

63. PECP-8 (APN-113) - Modification of the Rectifier Tube Subassembly 2769-5005G1, 29 June 1965

64. PECP-9 (APN-113) - Change of Counter Oven Thermostat in Waveform Converter, 29 June 1965

65. PECP-10 (APN-113) - Improved Heater Switch for the Mixer Stage, Z1, 29 June 1965

APPENDIX B

LIST OF EQUIPMENT ASSIGNED BY CONTRACT FOR INVESTIGATION

APPENDIX B

LIST OF EQUIPMENT ASSIGNED BY
CONTRACT FOR INVESTIGATION

1. Subsystems

The following subsystems were assigned for investigation by the contract:

(1) AN/APN-135 Beacon Radar

(2) AN/APX-47 IFF

(3) AN/APN-136 Beacon Radar

(4) AN/ARC-74 Emergency UHF Communication

(5) AN/ARN-69 Instrument Landing System, including ID-660

(6) AN/APN-113 Doppler Radar

(7) AN/APN-110 Radio Altimeter

(8) AN/ASQ-42(V) Weapons Control System (Offensive)

(9) MD-7 Fire Control System

(10) AN/ALQ-57 DECM, including AN/ALE-16, AN/ALR-12, AN/ALQ-16 (T-2 RH, T-4 LH, T-4 Aft)

(11) AN/ASH-17 Data Recording System

(12) AN/ARC-57 UHF Command Set

(1) APN-113 Doppler Radar Subsystem

(a) Klystron Frequency Control (LRU), P/N 2764-5023G3

(b) IF Amplifier-Frequency Converter (LRU), P/N 2771-5017G6

(c) AF-IF Amplifiers (LRU's), P/N's 2762-5011G1, -5011G2

(d) Frequency Trackers (LRU's), P/N's 2763-5028G3, -5028MD1, -5028G4

(e) Power and Signal Distribution Panels (LRU's), P/N's 2768-5063G1, -5063G2

(f) Klystron Assembly (LRU), P/N 2778-5011G1

(g) Coherency Test Unit (LRU), P/N 2765-5003G4

(h) Klystron Temperature Control (LRU), P/N 2770-5005P4

(2) ALQ-16 DECM, T-2 RH Subsystem

(a) Locked Oscillator Receiver (LRU), P/N 02-137070-1

(i) Modulator Receiver (Subassembly), P/N 89-136066-1

(ii) AD Receiver (Subassembly), P/N 89-136076-1

(iii) Generator Programmer (Subassembly), P/N 89-137083-1

(iv) HV Power Supply (Subassembly), P/N 89-119116-3

(v) Programmer Delay (Subassembly), P/N 89-129767-4

(vi) Electron Tube and Cap Assembly, P/N 13-136193-1

(b) Driver Amplifier, P/N 02-129930-1

(i) HV Power Supply (Subassembly), P/N 89-129951-1

(ii) Electron Tube and Cap Assembly, P/N 13-136066-3

(c) Power Amplifier, P/N 02-137090-2

(i) HV Power Supply (Subassembly), P/N 89-129953-3

(ii) Generator Range Receiver (Subassembly), P/N 89-137092-1

(iii) Electron Tube Network Assembly, P/N 89-129600-2

(d) Solenoid Power Supply, P/N 02-136267-4; and Power Supply Assembly, P/N 89-136685-1

(3) ALQ-16 DECM, T-4 LH Subsystem

(a) Locked Oscillator Receiver (LRU), P/N 02-136166-8

(i) Programmer Generator (Subassembly), P/N 89-137083-1

(ii) Pulse Amplifier (Subassembly), P/N 89-136541-2

(iii) Delay Programmer (Subassembly), P/N 89-129767-4

(iv) Electron Tube and Cap Assembly, P/N 13-136358-1

(b) Driver Amplifier (LRU), P/N 02-136356-1

(i) Voltage Regulator (Subassembly), P/N 89-131075-4

(ii) Electron Tube and Cap Assembly, P/N 13-136364-2

(c) Power Amplifier (LRU), P/N 02-136170-6

(i) Power Supply (Subassembly), P/N 89-137023-2

(ii) Pulse Generator Power Supply (Subassembly), P/N 89-119921

(iii) Range Receiver Generator (Subassembly), P/N 89-119946-2

(iv) Electron Tube and Cap Assembly, P/N 89-1296000-2

(d) Solenoid Power Supply (LRU), P/N 02-136348-2

(i) Relay Assembly, P/N 89-136886-1

(ii) Magnetic Preamplifier (Subassembly), P/N 89-136341-1

(iii) Magnetic Amplifier (Subassembly), P/N 89-119939-2

(4) ALQ-16 DECM, T-4 Aft Subsystem

(a) Locked Oscillator Receiver (LRU), P/N 02-136270-6

(i) BL Pulse Amplifier (Subassembly), P/N 89-136360-2

(ii) Electron Tube and Cap Assembly, P/N 13-136352-2

(iii) Generator Programmer (Subassembly), P/N 89-137083-1

(iv) Pulse Generator (Subassembly), P/N 89-186077-2

(v) Signal Generator (Subassembly), P/N 89-136359-1

(vi) Receiver Modulator (Subassembly), P/N 89-136075-2

(vii) Delay Programmer (Subassembly), P/N 89-129767-4

(viii) HV Power Supply (Subassembly), P/N 89-137197

(ix) AD Receiver (Subassembly), P/N 89-136076-1

(b) Driver Amplifier (LRU), P/N 02-136269-4

(i) HV Power Supply (Subassembly), P/N 89-136553-1

(ii) Voltage Regulator, P/N 89-136554-3

(iii) Electron Tube and Cap Assembly, P/N 13-136354-2

(c) Power Amplifier (LRU), P/N 02-136268-3

(i) HV Power Supply (Subassembly), P/N 89-137023-2

(ii) Pulse Generator Power Supply (Subassembly), P/N 89-119927-1

(iii) Voltage Regulator (Subassembly), P/N 89-136713-1

(iv) Electron Tube and Cap Assembly, P/N 13-13-137265-1

(v) Range Receiver Generator (Subassembly), P/N 89-119946-3

(5) AN/ASQ-42(V) Weapons Control System (Offensive)*

(a) Electronic Marker Trigger Generators, P/N's 3361-5023G1, -5023G2, -5023G3, -5025G1**

(b) Off-Center Deflection Generators, P/N's 3364-5025G1, -5027G1

(c) Gate Generators, P/N's 3362-5024G1, -5026G1

(d) Sweep Amplifier Resolver Generators, P/N's 3363-5023G1, -5023G2

* All LRU's and following assemblies.

** Part numbers for components (a) through (g) are Raytheon part numbers.

(e) Range Cross-Hair Generators, P/N's 3360-5025G1, -5025G2, -5025G3

(f) Magnetic Amplifier, P/N 2672-5001G3

(g) Video Amplifier, P/N 3861-5001G1

(h) Summing Amplifier, P/N 1782449

(i) Vertical Gimbal Amplifier, P/N 1782447

(j) Integrator Amplifier Assembly, P/N 1782960

(k) Coincidence Amplifier (CA-4-2), P/N 487137

(l) Magnetic Amplifier (M-1150-2), P/N 436620-3

(m) Integrator Amplifier (IAVPA-4-2), P/N 487139

(n) Coincidence Amplifier (CA-1-3), P/N 487136

(o) Magnetic Amplifier (M-1069-2), P/N 436621

(p) Electronic Amplifier (CRA-1-2), P/N 487158

(q) Feedback Amplifier (FA-7), P/N 615212

(r) Servo Amplifier (SA-VA-3-2), P/N 489575

(s) Amplifier (XA-2-2), P/N 487135

(t) Magnetic Amplifier (M-1068-2), P/N 436620-2

(u) Feedback Amplifier (FA-15), P/N 627665

(v) Voltage Preamplifier (SAVPA-4), P/N 485295

(w) Servo Power Amplifier (SA-2-3), P/N 490187

(x) Servo Preamplifier (SAPA-2-4), P/N 489531

(y) Accelerometers, P/N's 1501033-1, 1504982, 1507962-1

(z) Feedback Amplifiers (FA-12-3), P/N's 486849, 490509

(aa) Control Motors (B-1 through B-6), P/N 742446-2

(bb) Slant Range Assemblies, P/N's 495108-1, 491444, 491444MD1, 490271

(cc) Magnetic Amplifier (M-1214), P/N 436622

(dd) Motor Generators (MG-2, -3, -6, -7), P/N 489565-1

(ee) Front End Assemblies, Fixed-Point Longitude, P/N's 491132, 490228, 495114-1

(ff) Integrator Assembly, P/N 489226

(gg) Sidereal Hour Angle Counter Assemblies, P/N's 486035, 490179, 495101

APPENDIX C

SUBSYSTEM MTBF VALUES ADJUSTED BY TIMER READINGS

APPENDIX C

SUBSYSTEM MTBF VALUES ADJUSTED BY TIMER READINGS

To increase the accuracy of observations in the B-58 environment, a sample of elapsed time indicator (ETI) readings was obtained from 19 subsystem timers in each of 49 aircraft. Evaluation of these readings and direct observation determined that only 85% of the timer positions produced valid readings. The remaining 15% fell into three categories: (1) no timer installed, (2) timer disconnected by Time Compliance Technical Order (TCTO), or (3) timer defective. Corrective action was initiated by maintenance personnel at each base when they were advised of the location of defective timers.

Readings were obtained on an "as available" basis, and each set of readings, together with the corresponding airframe hours, was compared with previous readings to ascertain differences. The ratio of timer change to airframe hour increase was then computed to provide adjustment factors for each subsystem, except for the three AN/ALQ-16 (DECM) "T" subsystems. Timer readings for these subsystems were determined to be unreliable since many of the timers had been disconnected by TCTO or rewired to monitor a specific function; or they were energized only during radiate periods (high-voltage application) and were thus unrelated to the basic electrically energized time.

Each timer on the aircraft timer panel is linked to a specific subsystem by a number. Timer numbers and corresponding subsystems observed during the study are shown in Table C-1. Also shown in Table C-1 are the percentage ratios of ETI hours to aircraft flight hours corresponding to the various sybsystems.

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TABLE C-1

SUMMARY OF B-58 TIMER OBSERVATIONS

Timer Number	Equipment	Percent $\left(\frac{\text{ETI}}{\text{Aircraft}}\right)$	Number of Readings	Percent "No-Change" Readings
1	AN/ARC-57	107.9	74	-
2	AN/ARN-65, AN/ARN-69	119.0	68	-
3	AN/ALQ-16(T-2RH)	Readings Invalid	50	-
4	AN/ALQ-16(T-4LH)	Readings Invalid	83	-
5	AN/ALQ-57, AN/ALR-12	73.4	77	6.5
6	ASH-17	105.8	72	1.4
7	AN/APN-110	34.2	78	7.7
8	AN/ASQ-42(V), Astro Tracker	140.0	74	1.3
9	AN/APN-113	142.0	75	1.3
10	AN/ASQ-42(V), Search Radar	112.9	85	2.4
11	AN/ASQ-42(V), Stabilizing Equipment	144.3	65	1.5
12	AN/ASQ-42(V), Navigation Computer	164.8	67	1.5
13	AN/APX-47	111.8	66	1.5
16	MD-7	49.9	72	-
18	AN/APN-135	51.0	76	2.6
19	AN/APN-136	22.1	79	12.6
20	AN/ARC-74	2.6	86	58.1
32	AN/ALQ-16(T-4 Aft)	Readings Invalid	22	-
33	AN/ALE-16	5.0	40	17.4

The number of readings of each timer is given, and the percentage of readings that indicated no change from previous reading is recorded. The ETI to aircraft ratios approximate the modal value, or most commonly occurring value, of the set of ratios determined from all the 49 aircraft for each subsystem.

Adjusted MTBF's for both aircrew-reported and ground-crew-discovered failures were computed from data acquired as outlined above. The adjustment was applied to the combined airframe hours for Little Rock and Bunker Hill AFB's, by use of a factor equal to the mean ratio of clock hours to airframe hours, for each subsystem or LRU for which valid clock readings were available. All computations were based on the assumption of an exponential distribution, and each level of complexity was considered an individual entity; that is, regardless of the number of LRU's or assemblies involved in the maintenance of a single subsystem, it was considered as only one subsystem failure. A similar method was used for LRU and assembly MTBF computations.

Observed MTBF's at the subsystem level are presented in Figure C-1. As previously stated, no adjustment factor was applied to the three AN/ALQ-16 (DECM) "T" subsystems. Complete data for all levels of surveillance on the B-58 avionic subsystems are being supplied to WRAMA as a separate report coincident with the submission of this report.

* No adjustment factor applied.

FIGURE C-1

CURRENT B-58 OBSERVED AVIONIC SYSTEM AND SUBSYSTEM MTBF'S

APPENDIX D

BASIC "FLY-ROD" INFORMATION AND ACQUISITION AND TABULATION OF ARINC RESEARCH MTBF DATA

APPENDIX D

BASIC "FLY-ROD" INFORMATION AND ACQUISITION AND TABULATION OF ARINC RESEARCH MTBF DATA

1. Basic "Fly-Rod" Information

The basic purpose of the "Fly-Rod" program was (1) to provide lower operating temperatures within a selected group of high-failure-rate components of the ASQ-42(V), and (2) to determine the failure-rate reduction. The selected aircraft, 15 in number, were separated into three groups and designated Groups "A", "B", and "C".

(1) Group "A". Five aircraft were modified so that the selected high-failure rate components were supplied additional cooling air, and thus operated at lower temperatures during both flight and ground operations.

(2) Group "B". Five aircraft were modified by installing a warning device designed to preclude operation, while the aircraft are on the ground, of the high-failure avionic components without normal cooling air being supplied.

(3) Group "C". Five aircraft were selected as a control group and were not modified. Special record-keeping functions were applied to these aircraft as well as to the 10 in Groups "A" and "B".

2. Acquisition and Tabulation of ARINC Research MTBF Data

The ARINC Research data acquisition program for the B-58 was adapted to support the "Fly-Rod" program and make computations on the observed MTBF data. Interim reports on

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AD-A054 600 ARINC RESEARCH CORP WASHINGTON D C F/G 1/3
B-58 AIRCRAFT AVIONIC SUBSYSTEMS RELIABILITY AND MAINTAINABILIT--ETC(U)
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UNCLASSIFIED 318-01-2-480 NL

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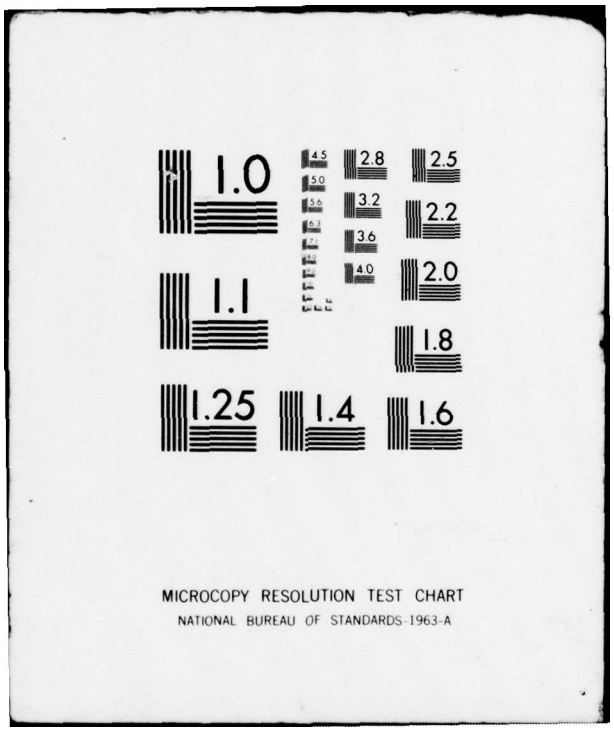
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6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

"Fly-Rod" were supplied to the contracting agency during the course of the ARINC Research project. Data on the complete "Fly-Rod" program are shown in Table D-1. The data in the table summarize the in-flight performance of five groups of aircraft as tabulated below:

Group Number	Group Name	Number of Aircraft	Total Flights	Total Flight Hours
1	Fly-Rod "A"	5	146	912.6
2	Fly-Rod "B"	5	167	1035.2
3	Fly-Rod "C"	5	173	1089.9
4	Other, Little Rock	30	249	1517.9
5	Bunker Hill	44	578	3672.0

The only subsystems reported in Table D-1 were those in which one or more LRU's were directly affected by Group "A" modifications. All of the major LRU's were reported for each of the subsystems being evaluated.

The MTBF summary represents subsystem and LRU performance based upon accumulated flight time, operator (aircrew) complaints, and a simple level of verification, which is evidenced by the performance of any corrective maintenance following a complaint, other than "no malfunction found".

Blank spaces in the MTBF table indicate that there were no failure observations for that group item.

Confidence intervals were computed for each MTBF to facilitate an evaluation of the differences noted among the five aircraft groups.

Evaluation of these data and the significant statistical difference charts (made to facilitate comparison between the "Fly-Rod" groups), provided at the completion of the task, was accomplished by the contracting agency.

TABLE D-1

SUMMARY OF MTBF'S FOR "FLY-ROD" PROGRAM

Item Name	Fly-Rod A			Fly-Rod B			Fly-Rod C			Other, LR AFB			BH AFB		
	UCL	MTBF	LCL	UCL	MTBF	LCL	UCL	MTBF	LCL	UCL	MTBF	LCL	UCL	MTBF	LCL
ASQ-42(V) Computer-Stabilization Equipment	11.2	9.2	7.6	10.6	8.8	7.4	9.1	7.7	6.6	8.9	7.8	6.8	10.1	9.1	8.3
Astro Panel	324.0	152.0	69.9	105.0	64.7	39.8	265.0	136.0	69.2	220.0	126.0	72.4	181.0	127.0	88.2
Indicator Panel	109.0	65.2	38.6	84.9	54.5	34.9	58.6	40.4	27.7	93.7	63.2	42.5	79.1	61.2	47.7
Offset-Storage Panel	837.0	304.0	104.0	368.0	172.0	79.3	1760.0	545.0	151.0	539.0	253.0	116.0	168.0	118.0	83.4
Navigation Control Panel	264.0	130.0	63.4	150.0	86.3	49.4	83.8	54.5	35.2	153.00	94.9	58.4	121.0	89.6	66.0
Sighting-Test Panel	132.0	76.1	43.6	67.2	45.0	30.0	61.2	41.9	28.6	89.3	60.7	41.1	80.6	62.2	48.4
Navigation Rack	66.1	43.5	28.4	53.4	37.0	25.6	49.8	35.2	24.8	41.9	31.6	23.8	85.5	65.8	50.7
Heading Rack	324.0	152.0	69.9	216.0	115.0	60.6	83.8	54.5	35.2	117.0	75.9	49.1	252.0	167.0	110.0
Sighting Rack	92.2	57.0	35.1	105.0	64.7	39.8	176.0	99.1	55.3	198.0	117.0	68.2	137.0	99.2	72.0
Steering Rack	79.7	50.7	32.1	150.0	86.3	49.4	89.3	57.4	36.8	54.7	39.9	29.1	238.0	160.0	106.0
Sighting Range Rack	79.7	50.7	32.1	84.9	54.5	34.9	67.3	45.4	30.6	124.0	79.9	51.2	62.5	49.6	39.6
Voltage Regulator Rack	415.0	182.0	78.3	300.0	148.0	71.9	142.0	83.8	48.9	198.0	117.0	68.2	480.0	282.0	165.0
Airspeed Computer Rack	147.0	83.0	46.3	216.0	115.0	60.6	102.0	64.1	40.1	245.0	138.0	77.0	156.0	111.0	79.2
Precision Frequency Source	3770.0	913.0	164.0	4280.0	1040.0	187.0		------		2450.0	759.0	211.0		------	
Tracking-Flight Control Unit	3770.0	913.0	164.0	471.0	207.0	88.9	4500.0	1090.0	196.0	1390.0	506.0	173.0	1060.0	525.0	255.0
Auxiliary Control Panel		------		4280.0	1040.0	187.0	4500.0	1090.0	196.0	2450.0	759.0	211.0	3370.0	1220.0	420.0
Stabilization Computer Unit	1470.0	456.0	127.0	4280.0	1040.0	187.0	671.0	272.0	106.0	317.0	169.0	88.8	766.0	408.0	215.0
Stabilization Amplifier Unit	109.0	65.2	38.6	368.0	172.0	79.3	119.0	72.7	44.0	124.0	79.9	51.2	115.0	85.4	63.4
Prime Navigation Stabilization Unit	147.0	83.0	46.3	300.0	148.0	71.9	119.0	72.7	44.0	110.0	72.3	47.3	137.0	99.2	72.0
Stabilization Computer Amplifier	222.0	114.0	57.9	252.0	129.0	65.7	74.6	49.5	32.7	133.0	84.3	53.3	168.0	118.0	83.4
Auxiliary Reference Unit	99.7	60.8	36.9	300.0	148.0	71.9	130.0	77.9	46.1	93.7	63.2	42.5	137.0	99.2	72.0
Malfunction Control Panel	3770.0	913.0	164.0		------		1760.0	545.0	151.0	690.0	304.0	130.0	2260.0	918.0	358.0
ASQ-48(V) (Astro Tracker)	66.1	43.5	28.4	70.9	47.1	31.1	58.6	40.4	27.7	85.3	58.4	39.8	65.4	51.7	41.1
Astro Tracker	415.0	182.0	78.3	950.0	345.0	118.0	387.0	182.0	83.6	439.0	217.0	105.0	252.0	170.0	110.0
Astro Tracker Amplifier	85.7	53.7	33.5	84.8	54.5	34.9	89.3	57.4	36.8	117.0	75.9	49.1	76.2	59.2	46.3
ALQ-16 (T-4LH)	132.0	76.1	43.6	216.0	115.0	60.5	158.0	90.8	52.0	245.0	138.0	77.0	132.0	96.6	70.4
Receiver Locked Oscillator	562.0	228.0	89.0	368.0	172.0	79.3	387.0	182.0	83.6		------		216.0	147.0	100.0
Driver Drawer	1470.0	456.0	127.0	1670.0	518.0	144.0		------		2450.0	759.0	211.0	766.0	408.0	215.0
Power Amplifier Drawer	415.0	182.0	78.3	4280.0	1040.0	187.0	1000.0	363.0	125.0	934.0	379.0	148.0	480.0	282.0	165.0
Solenoid Power Supply		------		1670.0	518.0	144.0	1000.0	363.0	125.0	1390.0	506.0	173.0	1300.0	612.0	281.0
ALQ-16 (T-4Aft)	132.0	76.1	43.6	368.0	172.0	79.3	158.0	90.8	52.0	142.0	89.3	55.8	97.3	73.4	55.9
Receiver Locked Oscillator	837.0	304.0	104.0	471.0	207.0	88.9	495.0	218.0	93.6	539.0	253.0	116.0	238.0	160.0	106.0
Driver Drawer		------		4280.0	1040.0	187.0		------		2450.0	759.0	211.0	532.0	306.0	175.0
Power Amplifier Drawer	324.0	152.0	69.9	4280.0	1040.0	187.0	1760.0	545.0	151.0	690.0	304.0	131.0	345.0	216.0	135.0
Solenoid Power Supply	562.0	228.0	89.0	1670.0	518.0	144.0	495.0	218.0	93.6	1390.0	506.0	173.0	401.0	245.0	148.0
ARN-64 (TACAN)	147.0	83.0	46.3	105.0	64.7	39.8	130.0	77.9	46.1	104.0	69.0	45.6	68.7	54.0	42.7
TACAN Receiver-Transmitter	222.0	114.0	57.9	135.0	79.6	46.6	158.0	90.8	52.0	133.0	84.3	53.3	97.3	73.4	55.9
APN-113 Doppler Radar	45.1	31.6	21.9	30.7	23.0	17.2	28.9	21.8	16.6	27.9	22.0	17.4	23.5	20.3	17.5
IF Amplifier-Frequency Converter	324.0	152.0	69.9	471.0	207.0	88.9	495.0	218.0	93.6	1390.0	506.0	173.0	206.0	141.0	96.4
Ripple Filter	3770.0	913.0	164.0		------		1000.0	363.00	125.0	690.0	304.0	130.0	650.0	367.0	200.0
Transmitter Antenna Assembly	3770.0	913.0	164.0		------		1000.0	363.0	125.00	690.0	304.0	130.0	3370.0	1220.0	420.0
AF-IF Amplifier	415.0	182.0	78.3	4280.0	1040.0	187.0	495.0	218.0	93.6	2450.0	759.0	211.0	118.0	87.4	64.7
Frequency Tracker (3)	498.0	274.0	149.0	202.0	135.0	90.0	280.0	182.0	115.0	312.0	207.0	137.0	327.0	245.0	180.0
Klystron Frequency Control	3770.0	913.0	164.0	1670.0	518.0	144.0	387.0	182.0	83.6	220.0	126.0	72.5	59.8	47.7	38.2
Waveform Converter		------		4280.0	1040.0	187.0	1760.0	545.0	151.0	2450.0	759.0	211.0	437.0	262.0	155.0
Power and Signal Distribution Panel	415.0	182.0	78.3	300.0	148.0	71.9	227.0	121.0	63.7	439.0	217.0	105.0	121.0	89.6	66.0
High-Voltage Power Supply	1470.0	456.0	127.0	471.0	207.0	88.9	671.0	272.0	106.0	539.0	253.0	116.0	141.0	102.0	73.7
Velocity Computer Power Supply	837.0	304.0	104.0	637.0	239.0	101.0	1000.0	363.0	125.0	317.0	169.0	88.8	109.0	81.6	61.0
Coherency Test Unit	264.0	130.0	63.4	637.0	239.0	101.0	315.0	158.0	75.7	317.0	169.0	88.8	345.0	216.0	135.0
Klystron Temperature Control	1470.0	456.0	127.0		------		4500.0	1090.0	196.0	6270.0	1520.0	273.0	2260.0	918.0	358.0
ASQ-42(V) (Search Radar)	18.9	14.7	11.5	15.7	11.1	9.1	14.4	11.7	9.6	15.3	12.8	10.7	14.5	12.9	11.5
Receiver-Transmitter-Modulator Unit	78.7	54.7	38.1	75.0	49.3	32.2	67.3	45.1	30.5	58.3	42.2	30.4	71.0	55.6	43.9
Photo-Recorder Unit	264.0	130.0	63.4	97.2	60.9	38.1	119.0	72.7	44.0	98.6	66.0	44.0	50.3	40.8	33.3
Indicator Console Unit	38.7	27.7	19.7	33.3	24.6	18.2	30.8	23.3	17.4	32.1	24.9	19.4	33.3	28.0	23.7
Control Servo Unit	415.0	182.0	78.3	216.0	130.0	80.0	671.0	272.0	106.0	181.0	108.0	64.2	592.0	334.0	186.0
Indicator Power Supply		------		1670.0	518.0	144.0	1000.0	363.0	125.0	6270.0	1520.0	273.0	3370.0	1220.0	420.0

APPENDIX E

AN/ASQ-42(V) WEAPONS CONTROL SYSTEM RELIABILITY MODEL

APPENDIX E

AN/ASQ-42(V) WEAPONS CONTROL SYSTEM RELIABILITY MODEL

This appendix describes a mathematical modeling procedure, the Computerized Reliability Analysis Method (CRAM), which involves the use of a digital computer for the reliability study of the ASQ-42(V) Weapons Control System. The factors considered, and steps required, in the study are as follows:

(1) System environment and operational concepts

(2) Functional system description

(3) Steps in the modeling process to determine reliability impact

(4) Application

Two hypothetical situations are presented to show the adaptability and potential of this approach to reliability improvement.

1. System Environment and Operational Concepts

The B-58 presents a strenuous, if not challenging, environment to its equipment: space is limited, operating temperatures are high, and cooling air is rationed.

The AN/ASQ-42(V) Weapons Control System, in use since the late 1950's, is the bombing and navigation system for the B-58. In most instances, it uses subminiature tubes rather than transistors. Fundamentally, the ASQ-42(V) is an inertial guidance system with velocity, heading, and position-error corrective capabilities. While the system has degenerate mode redundancy,

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there are almost no completely redundant elements. Many of the prime functional blocks, however, can be replaced by dissimilar equipment, but of inferior performance characteristics. The system may or may not perform adequately when operating in degenerate modes. Adequate operation will depend upon such factors as mission requirements, the length of operation in degenerate modes, and the navigator's skill.

In general, the system is not packaged functionally. Rather, different elements and functions are contained in various LRU's, and most LRU's contain several functions. This situation, together with the substantial degenerate mode redundancy, makes intuitive evaluation difficult, if not impossible, in assessing the impact of LRU reliability improvement upon overall system reliability. In addition, the multifunction LRU's do not possess an overall reliability value in the usual sense. Therefore, MTBF figures for LRU's, while useful in maintenance and logistic analysis, cannot be used in the system reliability analysis. Instead, such analysis must be based upon the functional description of the system where both prime and redundant modes of operation are considered.

2. Functional System Description

Table E-1 lists the functions and elements that comprise the ASQ-42(V), together with the function symbols that are used in the model.

The Inertial Guidance System consists of two stable platforms: the Prime Inertial System and the Auxiliary Inertial System; the latter is inferior in performance. Outputs from either Inertial Guidance System are processed by the Course/Position Computer, which then provides numerical readouts of both the position and the heading required to follow a great-circle course to a more distant position.

TABLE E-1

ELEMENTS AND FUNCTIONS OF THE ASQ-42

Component Element	Symbol	Function
Prime Inertial System	PI	Inertial Guidance
Auxiliary Inertial System	AI	
Astro-Tracker	AT	Heading Correction
Remote Compass Transmitter (Flux Gate)	RC	
Doppler Radar	DR	Groundspeed Correction
Airspeed Computer	AS	
Search Radar	SR	Position Correction
Navigation Unit	CP	Course/Position Computer
Free-Fall Bombing Equipment	BB	Ballistic Bombing Computer

Long-term errors, due to drift within the Inertial Guidance System, can be corrected by the following means:

(1) Use of the Astro-Tracker or the Flux Gate Compass for heading correction

(2) Use of the Doppler Radar for groundspeed correction

(3) Use of the Search Radar for position correction

The computations necessary to determine the correct bomb-release point are performed by the Ballistic Bombing Computer in conjunction with the Course/Position Computer.

3. Modeling to Determine Reliability Impact

To determine which improved LRU's would have the greatest impact on mission reliability, a set of mathematical models is required. In order to portray specific aspects throughout the course of the mission, the individual reliability values for various system functions are first varied, and then the functions are analyzed in terms of LRU's which affect the function reliabilities. Were it not for the development (under a NASA contract) of CRAM, which reduces the computation time for model exercises from several days to a few minutes, the analysis would be expensive and time-consuming.

The detailed modeling procedure is as follows:

STEP 1. Define the System Configuration and Mission Profile. This step provides the basis for the remainder of the activity.

STEP 2. Construct Reliability Models for Each Mission Phase of Interest. Reliability diagrams are first prepared for each phase of the mission, starting with the initial phase. The succeeding diagrams must explicitly include the conditions for success from the preceding phases as well as for the phase to which the diagram is applicable. Success in the preceding phases always is necessary to obtain success in the remaining phases.

After the reliability diagrams are prepared, reliability equations are derived from the diagrams. For complex systems, the equations are first written in Boolean algebra. Then they are converted into an expression which gives reliability as the algebraic sum of those terms which contain reliability values for various system elements.

Conversion from the Boolean equation into the final expression can be tedious and time-consuming. A computer program, developed as part of CRAM, permits this operation to be performed by computer, if desired.

STEP 3. Determine the Failure Rate Values for Each Element. Failure rate values for system elements may be estimated, extrapolated from data of other systems, or derived from observed data for the system under study. The failure rate values for the present study come from observed part-failure data. These data were processed to ensure that only part failures resulting in a function loss during a mission were included.

STEP 4. Compute the Mission Reliability. Step 4 is the initial exercise of the model. Failure rate values are inserted into the reliability model for the phases of interest, and the overall mission reliabilities are computed. For the ASQ-42(V), reliability equations involve as many as 24 terms, each of which, in turn, is the product of as many as 10 variables.

The computations were performed on a 1401 computer and based on the CRAM program. Not only did the use of CRAM reduce costs and substantially shorten computation time, but it also greatly reduced the probability of manual errors. Similarly, errors that may occur during the preparation of the input data are readily detected.

STEP 5. Compute the Impact of Element Reliability Improvement on Mission Reliability. For each system function of interest, a hypothetical Improved Failure Rate Value is established. For this study, the Improved Failure Rate Value for each function was hypothesized as one-half of the Failure Rate Value observed. The Improved

Failure Rate Value for each function is then individually inserted into the reliability model, while the Failure Rate Values for the other functions are maintained at their original values. The computed Improved Mission Reliability thus reflects only the improvement due to the reliability improvement of one function for which an Improved Failure Rate Value has been used. It is emphasized that the entire computation must be repeated for each function, and that the use of a computer program such as CRAM is virtually imperative for a complex system.

STEP 6. Compute Reliability Improvement Index. The Reliability Improvement Index for each function is computed by dividing the Improved Mission Reliability of the function by its original Mission Reliability. All the functions are then ranked in order by the value of their Reliability Improvement Indices.

STEP 7. Rank Significant LRU's. The LRU's contributing 10% or more to the function's Failure Rate Value are ranked for each function with a significant Reliability Improvement Index. This step will reveal those LRU's which have the greatest effect on mission reliability.

STEP 8. Compute the LRU Improvement Required. This final step indicates the improvement required in the LRU's ranked in Step 7. The computation is performed by solving the following equation:

$$\text{Improvement Ratio required} = \frac{S}{S - 50},$$

where S is the total percentage contribution of the ranked LRU's to the total function failure.

4. Application

Two hypothetical studies were carried out. The initial study involved two rather basic system configurations, while the second utilized a much more complex configuration.

4.1 The Initial Study

The initial study was undertaken to show the utility of the approach and to emphasize the difference between the system's prime mode and a selected degenerate mode. The configurations are shown in Table E-2

TABLE E-2

SYSTEMS CONFIGURATIONS FOR THE INITIAL STUDY

PRIME MODE
Mission success requires the following functions:
PI
AT
DR
RA
SR
CP
BB (through Bomb Run)
DEGENERATE MODE
Mission success requires the following functions:
Either SR or (CP and
BB through Bomb Run, and
Either PI or AI, and
Either AT or RC, and
Either DR or AS)

There is no redundancy in the prime mode. In the degenerate mode, success of the Search Radar alone will fulfill the requirement for mission success. Mission success can also be obtained if:

(1) The Course/Position Computer and the Ballistic Bombing Computer do not fail, and

(2) There is no failure in (a) one of the two Inertial Guidance Systems, (b) one of the two heading correction elements, or (c) one of the two ground-speed correction elements

Table E-3 shows the mission profile hypothesized for the initial study. During certain mission phases, the Search Radar, the Doppler Radar, and the Astro-Tracker were not available. Since the reliability model does not permit use of unavailable equipments, the mission profile greatly reduces the redundancy available from the Search Radar. Mission success, however, could be obtained in a land-only mission with just the Search Radar operative in the degenerate mode.

TABLE E-3

MISSION PROFILE FOR THE INITIAL STUDY

Phase	Environment	Time (Hours)
1	Land	1.0
2	Sea	1.0*
3	Mirror sea	0.5**
4	Dusk at sea	0.5***
5	Bomb run over land	0.5
6	Sea	2.5*
7	Land	1.0
Total Mission Time		7.0

* SR not available.
** SR and DR not available.
*** SR and AT not available.

Table E-4 shows the Reliability Improvement Index for both the degenerate and prime modes. The Search Radar has a significant Reliability Improvement Index in the prime mode, but has almost no effect on mission reliability in the degenerate mode because of the limited utility of the Search Radar, as discussed above.

TABLE E-4

RELIABILITY IMPROVEMENT INDEX FOR THE INITIAL STUDY

Function	Prime Mode	Degenerate Mode
CP	1.37	1.33
SR	1.31	1.02
DR	1.16	1.00+
AT	1.12	1.00+
PI	1.09	1.00+

NOTE: Index for other functions was 1.00+.

4.2 The Second Study

The second study utilized a more complex system configuration and two somewhat simplified missions. The system configuration is shown in Table E-5. In this configuration the Transverse Coordinate Computer (CT) and the Normal Coordinate Computer (CN), which in the initial study were part of the Course/Position Computer (CP), were considered here as separate elements.

The Search Radar is not considered necessary for mission success as long as the Prime Inertial Guidance System, the Astro-Tracker, the Doppler Radar, the Course/Position Computer, the Ballistic Bombing Computer, and both Coordinate

Computers do not fail. Except during Phase 2, the Search Radar is required for mission success if any degenerate or redundant units, such as the Auxiliary Reference System, the Flux Gate Compass, and the Airspeed Computer, are used. The Search Radar also is required if either of the Coordinate Computers fail.

TABLE E-5

SYSTEM CONFIGURATION FOR THE SECOND STUDY

Mission success requires:

PI or (AI and SR), and

AT or (RC and SR), and

DR or (AS and SR), and

CR, and

BB (through the bomb run), and

CN and CP or

CN and SR or

CT and SR

The two mission profiles used for the second study are shown in Table E-6. Note that the Doppler Radar is essential during certain mission phases.

Table E-7 shows the Reliability Improvement Indices for the various elements through Phase 3, the bomb run. The indices were not substantially different for the complete mission. There is also little difference between the indices for Missions A and B.

TABLE E-6

PROFILES FOR MISSIONS A AND B

Mission A			Mission B		
Phase	Environment	Time (Hours)	Phase	Environment	Time (Hours)
1	Land	4	1	Land	4
2	Sea	3-2/3*	2	Sea	3-2/3*
3	Low level bomb run	1-1/3*	3	Bomb run	2/3
4	Land	1	4	Land	1
Mission Time through Bomb Run:		9 hours			8-1/3 hours
Total Mission Time:		10 hours			9-1/3 hours

* Doppler Radar is required during this phase.

TABLE E-7

RELIABILITY IMPROVEMENT INDEX FOR THE SECOND STUDY (THROUGH BOMB RUN)

Function	Improvement Index	
	Mission A	Mission B
CP	1.49	1.45
DR	1.25	1.22
SR	1.12	1.12
PI	1.06	1.05
AT	1.04	1.04

NOTE: Indices for other functions were less than 1.04.

As in the initial study, the Course/Position Computer has the largest effect on mission reliability. The requirement for the Doppler Radar during Phases 2 and 3 of Mission A, and Phase 2 of Mission B, results in a relatively high index for the Doppler Radar. Use of the Search Radar in any degraded mode also has a similar effect upon the Search Radar Index.

From the results of this study, it is apparent that both system configuration and mission profile have a significant effect upon the Reliability Improvement Index.

5. LRU Ranking

Table E-8 shows the ranking of the significant LRU's in the Course/Position Computer, the Doppler Radar, and the Search Radar.

The relatively low contribution of individual LRU's to the Course/Position Computer's Failure Rate Value indicates that there is no single specific group of LRU's in the Course/Position Computer where reliability improvement would have an appreciable effect on mission reliability.

In the Doppler Radar, only one LRU, the Frequency Tracker, contributes substantially to the radar's Failure Rate Value. Except for the Frequency Tracker, failure rate contributions are scattered throughout the other LRU's used.

In the Search Radar, however, three LRU's contribute over 90% of the failures; and, of these, two LRU's contribute over 75%. Here, mission reliability could be improved by a concentrated effort on three units. If a configuration and mission similar to the Prime Mode and Mission Profile of the initial study are used as a standard, a two-to-one failure rate improvement in each of these three LRU's would result in a 30%

improvement of mission reliability. If a system configuration and mission profile similar to either of those in the second study are used as a standard, the mission reliability improvement would be 12%.

TABLE E-8

SIGNIFICANT LRU RANKING

LRU	Percent of Failure Rate
Course/Position Computer (CP)	
Navigation Rack	16.4
Sighting Range Rack	14.8
Sighting Test Panel	13.2
Indicator Panel	12.8
Doppler Radar (DP)	
Frequency Tracker	33.8
Klystron Frequency Control	13.1
HV Power Supply	10.8
Search Radar (SR)	
Indicator Console Unit	51.6
Receiver-Transmitter Modulator	24.9
Antenna Unit	12.9

6. Conclusions

The study shows that precise definitions of system configuration and mission profile are necessary to analyze the impact of unit reliability improvement on mission reliability. In the hypothetical studies, analysis indicates that unit improvement of the Course/Position Computer would have the greatest impact upon overall mission reliability. The analysis also indicates that only the Search Radar appears readily capable of substantial improvement without an overall redesign effort.