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AVIONICS MAINTENANCE STUDY.(U)

JUN 77 P R OWENS, M R ST. JOHN, F D LAMB

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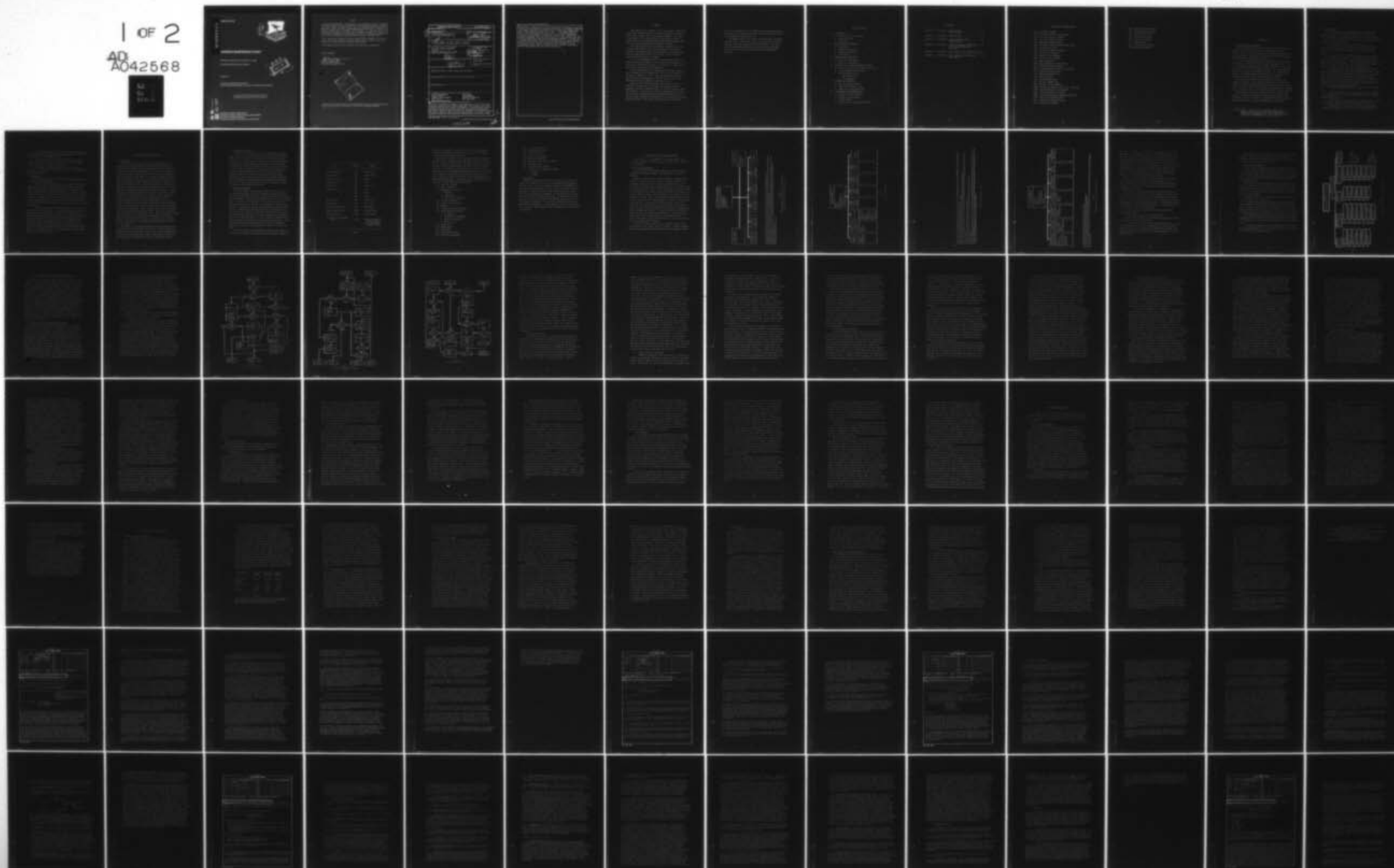

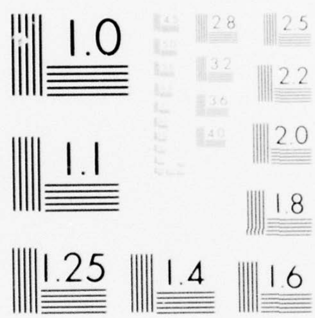

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AVIONICS MAINTENANCE STUDY

MAJOR P. R. OWENS, M. R. ST. JOHN, F. D. LAMB

ELECTRONIC TECHNOLOGY DIVISION

JUNE 1977

TECHNICAL REPORT AFAL-TR-76-90
FINAL REPORT FOR PERIOD 5 JANUARY 1976 THROUGH 30 JUNE 1976

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FOR THE COMMANDER:

Stanley E Wagner

STANLEY E. WAGNER, Chief
Microelectronics Branch
Electronic Technology Division

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFAL-TR-77-90	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): AVIONICS MAINTENANCE STUDY	5. TYPE OF REPORT & PERIOD COVERED: FINAL rept. 5 JAN 76 - 31 JUN 76
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Major P. R. Owens, M. R. St. John, F. D. Lamb	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: AIR FORCE AVIONICS LABORATORY, AFAL/DHE, WRIGHT-PATTERSON AFB, OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: P. E. 62204F, Project/Task/Work Unit 6096 05 72
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: June 1977
	13. NUMBER OF PAGES: 97
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AVIONICS MAINTENANCE
FAULT ISOLATION
AUTOMATIC TEST EQUIPMENT
BUILT IN TEST
MAINTENANCE ORGANIZATION
REPAIR DEPOT
MAINTAINABILITY
LOGISTICS SUPPORT COST
LIFE CYCLE COST

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Avionics maintenance has become a major contributor to the life cycle cost of weapons systems and this study was undertaken to gain insight into factors contributing to the cost of avionics maintenance. To become familiar with the procedures employed and operating conditions encountered in the operational Air Force, a team from the Air Force Avionics Laboratory visited several avionics maintenance squadrons, along with depot organizations at Air Logistics Centers. Through interviews with both supervisors and maintenance technicians at these

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organizations, a familiarization with the working level procedures was acquired. Similarities and differences in procedures, personnel, test equipment, complaints, and equipment supported at installations under different major commands were noted. A wide range of avionics from old, tube type equipment through the latest solid-state equipment just being introduced into the inventory was considered in the selection of organizations to be visited. Difficulties in obtaining replacement parts and dissatisfaction with test equipment were found to be the problems most often voiced by maintenance personnel. To persons from a laboratory environment, the age of some equipment still in use was shocking and the necessity for designing avionics to provide reliable service for 15 to 20 years was strongly realized. The need for early consideration of ATE requirements to insure rapid, cost-effective fault isolation in new avionics design is emphasized as one conclusion to the study.

FOREWORD

This report is an assessment of Air Force avionics maintenance as presently implemented and as it might be affected by changes in policy and procedures and by technology development. The intent of the report is to inform AF Avionics Laboratory management on current practices and identify actions the Laboratory might take to solve some of the known avionics maintenance problems.

The reader should bear in mind that the authors are not all-knowing. While each of us has been involved to some extent in electronics maintenance, most of the information contained herein has been gathered from others by interviews. This introduces several problems which are as follows:

First, is the problem of time. To gather perfect data would require forever since changes in the system occur continually, e.g., new systems entering the inventory. To be useful, a report must be written even if the data set is incomplete.

Second, imperfections are introduced into the data through all the ways humans have of coloring data. Most of this coloring is unconscious; some of it is not. Since the interview technique was the main source of information, we are passing on to the reader impressions we have of what many others have said.

Third, not all the data one might desire on the subject is presented. In some cases, the authors may not have asked the appropriate questions, while in others, the desired data was simply not available. Errors may also have been introduced into the data due to reliance on memory to avoid the inhibitory effect of note taking or tape recording in the presence of the maintenance personnel being interviewed. Very little statistical data are presented.

With all its imperfections, the authors believe the study presents an accurate and useful picture of the avionics maintenance process and the problems associated with it.

The authors thank all the people who provided the information contained herein. Without the facts and opinions they so frankly provided, this study could not have been completed. The authors take full responsibility for any errors which may have slipped into the report, and for the conclusions and recommendations presented.

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APPENDICES

DEFINITION OF ABBREVIATIONS

ADC - Air Defense Command

AFIT - Air Force Institute of Technology

AFLC - Air Force Logistics Command

AFSC - Air Force Speciality Code

AGE - Aerospace Ground Equipment

AGMC - Aerospace Guidance and Meterology Center

ALC - Air Logistics Center

AMS - Avionics Maintenance Squadron

ART - Air Reserve Technician

ATE - Automatic Test Equipment

BITE - Built-in Test Equipment

CND - Cannot Duplicate

DCM - Deputy Commander for Maintenance

ECP - Engineering Change Proposal

GPATS - General Purpose Analysis & Test System

GPS - Ground Processing System

INS - Inertial Navagation Set

LCC - Life Cycle Cost

LRU - Line Replaceable Unit

LSC - Logistics Support Cost

MAC - Military Aircraft Command

MADAR - Malfunction Analysis, Detection, & Reporting

MATE - Modular Automatic Test Equipment

NRTS - Not Replaceable This Station

PMEL - Precision Meausrement Equipment Laboratory

RADC - Rome Air Development Center

RIW - Reliability Improvement Center

SAC - Strategic Air Command

SEM - Standard Electronic Module

SHP - Standard Hardware Program

SPO - System Project Office

SRU - Shop Replaceable Unit

TAC - Tactical Air Command

TO - Technical Order

TRC - Technical Repair Center

UR - Unsatisfactory Report

I. INTRODUCTION

A. Why the Study Was Conducted

In the last few years, avionics costs have received increasing high-level attention. The reason for this attention is that avionics costs are large and have been rising faster than aircraft costs in general. Aircraft being acquired today have approximately half their total value tied up in avionics.

It is not surprising that avionics maintenance costs have also been rising with respect to other aircraft maintenance costs. It was conservatively estimated that in fiscal 1974 the Air Force spent $1.5 billion for avionics maintenance alone*. The reasons for the rapid rise of avionics maintenance costs are: (1) an exponential increase in avionics complexity with respect to time and (2) the inflation of people costs in this labor intensive field.

The high-level attention given to reducing avionics costs prompted contractors and government employees alike to devise and propose for funding many ideas which were alleged to reduce avionics life-cycle costs. Many of these proposals were dependent on reducing avionics maintenance costs as the major part of the savings generated.

The Director, Electronic Technology Division, requested this study to be conducted so that he, other Laboratory managers, and Laboratory engineers could make more informed decisions on proposals whose expressed aim was avionics maintenance cost reduction.

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* Nelson, Gary R., Robert M. Gay, and Charles Robert Roll, Jr., Manpower Cost Reduction in Electronics Maintenance: Framework and Recommendations. Rand Report R-1483-ARPA, Rand Corp., Santa Monica, California, July 1974.

B. Study Objectives

1. To Find Out How Avionics Maintenance Is Accomplished In Today's Air Force. This objective was primary. The study will have been worthwhile if Laboratory personnel better understand the Air Force avionics maintenance process with its problems and strengths. Included in this objective were:

a. An understanding of the fault detection process. Who detects avionics malfunctions? How are the malfunctions detected? When are they detected? What problems are associated with the process?

b. An understanding of the fault isolation process. Who performs the fault isolation? Where is it accomplished? What data is available to assist the process? What sorts of equipment assist in fault isolation? How effective is this equipment? What changes are occurring and anticipated in the fault isolation process?

c. An understanding of work and documentation flows within the avionics maintenance system. Who accomplished what tasks? When does a piece of avionics get handed off to another level of maintenance? What data is transferred at the various handoff points? How is the data transfer accomplished? How effective is the data transfer? What are the problems with work and documentation flows? What changes are occurring and anticipated?

2. To Analyze the Data Collected. Included in this objective were:

a. Assessment of built-in test equipment (BITE) and automatic test equipment (ATE) with respect to the equipment in the inventory and the people using it.

b. Assessment of the various logistics support concepts in use and proposed to determine the problems and potentials of each.

c. Determination of problem areas amenable to technological solution by the Laboratory or the Electronic Technology Division.

3. To Recommend Programs and/or Changes to Decrease the Costs and Improve the Effectiveness of Avionics Maintenance. Included in this objective were recommendations for:

a. Both long and short term programs and their associated payoffs by which the Laboratory could ease maintenance problems through technology or equipment developments.

b. Strategies for optimizing mean time between failure and mean time to repair while minimizing life-cycle costs and maximizing equipment availability.

C. Limitations

Two of the factors which constrained the study and determined its character bear mentioning.

1. First, the study team members were not experts in the maintenance field. Each had limited experience with DOD maintenance. None of the team members, however, had worked as a technician or a supervisor in Air Force avionics maintenance. While this was indeed a limitation (since it required a familiarization period), it had its advantage. The authors hope the presentation of the process will be more understandable to those outside the maintenance field because we tried to take nothing for granted in finding out how the maintenance system works.

2. Second, compiling and reducing statistical data was not one of the objectives of the study. It became apparent that much of the data which would be useful (many of the costs, workhours, failure rates, mean time between failure and mean time to repair) were either inaccessible, widely scattered, or biased by the management and reporting system. The authors had little or no experience in estimating such data from available data. Many of the statistical aspects of avionics maintenance have been covered piecemeal in other studies. An integrated statistical picture might be an appropriate subject for a follow-on effort.

II. HOW THE STUDY WAS CONDUCTED

A. Background

At the outset of this program it was realized that a background phase would be required for the Avionics Maintenance Team to survey the available literature and become familiar with avionics maintenance procedures and terminology. A search of the Defense Documentation Center and the Defense Logistics Studies Information Exchange revealed a large amount of information related to maintainability, reliability, and life cycle cost models/techniques. This data was obtained and to the maximum extent possible studied by the team members prior to visits to operational commands. During this phase the team members also familiarized themselves with the Air Force maintenance management philosophy as contained in AFM 66-1. Finally, meetings were held with local personnel familiar with the Air Force maintenance system and familiar with problems being encountered in the field. The objectives of these meetings were not only to gather background material on avionics maintenance, but also to obtain critical reviews of the study program plan, establish priority areas to investigate, and to obtain opinions/suggestions for methods to improve the maintenance system. Meetings were held with personnel from the AFIT Defense Systems and Logistics School and a representative (Capt Thomas Davis) from the F-15 SPO. An AFLC workshop concerning changes in parts stocking policies was attended. These meetings provided invaluable data especially on new trends in avionics maintenance using automatic test equipment and the problems associated with this concept.

In summary, this background development phase determined that no equivalent effort existed within the Air Force, established that the program could provide worthwhile inputs to the Avionics Laboratory for impacting avionics maintenance problems, and provided the study team with the necessary background to effectively conduct the program.

B. Organizations Visited

To obtain an overall view of avionics maintenance procedures and problems it was decided to visit Avionics Maintenance Squadrons (AMS) associated with all the Air Force's CONUS flying Commands. Furthermore, it was necessary to select bases so that data could be obtained on the major weapon systems in the Air Force inventory. To complete the avionics maintenance picture, trips were scheduled to various depots responsible for providing avionics maintenance support to the operational units. It was also decided that it would be beneficial to obtain information from a Navy Avionics Maintenance Facility with the objective being to gather comparable data on maintenance procedures employed and problems encountered. Table #1 lists the operational bases visited, responsible commands, and weapon systems supported by the AMS.

C. Interview Techniques

One of the primary data gathering methods of this study was to get firsthand knowledge of avionics maintenance problems by interviewing shop chiefs and technicians within the various AMS. However, the disadvantage of interviewing personnel within the military environment, at any level, is to get them to "open up" and express their opinions without fear of reprisal. In an attempt to eliminate this problem it was necessary to aviod the appearance of being inspectors. This was accomplished by informing each person interviewed of the objectives of the study and our function within the Air Force prior to asking detailed questions. To further encourage the personnel to express their feelings candidly, it was decided to eliminate the use of tape recorders and limit note taking during the interviews. This required the Avionics Maintenance Team to recall the information obtained at a later time and introduced one source of error to the study.

Due to the limited time frame/budget assigned to the study, it was necessary to limit the time spent in each area where information

Base	Command	Support
Kincheloe AFB, MI	SAC	B-52, KC-135
Grissom AFB, IN	SAC	KC-135, EC-135
Plattsburg AFB, NY	SAC	FB-111
Homestead AFB, FL	TAC	F-4E
Luke AFB, AZ	TAC	F-15, F-4C
Langley AFB, VA	TAC	F-15
	MAC	C-130
	ADC	F-106
Dover AFB, DE	MAC	C-5A, C-141
Reese AFB, TX	ATC	T-37, T-38
NAS North Island, CA	Navy	ASW Systems
Warner Robins AFB, GA	AFLC	Avionics Depot
McClellan AFB, CA	AFLC	F-III (Depot)
AF Guidance & Meterology Center	AFLC	Inertial Navigation Systems (INS) Precision Measuring Equipment (PME)

TABLE I

was desired. However, at several of the AMSs the team members interviewed both first and second shift personnel in an attempt to maximize the information obtained.

Meetings were held by the Avionics Maintenance Team prior to making the first scheduled trip to determine categories in which specific questions could be asked. The first two trips were used not only to obtain information for the study, but also to update the areas to be explored. Specific questions asked during the interviews varied and depended upon many factors such as the weapon system supported, informality of the interview conditions, the need to explore a certain area further, and the temperament of the person being interviewed. The following list contains the general categories in which information was obtained:

(1) Age of the system

(2) Parts availability

(3) Maintenance structure

  a. Workflow

  b. Documentation

  c. Time & cost accounting

(4) Aircraft scheduling

(5) Level of on-base repair

(6) Manning

(7) Training and personnel quality

(8) Troubleshooting procedures

  a. Hot Mockups

  b. Automatic test equipment

  c. Manual test stations

  d. Built-in-test

(9) Flightline AGE

(10) Depot support

(11) Inspections

(12) Preflight procedures

(13) Preventive maintenance

(14) Level of specialization

(15) Environmental effects

(16) Technical orders

(17) Avionics accessibility

(18) Debriefing procedures

(19) Maintenance data forms & feedback

(20) Problem systems

(21) Equipment design problems

(22) Automatic test equipment performance

a. Software

b. Hardware

D. Trip Reports.

After the completion of each trip, detailed trip reports were written and submitted to the Avionics Maintenance Team management for their review. These trip reports represent the foundation on which this technical report is written. The trip reports have been appended in "sanitized version" so the reader can obtain a better feel for the maintenance environment. We have endeavored to remove data which might be considered derogatory. Personnel were assured that our visits were for information gathering only and were not to be considered inspections. It would be a violation of their trust and openness to attempt to use these reports as a basis for punitive action. This is especially true since the authors are not qualified as inspectors.

III. MAINTENANCE ORGANIZATIONAL STRUCTURES

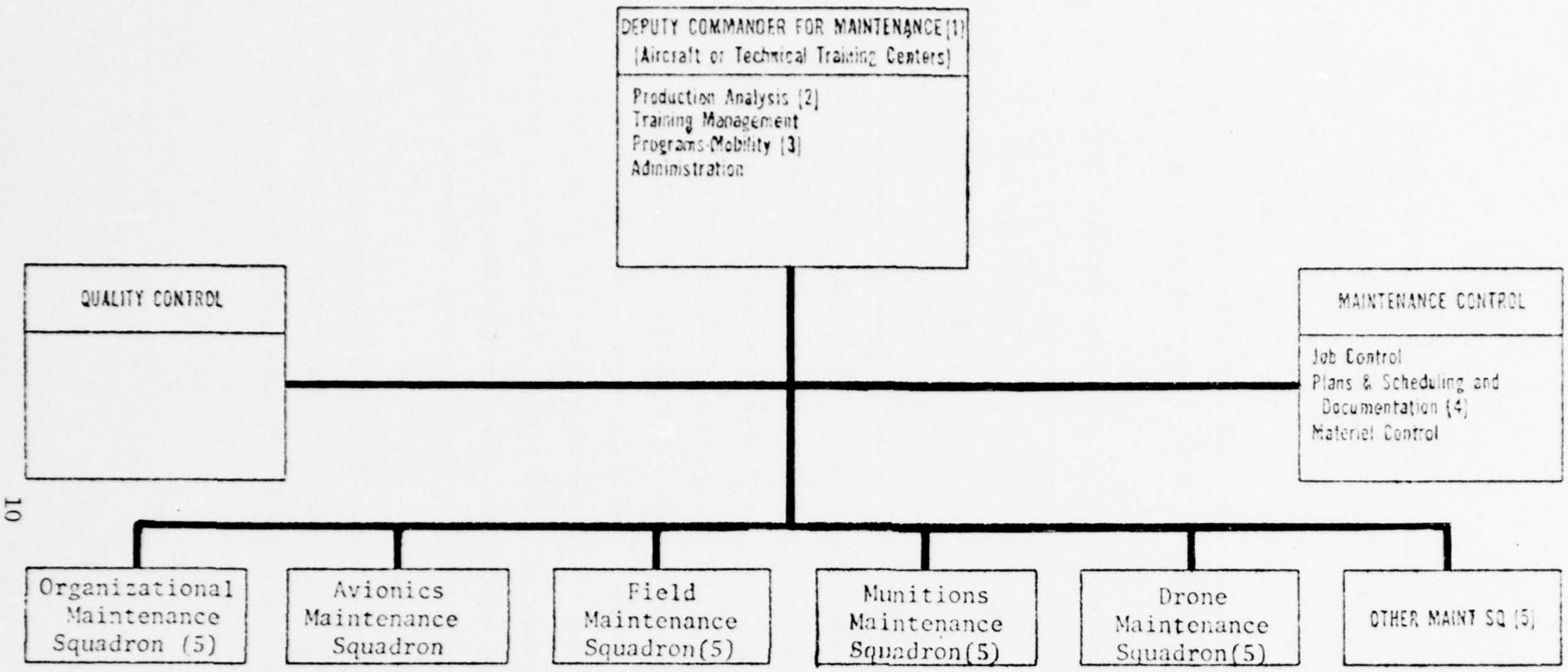
At this point, it is appropriate to briefly discuss organizational structures and the various ways in which these structures are implemented.

A. Base Level Maintenance

Figure 1 shows the functional organization under the Deputy Commander for Maintenance (DCM). The DCM reports to the Wing Commander.

Figure 2 illustrates the avionics maintenance squadron organization used when the weapon system does not use automatic test equipment in the shop. In this kind of squadron there are two possibilities for organizing such functional areas as mission systems or communications-navigation. Either the technicians in these areas will work both on the flightline and in the shop or the people will be split into two groups - those working at the flightline and those working in the shop. There exist squadrons organized both ways, and there are squadrons which are organized in a mixture of the two ways. In several cases, the decision of whether or not to split the technicians was apparently left to the shop chiefs. In the above cases, there was mobility between those who worked on flightline and those who worked on the bench. The people working the flightline tended to be the less experienced technicians. Air Force specialty codes (AFSCs) were the same within a given functional area. We refer to this organizational structure as a two tier structure (base and depot comprise the two tiers).

Figure 3 illustrates the avionics maintenance organization used with the F-111, FB-111, and F-15 aircraft. In these squadrons there was rigid partitioning of technicians into flightline work or



(1) Functions organized as sections, branches, or divisions based on overall organizational structure and size of function.
(2) Production analysis, training management, administration, and programs-mobility may each be organized directly under the deputy commander for maintenance, or they may be consolidated under one or more intermediate supervisor(s).
(3) Mobility authorized only for units having mobility requirement. When the wing logistics plans function is aligned under the deputy commander for maintenance, this element will be known as the logistics plans, programs and mobility division, and will have total functional responsibility.
(4) Includes the debriefing function.
(5) When required to support assigned mission.

Figure 1

Deputy Commander for Maintenance Organization

(Aircraft or Technical Training Centers)

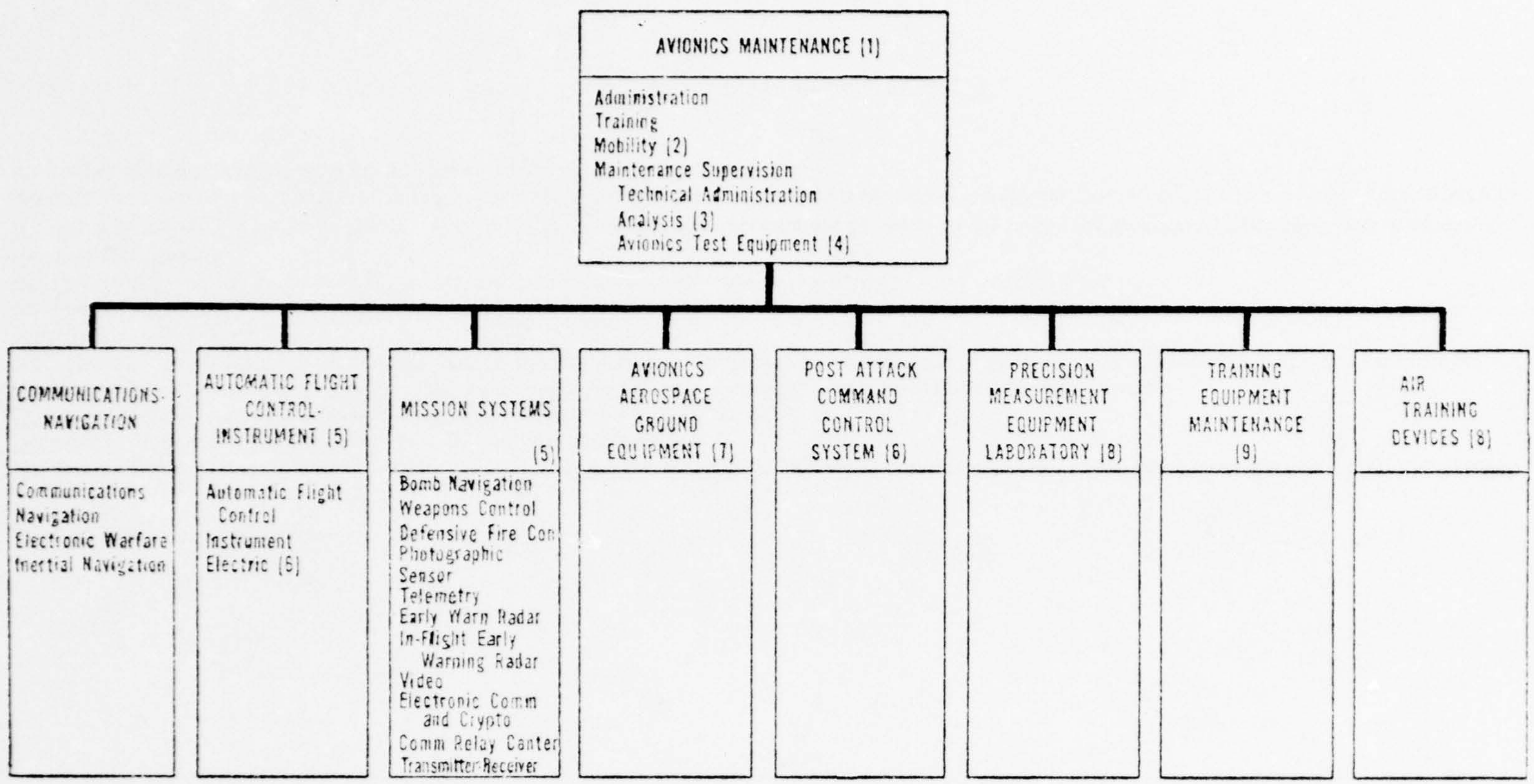
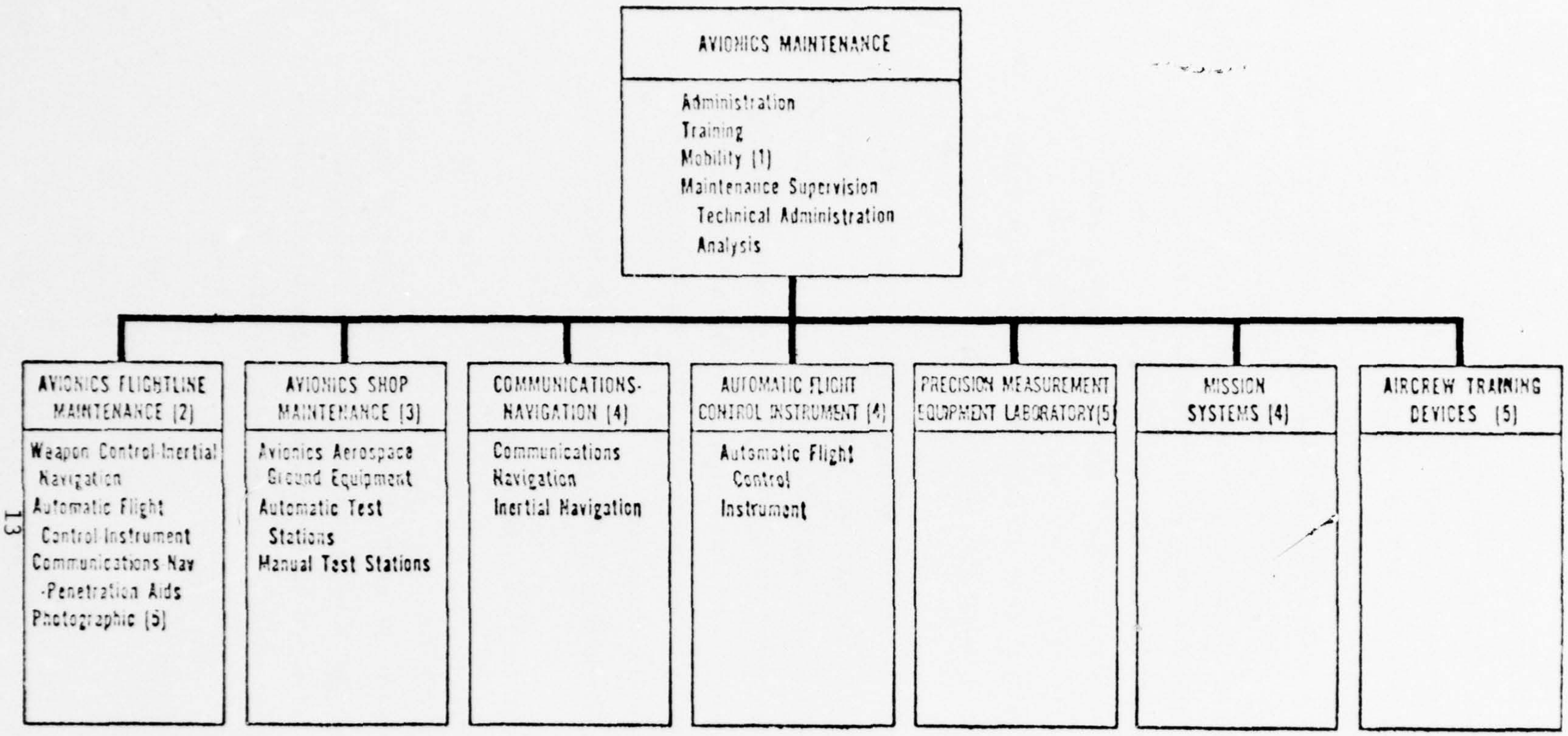


Figure 2

Avionics Maintenance

(1) Avionics maintenance will be organized as a squadron, division, branch, or section depending upon the size of the activity for aircraft equipped units.
(2) Mobility authorized only for units having a mobility requirement.
(3) Analysis authorized only for selected weapon systems based on complexity.
(4) An avionics test equipment function may be authorized to maintain, control, and issue common test equipment.
(5) Automatic flight control-instrument branch or mission systems branch may be combined with the communication-navigation branch when separate branch is not justified.
(6) Command option to alighnelectrical systems under field maintenance.
(7) Authorized only for units having maintenance requirements for peculiar avionics, AGE, and test equipment.
(8) When authorized.
(9) When authorized at technical centers. This function can be divided into separate activities to align with the functional responsibilities at technical training centers. *Training equipment assigned to avionics will be electronic oriented* and *may include missile equipment*, communications-electronic-meteorological training equipment, photographic equipment maintenance, and flight simulators.

Avionics Maintenance (Cont.)



(1) Mobility authorized only for units having a mobility requirement.
(2) Avionics flightline maintenance branch responsible for on-equipment maintenance.
(3) Avionics shop maintenance branch responsible for off-equipment maintenance.
(4) When authorized for units supporting other type aircraft such as KC-135. These functions may be combined depending upon the size of the activity.
(5) When authorized.

Figure 3

Integrated Avionics Systems Maintenance

shop work. The AFSCs were different and the supervisors were also different. The flightline people were system oriented. That is, they were concerned with signal flows between LRUs insofar as such system information could help them decide which LRU to remove and take back to the shop for checkout and repair. The shop people were LRU oriented. That is, they considered the LRU a separate entity and looked only for faults within the LRU. These weapon systems used no hot mockups and had extensive automatic and manual test stations. We refer to this structure as a three tier structure (flightline, shop, and depot form the three tiers).

The C-5A AMSs visited had a similar structure, except there was no division between flightline and shop people. The C-5A also used automatic and manual test stations extensively but there seemed to be no problems in using the same technicians for both flightline and shop work.

The military-civilian technician mixture varied from base to base. The authors conclude that SAC uses almost no civilian technicians, TAC uses a sprinkling of civilians, and MAC and ATC use on the order of 10% civilian technicians. The civilians lend stability and expertise to the AMS organizations which is important for complex troubleshooting tasks and training newcomers. The disadvantage of civilians in the base organizations are:

a. Their salaries are highly visible contrasted to their military counterparts.

b. They must be paid extra for overtime work.

c. They are not subject to the Uniform Code of Military Justice but to the Civil Service regulations.

d. They cannot be moved to where they are needed most as easily as military members can. These disadvantages are more theoretical than real, however, for we found that supervisors were almost unanimously pleased with the technical skill and knowledge the civilian technicians have.

Organization Sizes. AMSs usually have about 200-300 people, although a squadron as large as 680 people was encountered. A few organizations were encountered where avionics maintenance was a branch and was manned at under 100 people.

B. Depot Level Maintenance

Figure 4 shows the organization of the Airborne Electronics Division of the Warner-Robbins Air Logistics Center. The Division is the Technology Repair Center for Air Force avionics, i.e., the avionics depot. While not all avionics depot work is accomplished here, a major portion of the organic (non-contracted) work comes to Warner-Robins ALC.

The Production Branch performs the depot maintenance on the avionics equipment sent in by the base level organizations. The vast majority of the division's people are assigned to this branch since it does the work for which the division exists. The other branches provide support.

The Quality Branch is the organization of inspectors which checks the work of the technicians.

The Engineer/Planning Branch accomplishes the planning for depot support of new avionics with respect to manning, test equipment, floorspace, and utilities. This branch also conducts the work measurement surveys upon which the labor rates are calculated (the rates paid by the Item Managers for depot work on their items).

The Scheduling/Inventory Control Branch schedules the avionics through the repair facilities from beginning to end. This branch also unpacks, bins, moves, repacks and ships the avionics equipment items.

The Automated Equipment Engineering Branch works on software for the depot automatic testers, both the "universal" testers and the system specific automated testers.

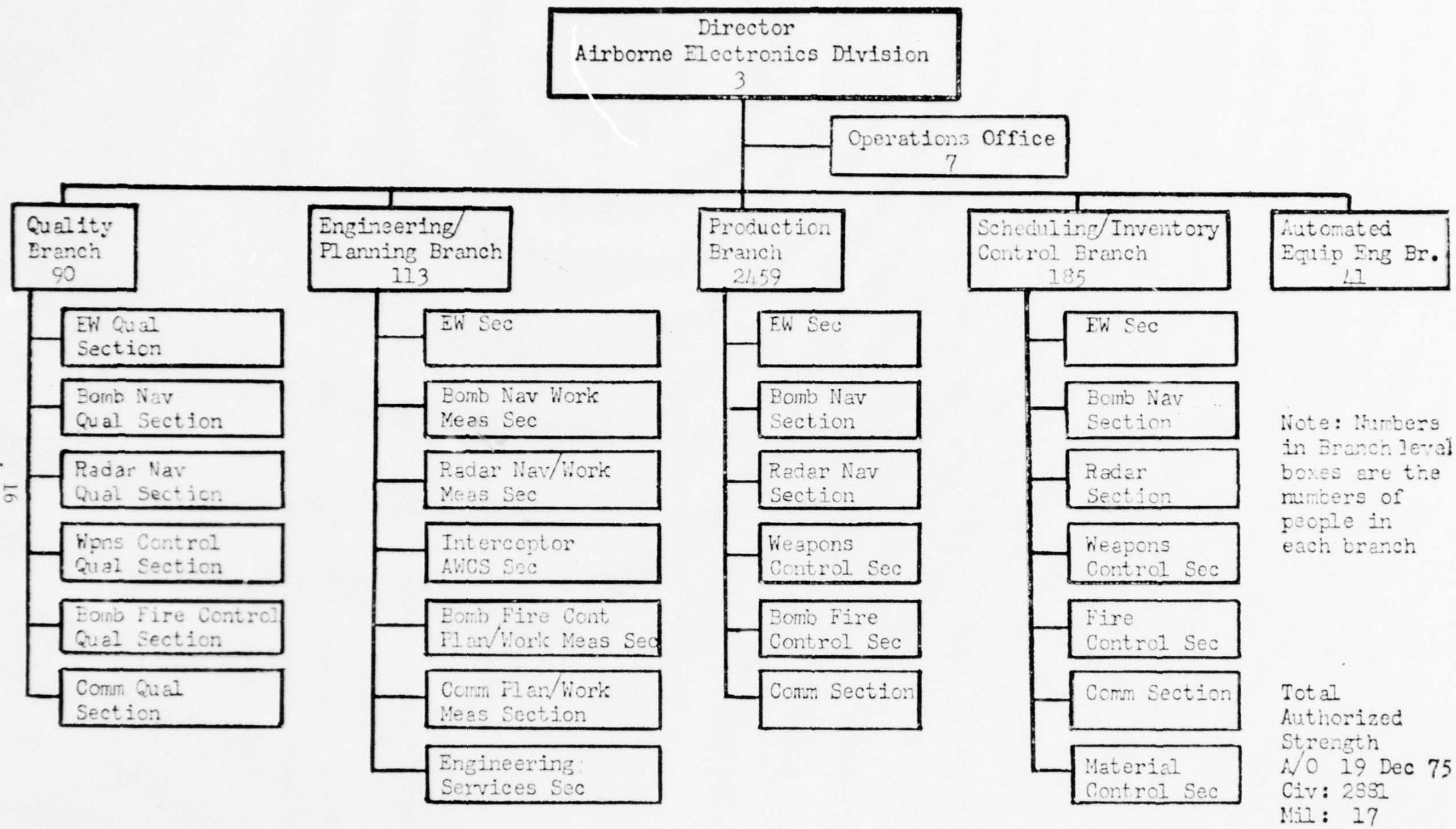


Figure 4

Airborne Electronics Division of Warner-Robins ALC

IV. OVERVIEW OF AF AVIONICS MAINTENANCE PROCESS

The avionics maintenance process consists of detection, fault isolation, and correction of malfunctions which occur in avionics systems. To accomplish this, thousands of personnel are assigned to avionics maintenance squadrons (AMS) all over the world and to technical repair centers (TRC) located at several Air Logistic Centers (ALC). The manner in which the maintenance process is to be managed is established in AF Manual 66-1. Although the entire Air Force manages avionics maintenance in general accordance with AFM 66-1, variations in maintenance procedures were noted among the several organizations which were visited. These variations are primarily in the manner in which the work is distributed within the avionics maintenance squadrons and in the techniques used to identify and isolate faults in the equipment. The avionics maintenance process is a sequential process in which a malfunction is detected, reported, isolated, and corrected in a two or three tier organizational structure.

A. Work Flow in the Avionics Maintenance Process

The work flow in the avionics maintenance process progresses from detection of a malfunction of the aircraft avionics through isolation of the fault causing the malfunction to replacement or repair of defective components. Fault isolation is generally accomplished in a progressive manner starting at the system level and progressing through the line replaceable unit (LRU) level, the shop replaceable unit (SRU) level, and ultimately to the bit and piece level. Because of aircraft turnaround time constraints and limits on the levels of maintenance which can be accomplished within an organizational unit, avionics equipment is restored to operation through replacement of defective units rather than by troubleshooting a malfunction to the piece level and returning the same complement of units to the aircraft. Line replaceable units are high cost items with very limited numbers of spares. Because of this, LRUs must be restored to operating condition through replacement of shop replaceable units at base level rather than have a number of spares tied up in a time consuming depot repair cycle. If a good supply of SRUs is maintained at base level, there is a high probability that most LRU faults can be corrected at base level through replacement of SRUs. The defective SRUs removed from LRUs may be repaired at base level, returned to a depot for repair, or discarded (in cases where the SRU is an expendable item). In this repair by progressive isolation to smaller units and replacement at the unit level, no attempt is made to preserve the integrity of the composition of the avionics system. That is, serial number records are generally maintained of the composition of a system at the LRU level but seldom kept at the SRU level.

Figures 5, 6, and 7 show the work flow for avionics maintenance at the flightline, intermediate shop, and depot levels respectively.

1. Malfunction Detection on Aircraft

In older aircraft, malfunctions of avionics equipment are detected through observations of abnormal indications by the pilot or crew member. Newer aircraft such as the C-5A, F-111, and F-15 have built-in test (BIT) equipment which provide indications of malfunctions to supplement these inputs. The Malfunction Analysis, Detection, and Reporting (MADAR) system in the C-5A aircraft is a multiplexed recording system which monitors approximately 800 stations throughout the aircraft. MADAR monitors not only the operation of avionics systems but also other aircraft functions as well and provides a magnetic tape recording of systems performance during the entire sortie. We understand the B-1 Central Integrated Test System is similar in concept. The F-15 aircraft has a status panel which provides the pilot and groundcrew with indications of avionics systems malfunctions. The F-111 aircraft also has BIT

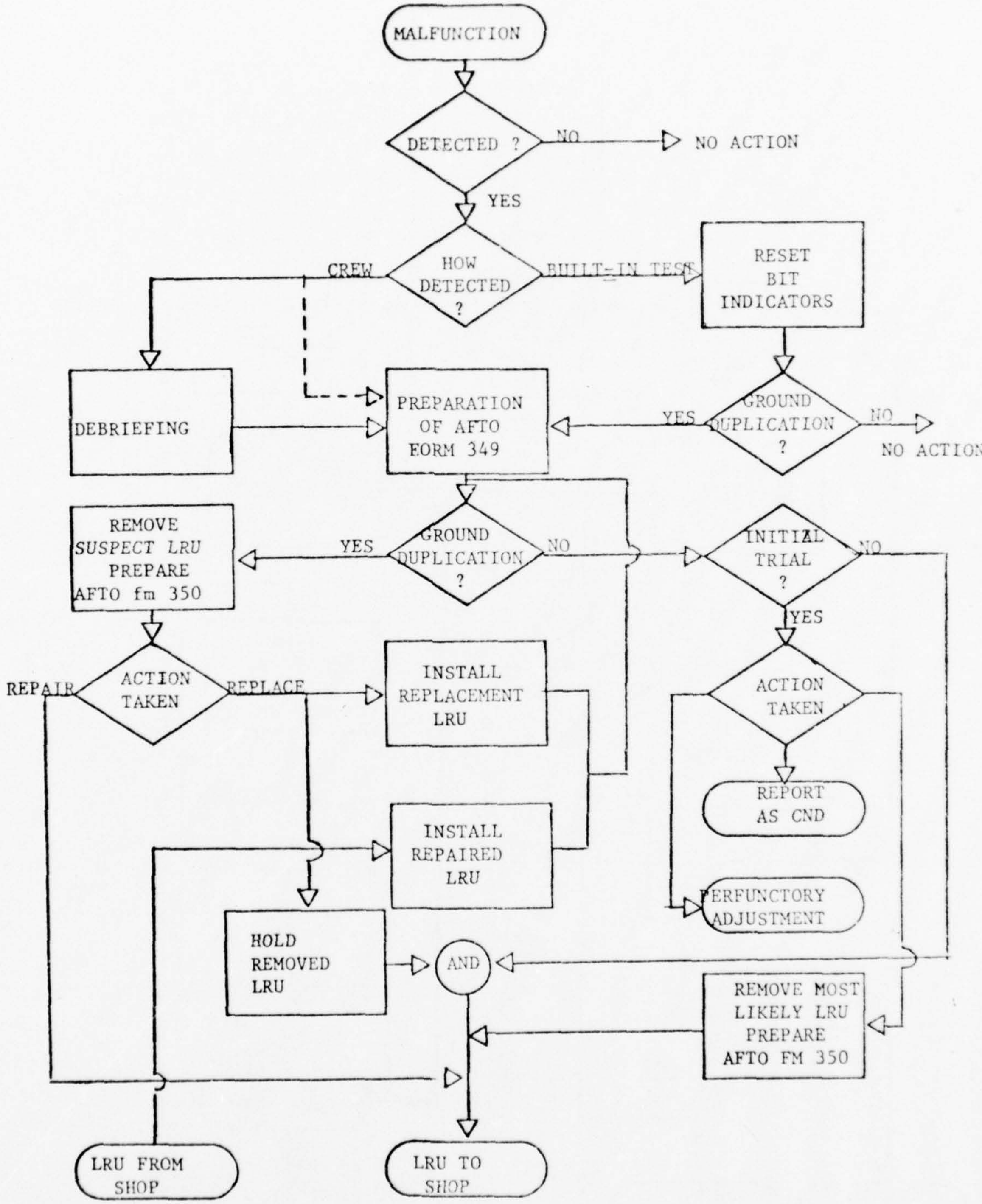


Figure 5

Work Flow on Flightline

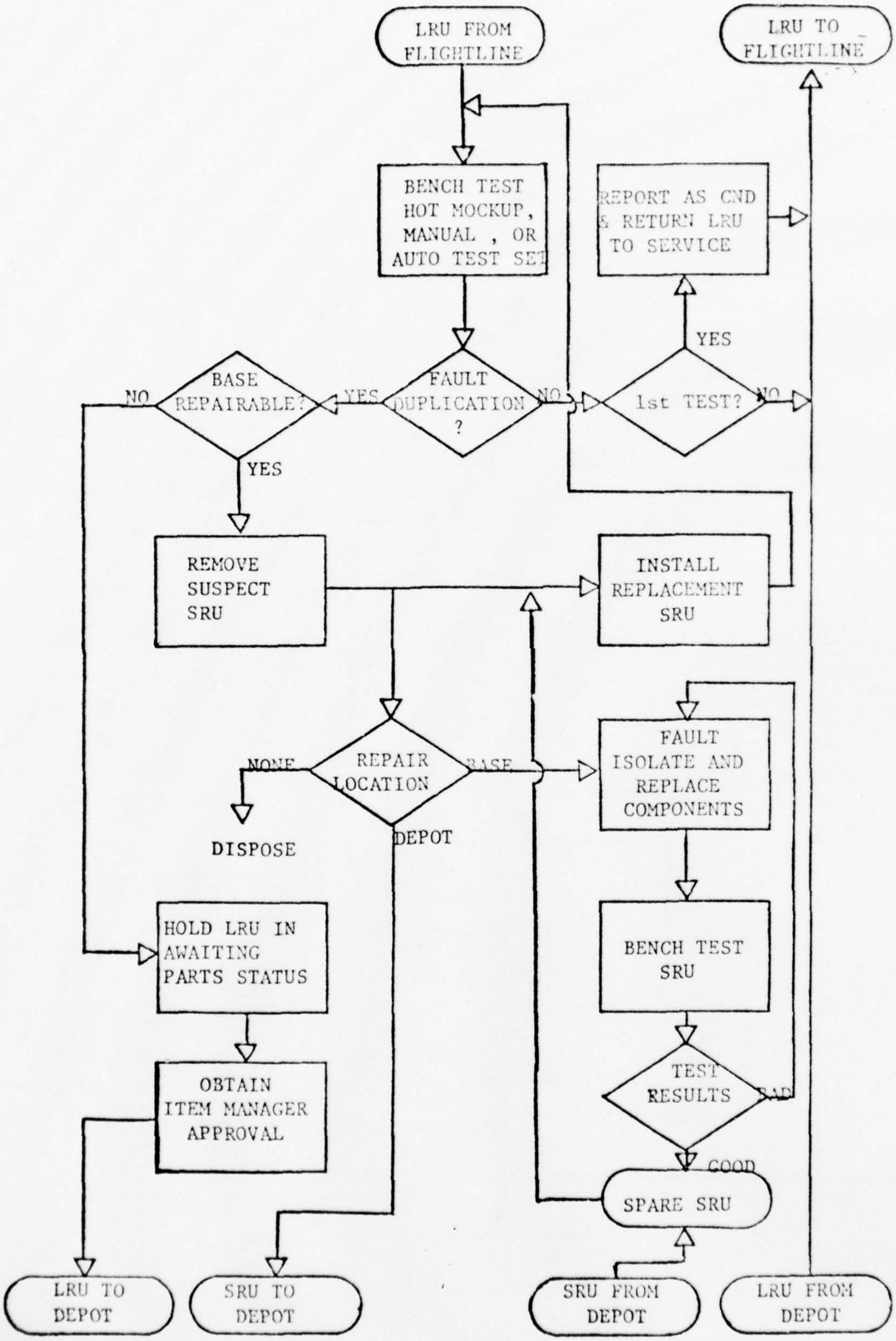


Figure 6
Work Flow In Intermediate Shop

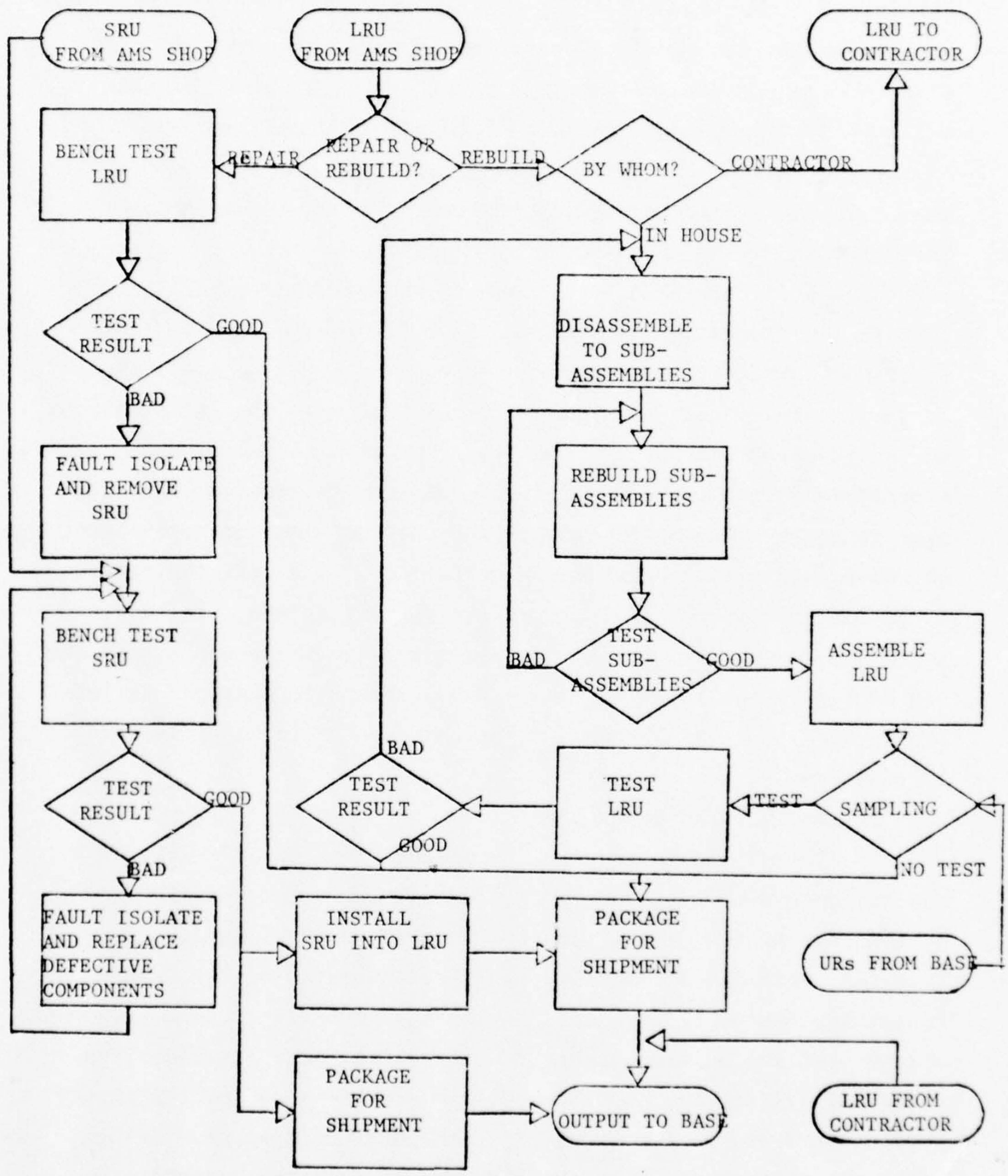


Figure 7

Work Flow at Depot Level

indicators for indication of the status of the avionics systems. Crew observed malfunctions or "squawks" are generally valid complaints except for occasional erroneous reports by student pilots who are unfamiliar with the operation of the equipment. In cases where a crew-reported malfunction occurs in an aircraft having built-in test equipment, the crew "squawk" is usually corroborated by the BIT indication. Malfunctions indicated by BIT, however, are less frequently corroborated by crew reports since transient or intermittent malfunctions may pass unnoticed by the crew but are indicated by the latching type indicators employed in BIT. Referring to the flow diagram in Figure 1, the "Detected?" decision block may initially seem to be pointless; however, it was included to show that avionics maintenance is generally accomplished only on an "as required" basis in response to reported malfunctions. Preventive maintenance on avionics equipment is usually limited to such tasks as changing dessicants and does not include replacement of components prior to catastrophic failure. A locally initiated exception to this policy is in effect at Langley AFB, Virginia, where the contact resistance of relays used in large numbers in the old MA-1 fire control system on F-106 aircraft is measured periodically and any relay having greater than one ohm contact resistance is replaced.

2. Malfunction Reporting

The AMS technician relies heavily upon the AFTO Form 349 (maintenance job order) which is prepared to report a malfunction. In the case of the C-5A aircraft, the AFTO Form 349 and the AFTO Form 781 (aircraft discrepancy log) are generated by the Ground Processing System (GPS) computer when the MADAR tape is read into the system. In the case of aircraft which do not have a malfunction recording system, the AFTO Form 781 is accomplished jointly by the crew members and representatives of the AMS during a debriefing after completion of a sortie. The debriefing after a sortie is handled in various ways throughout the Air Force. Some debriefings are rather formal, others are informal, and as indicated by the dotted line in Figure 5, the debriefing is sometimes omitted. Attendance at debriefings varies; in some cases, the aircraft commander gives advance notice by radio of the nature of malfunctions and this information is routed by Job Control to the AMS so that they can have appropriate technical representation at debriefings. In other cases permanent assignments are made for AMS representatives at debriefings. In case of training operations where there may be 200 sorties per day, time and manpower limitations preclude debriefings and the pilot fills out a debriefing form from which Job Control generates 349s without discussion of the problem with an AMS representative. Debriefings are usually held near the flight line but in some cases the debriefing is held even closer to the aircraft. At Dover AFB, the C-5A crews debrief the flight to the AMS representatives in a van which is driven out to the aircraft. At Plattsburgh AFB, the FB-111 crew remains in the aircraft for the debriefing so that failure symptoms can be demonstrated before the equipment is turned off. It is of great help to the AMS technician if he can actually observe the malfunction rather than having to rely on the pilot's discription of the problems. Ground duplication of the problem is very important, since if the malfunction cannot be duplicated before maintenance action is taken, the technician has no way of confirming the efficacy of the action taken. As mentioned before, BIT indications frequently cannot be duplicated on the ground and these are usually not written up on AFTO Form 349 unless they recur during ground operation after the BIT indicators have been reset.

3. Fault Isolation at Flightline

Flightline maintenance consists primarily of isolation of a fault to a particular LRU which can then be removed to the intermediate shop for further testing to isolate the fault to the SRU level. Actual repair of fault at the flightline is uncommon except for cases where a *minor* adjustment such as a squelch control adjustment or tightening of loose connectors, etc., is all that is required. Although some avionics equipment is modular in construction, aircraft turn-around time constraints, exposure to weather and inaccessibility of modules while the LRU is installed in the aircraft generally preclude the repair of the LRUs at the flightline.

The first step in flightline fault isolation is to attempt to duplicate the malfunction. If the malfunction cannot be duplicated, the technician must choose (a) to write a cannot duplicate (CND) report on the AFTO Form 349, (b) make some perfunctory adjustment, or (c) remove the most likely LRU for further testing which may lead to the isolation of an intermittent problem. Since a low CND rate is often a measure of the performance of the squadron, the technician may be influenced to avoid a CND report by making a perfunctory adjustment for the record. If the malfunction recurs when the equipment is operated, and the problem cannot be corrected by accessible adjustments, the suspect LRU is then removed from the aircraft.

In more complex avionics systems composed of several LRUs working together, there is sometimes difficulty in determining which LRU is defective. In the FB-111 aircraft, the BIT indications do not always identify a singular LRU but often only narrow the possible defective LRUs down to two or three. Because of the uncertainty as to which LRU should be removed from the aircraft, the 380th AMS at Plattsburgh AFB has a flightline van with a full complement of LRUs and this van, called the "Big Apple", is driven out to the FB-111 aircraft so that fault isolation to the LRU level can be accomplished by trial and error exchanging of LRUs in the aircraft with those in the "Big Apple". The F-15 aircraft has both a BIT status panel to indicate avionics malfunctions at the system level and BIT indicators on the individual LRUs within the systems.

The BIT indicators on individual LRUs should avoid the ambiguous indications experienced with the FB-111; however, technicians reported that the BIT indications are sometimes inaccurate with regard to the specific LRU and that exchange of non-indicated LRUs is sometimes necessary to clear BIT indicated system faults.

The trial and error substitution of LRUs to fault isolate to the LRU level is indicated by the dotted loop on the flow chart in Figure 5. When the fault has been eliminated by substitution of LRUs, the LRU which has been removed from the aircraft is then sent to the intermediate shop for repair. The fault isolation by substitution approach is reported to be working well with the "Big Apple" at Plattsburgh AFB, but this fault isolation technique also gives ambiguous indications if there happens to be more than one defective LRU in the system. In simpler systems where the technician has confidence in having the appropriate LRU, the LRU is sent to the intermediate shop for repair and the system is restored to operating condition either through use of a replacement LRU, if available, or if turn-around time constraints permit, through shop repair of the removed LRU and reinstallation of the LRU in the aircraft.

4. Fault Isolation in AMS Shop

After the flightline technician has isolated a system fault to the LRU level, an AFTO Form 350 is prepared and the defective LRU is taken to the intermediate shop. The AFTO Form 350 contains information transcribed from the AFTO Form 349 which identified the original system malfunction plus any additional information which may be added by the flightline technicians with regard to the symptoms or action taken to isolate the fault to the particular LRU. In a three tier organization, the flightline technicians and the shop technicians are in separate organizational units and have little or no direct contact. Because of this separation, the AFTO Form 350 is the primary channel through which the shop technicians learn about the fault in the LRU which they are expected to repair. In a two tier organization, both flightline and shop technicians are in the same unit and there is more opportunity for them to communicate. However, even in a two tier organization, the same technician may not necessarily bench test an LRU which he has removed from an aircraft. Operation of AMS shops is usually on a two or three shift, five, six or seven day a week basis except for precision measurement equipment laboratory (PMEL) and aerospace ground equipment (AGE) shops. In addition, the tendency is for the better and more experienced technicians to be assigned to the shop, while the more junior technicians are assigned to the flightline.

When an LRU is received in the AMS shop, it is bench tested either on a hot mockup or on a special test set. Hot mockup testing is generally accomplished on LRUs from older avionics systems while newer LRUs are more likely to be tested on either an automatic or manual test set designed to test specific sets of LRUs. A hot mockup is a full set of LRUs which are assembled to make a bench model of the particular avionics system. A hot mockup differs from the aircraft installation only in that it has readily accessible test points and includes test equipment such as signal generators to provide the inputs which would be received in the aircraft. Through observation of the performance of an LRU in a hot mockup along with knowledge of the circuitry, the shop technician can localize the problem by deduction.

Test sets, particularly fully automatic test sets, require little or no deductive reasoning by the shop technician but rather rely upon the reliability of the program written for the computer which controls the operation of the test set. In a test set, the LRU under test is tested as an individual box rather than as an operating component of an avionics system as is the case with a hot mockup.

If the LRU received from the flightline initially tests OK at the intermediate shop level, a CND (Cannot Duplicate) report is annotated on the AFTO Form 350 and the LRU is returned to service. There may, however, be pressure on the technicians to keep the CND rate low and a perfunctory adjustment or alignment may be reported even though no positive duplication of the malfunction was observed. In cases where a malfunction is confirmed in the intermediate shop, repair of the LRU is accomplished by replacement of defective SRUs within the LRU. Defective SRUs are identified either by a test set or by a technician using his troubleshooting ability to relate symptoms observed on a hot mockup to specific SRU functions. Regardless of the test procedure employed in the shop to fault isolate to the SRU level, the general practice is to replace the SRU which has been identified as defective and retest the LRU to confirm the efficacy of replacing the SRU. If, however, replacement of a suspect SRU does not effect a fix or if no replacement SRU is available, the LRU falls into a NRTS (Not Repairable This Station) status and is sent to a depot for repair or held until necessary parts become available for repair of the LRU at base level. Priority is placed on accomplishing repair of LRUs at base level and approval from the Item Manager for the LRU must be obtained before an LRU can be shipped to a depot for repair. Pending receipt of the Item Manager's approval for sending a defective LRU to depot, the LRU must be held at base level in an awaiting parts (AWP) status regardless of the reason for the LRU being unrepairable at base level. Defective SRUs removed from LRUs may, depending upon the specific SRU, be throw-away items, repairable at base level, or repairable only at depot level. Older SRUs employing tubes and discrete components are more likely to be classified as base repairable items while SRUs from newer systems of high density construction requiring special soldering skills generally are depot repair items.

5. Avionics Maintenance at Depot Level

At depot level, the equipment serviced covers a wide range in age and functions and no singular procedure is followed for all equipments. Although the avionics Technical Repair Center (TRC) is at Warner-Robins, some avionics maintenance is accomplished at other locations with different work procedures. The Aerospace Guidance and Metrology Center (AGMC) at Newark Air Force Station, Ohio, is responsible for maintenance of inertial navigational equipment and F-111 avionics are maintained at Sacramento ALC. Although there is no singular work flow which is followed in all depot maintenance, the highlights of maintenance procedures at depot level are shown in Figure 3.

Two types of maintenance are accomplished at depot level. Old equipment such as the APN-59 radar is completely refurbished at Warner-Robins ALC while newer equipments are repaired as required. The AFTO Form 350 which accompanies LRUs is not used at Warner-Robins ALC in the case of older equipments. Cannibalization for SRUs and even component parts at base level results in LRUs returned to depot being "suitcases for defective SRUs" and the problem described on the AFTO Form 350 does not reflect the actual status of the LRU. At AGMC, however, the AFTO Form 350 remains with the LRU and corrective action is indicated when the LRU is returned to the base. Another variation encountered in depot operation is that some maintenance work is performed by contractors.

When a piece of equipment is refurbished at Warner-Robins ALC, initial testing is bypassed and the equipment is disassembled for refurbishment of subassemblies. Components known to have high failure rates are replaced by specialists working on a production line type operation. Subassemblies are tested using either general purpose test equipment or, in some cases, special test sets are available. The refurbished subassemblies are then reassembled into complete LRUs. No attempt is made, however, to reassemble the same complement of subassemblies into an LRU.

At Warner-Robins ALC and AGMC, it was learned that final test and inspection is accomplished on a sampling basis and that 100% testing is performed only when unsatisfactory reports (URs) from bases indicate that defective units are being delivered. Some problems are attributed to damage while in transit and, therefore, test at base of LRUs received from depot is sometimes necessary to preclude installation of faulty equipment.

LRUs in the depot for repair rather than complete refurbishment are tested and fault isolation to the SRU level is accomplished on manual or automatic test sets. At AGMC, technicians operating automatic testers are rotated among test stations and the clean room operations in order to minimize boredom and frustration associated with operation of automatic test equipment. At Warner-Robins ALC, technicians are seldom rotated because of the nature of the testers and equipment serviced. Test equipment used in the Production Branch sections of the Airborne Electronics Division at Warner-Robins ALC include multipurpose, computer controlled test sets, specific LRU test sets, hot mockups, and general purpose instruments such as oscilloscopes, signal generators, and multimeters. This diversity of equipment and the high specialization of the technicians precluded rotation of assignments. At AGMC the work is limited to inertial navigation and guidance equipment.

In the case of the avionics in the F-111 aircraft, depot-level maintenance is unique. The original F-111 system concept was to have sophisticated automatic test equipment at base level which would permit avionics maintenance without reliance upon a depot. It was learned through experience that this concept was unsatisfactory when manned by enlisted personnel and alternate approaches for F-111 avionics maintenance were initiated. At Cannon AFB, the F-111D avionics maintenance was contracted to General Dynamics, the prime contractor on the F-111D, for a trial to determine if the base automatic test equipment approach could be made to work with civilian operators. This is being phased out and Cannon AFB was not included in the familiarization tour which preceded this report. A set of automatic test equipment which is identical to that used at base level has been installed at Sacramento ALC where it is operated by civilian technicians having greater experience than most enlisted personnel in the AMSs. The technicians at Sacramento ALC frequently can fault isolate to the SRU level on LRUs which have been received from bases; however, some faults cannot be isolated on the automatic test equipment regardless of the experience of the operator. When the fault cannot be isolated, the defective LRU is taken to the Avionics Integrated Support Facility (AISF) which has complete hot mockups of the several F-111 avionics suites. The AISF is operated primarily by contractor (Autonetics) personnel and is not intended to be a repair shop, but is unofficially used to fault isolate to the SRU level through exchange of SRUs while observing overall system performance in the hot mockup. Generally the types of faults so isolated are intermittent failures which tend to be missed by ATE.

B. Avionics Maintenance Personnel

Military, civil service, air reserve technicians (ART), and contractor personnel are employed to accomplish avionics maintenance. At base level, the AMSs are predominately military personnel organizations, while at depot level, the vast majority of assigned personnel are civilians. The use of civilians in avionics maintenance squadrons varies from base to base. Of the several bases visited, no civilians were observed in avionics maintenance squadrons at Strategic Air Command (SAC) bases, while at Military Airlift Command (MAC) and Air Training Command (ATC) bases, a minority representation of civilians were observed working along with enlisted personnel. Some of the civilians are civil service personnel, while others are air reserve technicians (ART). The principal merit of having some civilians in the AMS shops is that they are not subject to reassignment and, therefore, can provide continuity and greater expertise to the organization. During the Viet Nam war, maintenance technicians would often come to an AMS from technical school and work in the AMS for only a year before being transferred to SEA. Since at least one year on an assignment is necessary to build up expertise, the civilians were particularly essential during this period of relatively short assignments for the new technicians. The importance of keeping experienced avionics maintenance technicians is recognized in MAC and technicians assigned to C-5A aircraft have a special suffix on their Air Force Speciality Code (AFSC) which assures them of long term assignments to either C-5A home bases or enroute bases. In general, the use of combined military and civilian personnel at base level appears to have definite merit; however, some resentment by the enlisted personnel is possible since civilian technicians must be paid for any overtime while the enlisted personnel receive no overtime pay. Additionally, civilians generally receive higher pay for their work than do their military counterparts.

1. Qualifications of Avionics Maintenance Personnel

Avionics maintenance technicians are generally considered to be above average enlisted personnel. Those with the greatest ability and most experience tend to be assigned to bench work in the AMS shop, while the less experienced are more likely to be assigned to work on the flightline.

Diverse responses were received at various bases regarding the quality of recent graduates from the technical schools. It had been anticipated that the quality of Air Force enlistees would drop with the end of the draft, but apparently this factor has been offset by the tight job market. Several AMS shop chiefs stated that recently arrived technicians are extra sharp; however, some also were critical of the training being given in the technical schools. The wide range of technology in current avionics equipment presents a problem in providing appropriate training in the technical schools. The very old (15-20 year) equipment still in use in B-52s, KC-135s, etc., is a problem for the new technician since this obsolete equipment is passed over in the technical schools, whereas the new equipment such as that on the F-15 is not yet included in the training programs. The career development course for F-15 technicians is based on the F-111 avionics systems which are different from those of the F-15.

As avionics systems have become more sophisticated and complex, maintenance has shifted from reliance on deductive reasoning to the use of automatic test equipment, in which case the technician becomes an operator following specific instructions and is not expected to apply deductive reasoning. In the case of the F-15, the technical orders describe only how to operate the test equipment and do not include diagrams of the unit under test. Experienced technicians express dissatisfaction with being test set operators instead of using their knowledge to diagnose problems by troubleshooting through the circuitry. Several reports were also received about technicians being frustrated by automatic test equipment on systems other than the F-15. Older, more experienced technicians were more vocal in their dislike of ATE and a number of senior technicians are retiring early although ATE is not the only reason for this trend. The newer technicians seem much more receptive of automatic test equipment since they have not developed expertise in troubleshooting and, therefore, do not feel that their job has been usurped by the machines.

At the depot level, the technicians are all civilians, many of whom are considerably older (37 yr average at Warner-Robins ALC) than the enlisted technicians in the AMS shops and generally are at the WS-11 grade level. At Warner-Robins ALC, there is a formal training school for technicians. The school has 10 instructors, who, with the aid of video tapes, teach electronic fundamentals. Since depot level maintenance includes replacement of integrated circuits on high density circuit boards, the school also provides training in specialized soldering techniques.

2. Contractor Personnel

In addition to personnel employed by contractors in the performance of maintenance work farmed out by depots, a few contractor personnel are employed on site in the avionics maintenance squadrons and at the ALCs. For example, full time technical representatives of Honeywell assist in the operation of the model 1505 automatic test set in the C-5A AMSs. The model 1510 test set is computer controlled, but unlike many automatic test sets, permits the technician to interact with the computer to diagnose problems. The efficacy of this interactive mode of operation is largely dependent upon the skill of the technician, and the Honeywell representatives were reported to be very valuable. At Sacramento ALC, Rockwell employees work along with civil servants in the operation of the F-111 avionics suites in the Avionics Integrated Support Facility.

C. Principal Problem Areas

When inquiries were made at various avionics maintenance organizations regarding problems, the most common reply was "getting parts" followed by complaints about test equipment.

1. Replacement Parts

The maintenance policy of the Air Force is to operate with a minimum number of spare LRUs and to stock SRUs at base level so that LRUs can be repaired at base level and quickly returned to service. The minimal number of spare LRUs results in extensive cannibalization of LRUs among aircraft. For example, the LRUs carried in the "Big Apple" van at Plattsburgh AFB for flightline fault isolation through exchange of LRUs are cannibalized from aircraft not scheduled to fly on a particular day. The spare situation is generally not as tight for SRUs but is still limited in many cases. Cannibilization of LRUs for SRUs and even smaller parts is also practiced in AMS shops. Current AFLC operating procedures require that non-repairable LRUs be held at base until approval to send them to depot is received form the Item Manager. Technicians within the maintenance squadrons consider these defective LRUs fair game as a source of SRUs or smaller components needed for the repair of other LRUs. Because of this cannibalization at base level, LRUs received by depot may have several defective or missing SRUs and the AFTO Form 350 data accompanying the LRU is useless. Stripping of defective LRUs for parts is particularly common with older equipment such as the APN-59 radar set.

While at Warner-Robins ALC, we were shown a radar modulator which was received with all but one of the silicon controlled rectifiers (SCRs) removed at base level. We were advised that these particular SCRs had been difficult to obtain and the supervisor at Warner-Robins ALC speculated that the remaining SCR would probably be found to be defective and that the missing SCRs were good ones which had been removed to repair other modulators.

Although parts shortages leading to cannibalization cause extra work for AMS technicians, the technicians are doing a commendable job in keeping the aircraft flying on schedule. Aircraft are always scheduled to fly by tail number to avoid unequal distribution of flying time among the aircraft. It is important, particularly in SAC, that scheduled aircraft take off on time regardless of how many aircraft not scheduled for that day must be cannibalized to make the scheduled aircraft operational. In addition to the labor involved in swapping LRUs and SRUs, cannibalization also aggravates connector and cable problems in avionics systems. In the case of the very old avionics equipment, some replacement parts are unavailable because they use obsolete technology which has gone out of production. Electromechanical devices are particularly difficult to obtain for replacement use. While the old vacuum tube equipment has low reliability, maintenance technicians did not identify electron tubes, per se, as maintenance problems since spares are generally available and replacement is simple. This could change, however, when current stocks are depleted because many tube types have long been out of production and some major US tube manufacturers have closed down their production facilities.

It seems, however, except for very old parts, that most of the parts shortage complaints are attributable to austerity of the AFLC budget. At AMS shops, supervisors and even some bench technicians quoted exact costs for certain parts and showed great concern over the value of parts which could be salvaged. However, there is little concern about labor costs which may be incurred in cannibalization, salvage from SRUs, or partial repairs. At a SAC base, we were shown an LRU of a stabilization augmentation system in which certain electrolytic capacitors were failing. Since replacement before catastrophic failure is not authorized use of parts, in a short time period, the LRU would have to be removed and repaired several times until all of the particular capacitors had been replaced, thereby increasing the total labor cost considerably as compared to replacement of all capacitors at the same time on a given LRU.

Parts are particularly difficult to obtain to repair F-111 avionics system LRUs which have been returned to Sacramento ALC because base AMS shops have higher priority for obtaining replacement SRUs. This results in a high percentage of defective LRUs being held at Sacramento for lack of parts. The only way to obtain replacement SRUs without having base priority is to cajole the particular Item Manager into sending the necessary units. The Item Manager, however, cannot always make units available simply because there may not be enough in the inventory nor does he have funds available to procure more. Brief discussion with an Item Manager indicated that the manager is ultimately controlled by the budget from AFLC and regardless of the number of units required, the number procured will reflect any budget cuts which are imposed on the Item Manager.

LRU and SRU shortages also cause distortion of maintenance data. AMS technicians sometimes replace non-defective units hoping to find a system "mix" that will work with a unit which is out of tolerance but for which no replacement is available. This results in a higher indicated failure rate for associated units while concealing the identity of the unit which necessitated changing of other units. This problem is primarily associated with the F-15 where there are shortages of many LRUs and many test equipment problems exist.

In addition to complaints about difficulties in obtaining replacement parts, complaints were also heard about defective material being received from depot. Some of the defects are attributed to damage while in transit, others to poor contractor performance, and some to lack of adequate inspection and quality control at the depot. Some contractor repaired equipment was reported to have been received with parts missing and in such poor condition that repair in the AMS shop could not be accomplished. Equipment repaired or refurbished at depot is tested on a sampling basis except when unsatisfactory reports (URs) are received which indicate that 100% testing is necessary. At Warner-Robins ALC, we were advised that the UR rate is only about 1 1/2%, while at some AMS shops we were told that all incoming LRUs were tested and that up to 50% of them were either defective or out of tolerance. An explanation for this big difference is that the UR system is not working as it was intended to. At base level, URs are not written on all defective or out of tolerance equipment because there is a feeling that submission of an UR is just additional paperwork which will accomplish nothing. Responses to URs are said to often be perfunctory statements such as "Shipping damage" or "Material failure", thereby tending to discourage the origination of URs.

Another factor contributing to parts availability problems is the normal failure characteristics in which a relatively high failure rate early in the operation of a piece of equipment is followed by a low failure rate period which is quite long and lasts until wearout is indicated by a definite increase in the failure rate. At Warner-Robins ALC, we were advised that they are required to dispose of parts which appear to be in excess of requirements during the low failure rate period for equipment, and then purchase additional parts when failure rates climb as the equipment enters the wearout phase of its life. Reprocurement of parts at this time is sometimes far more expensive than the original spares because the parts are out of production and must be built on a custom basis.

2. Test Equipment

The second major problem area encountered was test equipment. In general, complaints about individual pieces of shop test equipment were about low reliability, poor stability, and excessive size. Some shops are using very old test generators for calibration of TACAN sets and the complaints about this equipment are valid. Some shops, however, have new equipment and this equipment is highly praised by the shop people. With regard to individual pieces of shop test equipment, there does not appear to be any technical problem but rather a logistics problem in obtaining modern test equipment to replace the old equipment which is being used in some shops. One problem identified with the replacement of obsolete test equipment is that the instructions in technical orders sometimes are inappropriate with regard to the use of test equipment other than the model specified by the T. O.

a. Built-In Test Equipment (BITE). Many maintenance technicians expressed critical comments with regard to built-in test equipment. The older technicians having experience in troubleshooting equipment which does not have BIT generally dislike and distrust BIT. The problem with BIT seems to be that it often gives fault indications which cannot be duplicated and that the fault indication does not accurately isolate the problem. In the FB-111A, it was reported that the BIT does not even isolate the fault to a single LRU and that isolation to the LRU level must be accomplished by substitution of LRUs on the flightline. Since the BIT in the F-15 has indicators on individual LRUs, one would think the problem of fault isolating to the LRU level would be solved. Technicians in the F-15 AMSs, however, report that replacement of non-indicated LRUs is sometimes necessary to restore the avionics to operation. This may, in some cases, be the result of action taken by the AMS technicians rather than being erroneous BIT indications. It was learned that maintenance technicians sometimes replace non-indicated, but related LRUs in a system when they do not have a replacement for an LRU which is indicated to be faulty. In this desperate, "do-anything-you-can" approach to getting a system back into operation, it appears that sometimes a mix of LRUs is found which is tolerant of a marginal LRU which has been identified by BIT and the system can be made to operate without replacing the indicated LRU. The efficacy of BIT cannot be accurately assessed unless adequate spares are available to permit the technician to take the action indicated by the BIT.

b. Automatic Test Equipment (ATE). Many shop supervisors interviewed at several AMSs expressed dislike and distrust of automatic test equipment. This attitude is particularly strong among the older maintenance personnel who have gained skill in fault isolation on hot mockups. They also expressed the desire to have a hot mockup to verify operation of LRUs after fault isolation and subsequent SRU replacement has been accomplished through the use of an automatic test set. In the use of the F-15 avionics, only a part of the ATE is operational and much remains to be done on software problems.

One problem which was identified is the determination of performance limits which will give agreement between the ATE in the shop and the BIT indication in the aircraft. Since much of the ATE for the F-15 avionics was not yet in operation at the time of this survey, many F-15 LRUs are returned to McDonnel-Douglas for repair. F-15 AMS technicians advised us that a hot mockup is used for fault isolation of the LRUs which are returned to the contractor.

The architecture of ATE is still evolving. The older ATE for the F-111 avionics uses a central computer while the ATE for the F-15 uses a separate minicomputer for each test set. The use of separate minicomputers is advantageous since this makes the several test sets independent of each other and failure of one minicomputer does not stop all ATE operations.

Some ATE methodologies afford more flexibility of operation than others. The F-15 ATE appears to be quite inflexible and designed for operation by a "trained monkey" having no knowledge of the operation of the LRU under test. With the F-15 ATE, the test sequence starts from the beginning after each corrective action has been made. It would seem desirable to be able to restart the test sequence at the point where a fault was identified until all faults have been isolated and then run only one verification test sequence from the beginning. In the case of the F-111 ATE at Sacramento LAC, confirmation of satisfactory performance is made by running an LRU in the hot mockup of the Avionics Integrated Support Facility after testing on the ATE. One piece of ATE which seemed to be well liked by maintenance personnel is the 1505 test set which uses a Honeywell computer and is used to fault isolate in autopilot and flight director LRUs of the C-5A aircraft. This test set is unique in that it permits the technician to interact with the computer in the determination of the location of a fault in the LRU. The 1505, however, cannot be operated by a "trained monkey"; in fact, a full time Honeywell representative is employed to assist in the operation of the model 1505 test set. Some ATE is used also at the depot level. At Warner-Robins ALC, a General Purpose Analysis and Test System (GPATS) is used but the time required and the validity of the results of GPATS testing are questionable. In the case of the APQ-120 fire control system, the GPATS test sequence of one of the LRUs takes 19 hours and a hot mockup test is still required to provide assurance that the LRU is truly operational. Warner-Robins ALC is having Westinghouse investigate methods of reducing the GPATS time for this LRU and it appears that the 19 hours can be reduced to 6 or 7 hours. The excessive time required to automatically isolate faults in the APQ-120 is attributed to not including adequate and appropriate test points at the time the APQ-120 was designed. Discussions regarding ATE made it quite clear that ATE requirements must be taken into consideration early during the design of avionics equipment rather than delaying consideration of ATE until the avionics design is fixed and production initiated.

ATE is supposed to minimize the training required by the technicians; however, ATE is also designed to fault isolate only 95% of the probable faults which may occur. Even if the 95% objective is achieved, and so far it hasn't been, there remain the 5% faults which are not isolated by ATE. Since LRUs are too expensive to throw away, it is necessary to train technicians to troubleshoot and apply deductive reasoning to fault isolate those LRUs which defy fault isolation on ATE. This means that comprehensive technical orders must be prepared even though most of the fault isolation will be accomplished on ATE, and the only savings would be in the number of copies of the TO required. The initial technical orders for the F-15 avionics were prepared for use by "trained monkeys" and as such, contained no schematics or other diagrams. Since the ATE for the F-15 is far from being fully operational, there exists a requirement for comprehensive technical orders which would aid the technicians in troubleshooting LRUs for which the ATE has not become operational.

V. TRADEOFF CONSIDERATIONS

The purpose of this section is to point out areas which require tradeoff studies either on a system by system basis or on a generic basis. The intent is to point out factors which merit consideration in such studies.

A. BIT, ATE, and Hot Mockups

One of the most difficult and crucial set of tradeoffs to be made for an avionics suite is the one which determines what the method of fault detection and isolation will be. Should BIT be used? If it is used, should BIT be used only down to the LRU level, or should it extend down to a group of SRUs or to one SRU? Should BIT be centralized (one LRU handling the BIT function for all avionics) or should each LRU (or SRU) have its own BIT circuitry? Should automatic test equipment be used in the shops or should hot mockups be used? If automatic test equipment is used, should it be a completely new set of test stations or should an existing test station or set of stations be adapted? If ATE is used, how flexible should it be with respect to operator use and with respect to reprogramming? Over all BIT and ATE considerations is the question of how much should be hardwired and how much should be under software control. The design alternatives are nearly endless. To decide among these alternatives, several considerations must be borne in mind.

1. BIT vs ATE

First, test and monitoring functions to be performed in flight are likely to cost more than the same functions performed in the shop or on the flightline. This is true because: (a) fewer copies of the flightline or shop equipment will be acquired than copies of airborne equipment, (b) shop or flightline ATE operates in more benign environments than does airborne equipment, (c) size, weight, and cooling constraints are more relaxed for shop or flightline equipment than for airborne equipment.

Second, some test and monitoring functions must be performed in-flight because these functions involve safety of flight or are mission essential. The cost effectiveness of including these functions on board is obvious because their failure produces a high probability of hazard or because the aircraft will not be able to perform its prime mission.

Third, still other test and monitoring functions may be cost effective if included on board the aircraft because (a) they pay for themselves in reduced numbers of ineffective maintenance actions by detecting and isolating failures in-flight which cannot be duplicated on the ground, or (b) they turn out to be cheaper to implement within the airborne electronics than in a separate test set.

2. BIT Considerations

Once it has been decided to include a specific test and/or monitoring function on board the aircraft, it is necessary to decide how these functions are to be implemented. Cost, performance reliability, maintenance philosophy, and technician skills must be weighed to decide whether the most effective mode of implementation is a (a) central BIT system controlled by one LRU fed by data from other LRUs, (b) BIT for each affected LRU which will isolate the fault to one LRU and no further, (c) BIT which will isolate the fault to a group of SRUs within the LRU, or (d) BIT which will isolate the fault to one SRU.

3. ATE and Hot Mockup Considerations

a. Shop vs flightline testers. Functions to be fault isolated on the ground may be performed either on the flightline or in the shop. If test equipment is designed to operate on the flightline, it will generally be more expensive than equipment designed to operate in the shop. This is primarily due to the more severe environment on the flightline and more restrictive constraints on size, weight, power and cooling for flightline equipment. On the other hand, flightline test sets may be more effective than shop test sets in isolating problems since they can be used immediately after a mission with the LRUs in place aboard the aircraft.

b. Hot Mockups vs ATE. Hot mockups generally provide more realistic signal inputs than provided by ATE. They can often lead to isolation of intermittent faults more readily than ATE. In the hands of experienced technicians they often provide faster fault isolation than ATE. They require no additional software costs. On the other hand ATE generally checks out each section of the LRU systematically. ATE requires less training in its operation than is required for hot mockups. For complex digital LRUs it seems ATE is the only feasible way to effectively fault isolate. For simpler LRUs, especially analog, the hot mockup may be the more effective method.

Two sins of the past should not be repeated. First, whatever test equipment is to be used with a system, the system and test equipment should be designed to play together. The aircraft LRUs must be designed with the method of test firmly in mind so that adequate test points are provided. The test equipment must provide unambiguous indications of which LRU or SRU has failed. Second, it should not be assumed that a new LRU or avionics suite necessarily needs a new test system. Testers in use in such weapons systems as F-15, F-111, or C-5 may well be adaptable to LRUs in new aircraft or to upgraded avionics in existing aircraft. The general purpose computers or minicomputers at the hearts of these systems should be amenable to reprogramming with minimal hardware changes. The question then becomes one of whether it is cheaper to invest in software and some hardware to adapt an existing tester to a new set of LRUs or whether it is cheaper to develop a completely new tester with its associated software.

Also to be considered in tester design strategy is the question of allocation of tasks among software, hardware, and technician. The data to date indicates: (a) Testers which require little participation or expertise of the technicians are likely to be expensive, particularly in the original software and revisions to it. This is because it is exceedingly difficult to anticipate all failure modes for a complex LRU, design tests to detect the failures unambiguously and keep up with design changes to the LRU with appropriate software modifications. (b) Testers which use computer and technician interactively require more training and skill of the technicians, but may yield more cost-effective results. (c) The cost of implementing computational functions in software is going up (software production is much more labor intensive than computational hardware production).

B. Number of Maintenance Tiers

At the base level the basic question is whether to separate technician skills into those required on the flightline versus those skills required in the shop, or whether to consolidate the skills. The separation can be one of Air Force Speciality Code (AFSC) with different supervisors for flightline and shop work within an avionics subsystem. Another possibility is to have technicians with the same AFSCs supervised by different supervisors depending on whether the technician works in the shop or at the flightline, but have the technicians assigned to one or the other areas. The final alternative is to have all technicians within a subsystem shop prepared to work either in the shop or at the flightline. Factors to be considered in such a decision include: subsystem complexity, ease of using BIT and/or ATE, cost of training technicians for flightline only or shop only, versus cost per technician of training technicians to be proficient at both shop and flightline, number of technicians required under each concept, average technician dead time, acceptable average down time per aircraft, quality of technicians and level of repair philosophy (e.g., are SRUs to be repaired at base level?). The problem is only partly quantifiable, and many of the factors interact, adding to the difficulty of analysis. Other things being equal, the fewer organizational divisions, the more effective will be the process.

C. Reparable vs Expendable SRUs

The question of whether it is cheaper to repair SRUs than to throw them away at the base level has already received some analysis. More analyses need to be conducted to answer such questions as: How much does it cost to pack, ship, unpack, test, and repair an "average" SRU? Would personnel savings result if expendable SRUs are used? What are the implications for AFLC manning and stocking policies? If some of the throwaway SRUs are sent back for failure analysis, how much does this impact projected savings. What is the optimum strategy for such a failure analysis program? It should be noted that if expendable SRUs are to be used, an initial high quantity buy should be made rather than periodic reprocurement. Such considerations also militate for defining standard SRUs which can be used in several types of LRUs.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Standard Electronic Modules

1. Conclusions. The cost of avionics maintenance could be significantly reduced through improvement of equipment reliability and use of a maintenance concept which minimizes the expenses associated with test facilities and technician training. These objectives were taken into consideration by the Navy in the Standard Hardware Program (SHP) which has resulted in a library of approximately 250 standard electronic modules (SEMs) and over 1300 special function modules in the same packaging format as the SEMs. A goal in the SHP was to maximize intra-system and inter-system commonality to achieve high usage of a limited number of types of modules and thereby benefit from cost savings normally realized with large volume, competitive procurements. In order to achieve high commonality, the SEMs resulting from SHP are limited to relatively simple functions on small modules. This leads to size and weight penalties because of the high frame and interconnect overhead which results when a complex system is implemented with a large number of small modules. These penalties are compounded by the additional circuitry which must be incorporated in the system to achieve the BIT capability which enables maintenance of the equipment by relatively unskilled technicians using a minimum of test equipment. The size and weight penalties associated with SEM implementation makes the concept unattractive for use in avionics equipment for tactical aircraft. The concept of using BIT for isolation to the module level is also unattractive for avionics because, with the exception of AWACS aircraft, aircraft installation generally precludes any on-board replacement of internal components. However, the convenience of the BIT maintenance concept and the requirement for stocking only a limited number of spare modules makes SEM attractive

for use in ground equipment such as flight simulators and automatic test equipment where size and weight are not critical.

Before a conclusion can be drawn with regard to the cost effectiveness of the SEM concept, consideration must be given to life cycle cost (LCC) of an avionics system rather than just considering the logistic support cost associated with maintenance. Recently completed LCC studies performed by Norden and Battelle Columbus Laboratories on a SEM implementation of a weather radar (SEMR) functionally similar to the old tube-type APN-59B and the solid-state APN-59X indicate that the high acquisition cost of SEMR offsets savings realized in logistic support cost. Table 2 shows the LCC comparison of SEMR with the APN-59B and APN-59X. Data for the APN-59B and APN-59X were extracted form "Reliability Test Report, APN-59B/Solid State APN-59X Radar" prepared by the Engineering Division at Warner-Robins ALC. LCC cost data for SEMR was taken from report prepared by Battelle Columbus Laboratory under contract with AFAL.

COST/SYSTEM	APN-59B (tube)	APN-59X (solid state)	SEMR (modular)
Acquisition	$8,500	$22,900	$70,000
Retrofit installation	N/A	N/A	10,000
LSC	57,200	8,800	16,000
TOTAL LCC	$65,700	$31,700	$96,000

Table 2

LCC comparison of tube, custom solid-state, and standard module radars based on 10-year operation in mixed C-135/C-130 fleet averaging 39 flight hours/aircraft/month.

The data clearly show that the high logistic support cost (LSC) of the old tube-type APN-59B dominates the LCC of this radar and that LSC is significantly reduced in both the custom and modular solid-state versions. Of particular concern, however, is the high acquisition cost of SEMR which makes the LCC for SEMR exceed that of both the custom solid-state APN-59X and the old tube-type APN-59B. In another study for AFAL, Westinghouse determined that the LCC for an F-16 radar signal processor would be higher with a SEM implementation using either DIP devices or flat pack devices than the custom design using DIP devices. Again, it was found that the higher acquisition cost for the SEM configuration outweighed the savings in LSC which would be realized during a 15-year operational life. From the data available at this time, it must be concluded that SEM does not offer savings in LCC of avionics systems even though it would reduce maintenance expense. Data are not available on the effect of SEM on the LCC of AGE such as flight simulators and ATE.

2. Recommendations. It is recommended that the LCC effect of SEM on AGE, particularly ATE, be investigated to determine the cost effectiveness of SEM in applications where size and weight penalties can be tolerated. It is also recommended that the factors affecting the acquisition cost of SEM be investigated to identify those which are dominant and to determine means of reducing acquisition cost of SEM systems. A program for the development of techniques for low-cost fabrication and test of hybrid circuits could benefit both the cost and size problems associated with SEMs. The use of hybrid circuits in SEMs would result in more complex functions for a given circuit area, thereby reducing the number of modules required to implement a system and reducing the size and weight penalty of SEMs. This would, however, also reduce the inter-system and intra-system commonality of modules and the cost advantages of large volume procurements would be diminished. If means of reducing acquisition

can be identified, further LSC reductions could possibly be made through investigation of advanced thermal environmental control designs which would reduce device junction temperatures to about 75°C and result in significantly improved module reliability.

B. Automatic Test Equipment

1. Conclusions. From observations of the operation of automatic test equipment, (ATE) it is concluded that the ATE now in use leaves much to be desired in reliability, speed, and effectiveness. The ATE was reported to have been designed to be able to fault isolate 95% of the probable faults in a system but shop personnel are of the opinoin that 50 to 80 percent would more accurately describe the performance of existing ATE. Some of the problems can be attributed to use of ATE on equipment which was not initially designed for use with ATE and consequently test data needed for unambiguous fault-isolation is not accessible in some cases. There is a serious problem in fault isolating intermittent malfunctions with ATE and in some cases the "hot mockup" appears to be superior to ATE in fault-isolating intermittent problems. In addition to technical deficiencies, ATE has resulted in a morale problem among technicians. They feel that ATE has reduced the technician to the trained monkey level and some questioned the wisdom of entering the avionics maintenance area as a career field. This problem was most prevalent among the older technicians who had extensive hands-on experience in fault isolating the older avionics equipment by means of the hot mockup technique. It is doubtful, however, that these same technicians would be able to fault isolate a modern piece of high density, digital avionics equipment by the trouble-shooting techniques which had been successful in the past. The younger technicians seem to be eager to learn to use recently developed ATE and, as the senior technicians retire, resentment toward the ATE approach will probably subside. It seems likely

that, as ATE comes into more widespread usage, avionics maintenance technicians will become equipment operators and the only highly-trained technicians required will be those responsible for keeping the ATE in operation. Since ATE will probably never be 100% effective, a problem may develop in determining what course of action to take in case of equipment which cannot be diagnosed by ATE and for which no qualified technicians are available. If future ATE and equipment designs are developed together so that the effectiveness of ATE is significantly higher than at present, it may be found to be less expensive on a LCC basis to write off some avionics equipment as being not-repairable rather than to provide training and facilities for a corps of advanced technicians having the skills necessary to repair that small percentage of equipment which would defy fault isolation on good ATE.

2. Recommendations. Probably one of the most important recommendations with respect to the ATE area is that ATE requirements be given early consideration in the design of future systems. In addition to early consideration to insure that system design and accessibility are compatible with ATE, experience gained in the use of ATE at ALCs should be used to provide both human factors design and technical feature inputs which may not be recognized at the system project office level or in a contractors environment. Software is and probably will continue to be a problem with ATE. In order to have flexibility in the operation of ATE and to be able to accommodate equipment changes in a timely manner, modular software which permits localized changes is recommended. A program for the development of Modular Automatic Test Equipment (MATE) has been initiated by the Test Equipment Group, ASD/AEGT, in the Aeronautical Systems Division. The stated objectives of the MATE program are: (1) reduction of LCC of weapon system support and ATE, (2) reduce proliferation of dissimiliar and expensive ATE, and (3) improve test efficiency. Emphasis of the MATE concept is on

modularity which permits use of basic MATE modules in various configurations to satisfy multiple avionics support requirements. Maximum use is to be made of off-the-shelf, commercial, programmable instruments as the MATE modules. These modules are then to be assembled together into the desired configuration for a particular application via a standard bus which is to be identified early in the MATE program. Through use of commercial equipment as MATE modules and a bus which is accepted by industry, a MATE system is a "living" system which can be readily updated as new-generation instrumentation becomes available. The primary implementation of the MATE concept is to be in new avionics systems; however, it may be applied to existing weapon systems as opportunities present themselves due to upgrading of existing systems through replacement of portions with new-generation components.

In the past, timing of ATE development with respect to the weapon system acquisition cycle has presented a serious dilemma. Early ATE development has been plagued with excessive changes in both hardware and software in response to equipment design changes during equipment development. While delayed ATE development can circumvent this problem, it can also result in slow and ineffective fault-isolation if the system designer does not adequately consider the testability of the system and critical stimuli or measurement points are not available to the ATE. One element of the MATE program is the development of guidelines to be used by equipment designers to insure compatibility of new equipment design with the use of ATE for fault-isolation at all levels of maintenance. Implementation of the use of standardized guidelines for equipment testability should alleviate the problems previously experienced with ATE.

C. <u>Failure Analysis</u>

1. <u>Conclusions</u>. From discussions at AMSs and ALCs, it seems that no one is concerned as to why avionics equipment fails. At the intermediate shop level, some technicians were concerned about secondary damage observed as the result of component failure and some had submitted suggestions such as the installation of a fuse to prevent secondary damage to circuit boards. At Warner-Robins ALC there is a concern about high failure rates on specific components, but the concern is with regard to running out of replacement parts rather than with investigating the cause of the failures.

2. <u>Recommendations</u>. It is recommended that action be taken to institute means of monitoring maintenance actions at both the intermediate level and depot level for the purpose of detecting high failure rate items which may be attributable to design deficiencies or *latent* component failures. This capability exists to some degree in the existing maintenance data collection system; however, it seems to be used primarily for cost accounting and parts justification and not to initiate failure analysis action. Failure analysis requires more in-depth understanding than would be expected of technicians at either the intermediate shop level or depot level and would probably be best accomplished by engineers at Rome Air Development Center (RADC). The technicians would, however, have to be instructed to provide more explicit technical details of maintenance actions performed than are now reported through the maintenance data collection system so that system failure patterns could be more readily identified. Emphasis would have to be placed on technical accuracy in reporting and minimizing wording of maintenance data to make the performing organization "look good". Failure analysis by RADC is suggested since RADC already has recognized expertise in the areas of reliability and physics of failure analysis for components, and therefore would

seem to be qualified to expand into failure analysis at the SRU and LRU level. An alternative which could be suggested on the basis of proximity to the problem, is establishment of a failure analysis organization at an ALC such as within the Avionics Division at Warner-Robins ALC. A failure analysis group would not only identify causes of failures and provide recommendations for ECPs to correct the problem, but also would develop expertise in circuit testing which would be used in establishment of testability requirements for new systems to be used with ATE.

D. The Reliability Improvement Warranty

The maintenance concept described in the previous section is the traditional process which was observed at the several avionics maintenance squadrons and depots. An alternate maintenance process which is coming into use by the military is to have maintenance performed by the equipment contractor under a Reliability Improvement Warranty (RIW). While RIW is a relatively new concept for Air Force avionics maintenance, it is not without precedent, since commercial airlines handle their avionics maintenance in this manner. A RIW is a procurement technique which can be used to motivate contractors to design and produce equipment having high reliability and low maintenance costs during field operational use. Under RIW, the contractor is committed to perform depot-type repair services at a fixed price for a specified duration of operating time, calendar time, or combination of both. Although much of the expenditures under RIW are for repair services accomplished, the prime objective of RIW is reduction of life cycle cost through improved reliability rather than cost savings which may be possible through using contractor repair services in lieu of government depot services. If a contractor is committed to perform repair services on his delivered equipment for an extended period of time at a fixed price, he has strong incentive to achieve or exceed the reliability level on which the warranty price is based. By directly observing all field failures and being responsible for repairs, the contractor can quickly identify failure patterns and is also motivated to institute corrective action through engineering change proposals (ECPs). Under RIW, the ECPs are introduced at no cost to the government and provision is made to assure a standard configuration at the end of the warranty period by requiring the contractor to install all ECPs in each unit that is returned for repair and to provide modification kits for the remaining units.

In the typical RIW repair process, a suspect unit is tested at the organizational level by military technicians, and units which are indicated as defective are returned to the contractor for repair. The hardware level to which the warranty applies varies and must be specified in each procurement. In some cases, LRUs are sealed and testing at the intermediate level is limited to verification of a BITE indicated fault at the LRU level while in other cases, the warranty applies to the shop replaceable unit (SRU), and fault isolation at the intermediate shop level is the same as with the conventional maintenance concept.

One problem observed at organizational level was that BITE is often inadequate to accomplish accurate fault isolation and that many CNDs were experienced in responding to BITE indicators. It can be assured that under RIW, the contractor will also experience some return of good units and incur costs in confirming operation of these units. To provide incentive for instituting corrective ECPs to BITE, an RIW procurement requires the contractor to absorb much of the expense associated with CNDs. In the interest of fairness, however, the contractor is usually protected from gross negligence by the operational organization in the identification of defective units by being compensated for processing CND units in excess of a specified percentage (usually 20%-30%) of total units returned.

The repair of avionics equipment at a central contractor facility not only affords the contractor direct observance of failure patterns in implementing corrective ECPs, but also can lead to the development of a high level of expertise for repair of the equipment. We were advised by some intermediate shop personnel that the high reliability of newer avionics equipment had an adverse effect upon the proficiency of maintenance technicians because of the few experience opportunities resulting from low failure rates. The personnel turn-over rate is also generally higher in a military maintenance organization than at a contractor's facility and this further aggravates the problem of maintaining technical proficiency for repair of avionics equipment at the intermediate shop level.

Current RIW procurements include the ARN-118 TACAN set which is being procured for use in several aircraft, a new inertial navigation set (INS) for the C-141 aircraft, and INS for the F-16 aircraft.

There is no standard RIW procurement since there are many variables to be considered with RIW. One area to be considered under RIW is the determination of the applicability of the warranty provisions. The exclusions under RIW are generally pieces of equipment which are lost or inoperative due to mishandling, fire, flood, explosion, crash, tampering or combat action. The repair of equipment which is excluded under RIW may be accomplished at a Government depot such as Warner-Robins ALC (as in the case with the ARN-118) or by a contractor under a separate contractual agreement.

The warranty period is a key parameter in RIW procurements. The warranty period may be specified in terms of specified number of months after acceptance or in terms of total number of operating hours for all the units. In the case of the ARN-118 TACAN, the warranty period is 60 months after acceptance of the first unit. The warranty period for the C-141 INS is 48 months, and for the F-16 INS, the warranty period is 48 months or 300,000 flying hours.

Some RIW procurements provide for optional extension of the warranty period. Observations made while touring maintenance squadrons indicate that avionics equipment is used for 15-20 years and that maintenance coverage beyond the initial 4 or 5 year period is essential to the operational readiness of the Air Force.

The hardware level to which the warranty applies also varies under RIW and must be specified for the particular equipment. In the case of the ARN-118 TACAN, the LRUs are sealed and the warranty applies to the LRU. In the case of the C-141 INS, the warranty applies to the SRU, if the SRU is removed and replaced by the government. The warranty applies to the module level in the case of the F-16 INS if removal and replacement of the module is accomplished by the government.

Failure verification procedures must be established under the terms of the contract. Ideally, BITE would provide failure indication and no intermediate shop test equipment would be required. In the case of the ARN-118 and the F-16 INS, failures are verified by the government, using a hot mockup in the intermediate shop in a manner similar to the traditional maintenance operation observed at several AMSs. No fault-isolation testing or tampering with the sealed LRU is permitted under the RIW agreement on the ARN-118 TACAN. The failure data is recorded on an AFTO Form 350 and the ARN-118 is returned to the contractor for repair. In the case of the F-16 INS, fault isolation to the module level is accomplished by the government. Under the C-141 and F-16 INS contracts, all returned material is the contractor's obligation while in the case of the ARN-118, the contractor is given some consideration for returned material which tests OK when received from the government. A retest OK (RTOK) rate of 30% must be accepted without compensation, but any additional non-verified failures result in a charge to the government of $100 per unit.

The mean time between failures (MTBF) and repair turn around time for the equipment are key parameters in determination of the operational availability of equipment and those parameters must be specified in RIW procurements. The details of method of measurement and measurement period for those parameters vary and must be specified in the contract. A related parameter is the number of spares provided and the determination of damages for delays in delivery of spares. The turn-around time allowed for the ARN-118 is 15 days while in the case of the F-16 INS, it is 22 days. Penalties are imposed in both cases for failure to meet the specified turn-around time. Under RIW, the penalty for not meeting turn-around time requirements may be either a specified dollar amount per day or the contractor may be required to furnish "loaner" spares as necessary to achieve the required operational availability.

There is little question that RIW offers a great potential for improving reliability and reducing life cycle costs for avionics equipment. Although there has been limited experience with long term warranties in the military, the experience has been generally favorable. It is recommended that current military RIW programs be closely monitored to evaluate their success and provide recommendations for future RIW procurements. The development of standard terms and conditions applicable to various warranty plans and equipment types would aid in implementation of future RIW procurements.

For further information on RIW, the reader is referred to the following sources:

1. H. Balaban and Major F. Nohmer, "Warranty Procurement - A Case History", Proceedings, 1975 Annual Reliability and Maintainability Symposium, Washington, DC, January 1975.

2. H. Balaban and B. Retterer, The Use of Warranties for Defense Avionics Procurement, RADC TR-73-249, June 1973.

3. C. R. Knight, "Warranties as a Life Cycle Cost Management Tool", EASCON '74, Washington, DC, October 1974.

4. USAF Directorate of Procurement Policy, Interim Guidelines Reliability Improvement Warranty (RIW), July 1974.

5. H. S. Balaban, Guidelines for Application of Warranties to Air Force Electronic Systems, RADC TR-76-32, March 1976.

APPENDIX A

STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname and Grade)		TO	ACTION	SIGNATURE (Surname and Grade)
1	DHE (Mr.Wagner)		S E Wagner 5 Mar 76	6			
2	DHM (Mr. Rees)		[illegible] 8 Mar 76 D Rees 8 Mar 76	7			
3	DH (Mr. Edwards)		[illegible]	8			
4				9			
5				10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INIT.	SUSPENSE DATE
P. R. Owens, Maj, USAF	AFAL/DH	52911	gmh	

SUBJECT	DATE
Trip Report for Trips to Kincheloe AFB, MI and Grissom AFB, IN	4 March 1976

SUMMARY

Travelers: Major P. R. Owens, Mr. M. R. St. John, and Mr. F. D. Lamb

Objective: To gather data for the Avionics Maintenance Study.

Dates and Places Visited: 23-24 Feb 76, Kincheloe AFB, MI
26-27 Feb 76 Grissom AFB, IN

Organizations covered in the interviews: 449 Avionics Maintenance Squadron, 449 BW (SAC), Maj J. E. Chestnut, Squadron Cmdr, Kincheloe
305 Avionics Maintenance Squadron; 305 Air Refueling Wing (SAC), Maj G. Miller, Squadron Cmdr - Grissom

Aircraft Maintained: B-52H (Kincheloe)
KC-135 (Kincheloe and Grissom)
EC-135 (Grissom)

Discussion:

1. Age of the Systems. Most KC-135 and B-52 avionics is over 20 years old. Electromechanical parts are wearing out in such systems as inertial navigation equipment and mechanically scanned antennas. The electronics technology is almost exclusively vacuum tube with only a few upgraded LRUs having discrete solid state components; almost no ICs used (we remember only one LRU using DIPS). We except the EC-135 Post Attack Command and Control System electronics, which was more modern. Several technicians in several shops commented that one of the more frequent causes of subsystem failure is old, brittle wiring. With minor exceptions those LRUs which had more modern technology were viewed with great favor by the technicians.

2. Parts Availability. As might be expected with a fairly old system, parts availability is a problem with several of the subsystems. Some of the subsystems were designed using fairly standard and still plentiful vacuum tubes, but others used special tubes or subsystem unique components. On such subsystems parts costs have been rising rapidly in recent years. The travelers expect to check with AFLC on the extensiveness of the reprocurement problem. The B-52 has more parts problems than the KC-135, being older and having more electronics. Some cases were reported of having to send to salvage an LRU because of lack of one component or SRU. This

happens because of the way in which the supply system operates. When the unit was sent to salvage the good parts were generally stripped and replaced with failed parts.

4. Maintenance Concepts Employed.

a. Two Tier Structure. Both organizations were enmeshed in an essentially 2-tier maintenance structure. Very little on aircraft maintenance was accomplished other than removal and replacement of LRUs, some instrument adjustments, and some mechanical adjustments such as boresighting antennas. The LRUs were removed by teams (generally two-man) from the same shop to which they were taken for troubleshooting and repair. At Kincheloe the various shops generally split their people into those who did the remove and replace on the flightline (generally requiring less skill) and those who isolated and replaced failed components or SRUs within the LRUs. At Grissom the manning was not considered sufficient to split out the technicians in this way, so people worked both on the flightline and in the shop.

b. Tail Number Scheduling. Tail number scheduling was used exclusively. It was felt that this practice generated a lot of cannabalization actions which cost more than double in remove and replace time because of the extra documentation required. People questioned felt that tail number scheduling was the only way to go; however, to keep the general quality of the aircraft assigned at an acceptable level of readiness, it was asserted that without this practice a few good aircraft would fly the majority of the hours in each month's schedule and "hangar queens" would proliferate. These opinions were based on previous experience in commands which didn't use tail number scheduling.

c. On-base Repair. Opinions regarding maintenance of LRUs not authorized on-base repair varied on a case by case basis. In some cases the opinion was that on-base repair was possible with the equipment and people on hand. In other cases the opinion was that either with more people or more equipment repair could better be accomplished at base level. In still other cases it was felt that the equipment/manning addition required would be too great at base level to make on-base repair cost-effective.

d. Hot Mock-ups. Hot mock-ups were used throughout the shops. The only automated mock-up seen was the one being installed for the EVS(which wasn't yet installed on Kincheloe's aircraft). Very few other mock-ups had rudimentary automated parts. Most were racks or benches with standard or special measurement gear, often built up on base to weapon system specification. The level of stimulus simulation was unsophisticated. No provisions were made for introducing spikes on the power or data lines simulating switching on the aircraft. The nearest thing to this which was available was the MADREC on the B-52s which was a multichannel recorder for several of the systems. Technicians could check this history for the flight to see if malfunctions occurred at the time of line spikes. Interaction between systems was not well simulated - judging by technicians' comments. There also was no environmental simulation.

e. Flightline AGE. There is no flightline avionics AGE for the KC-135 or B-52. Technicians will carry multimeters or oscilloscopies or other general purpose test equipment with them when necessary, but there is no equipment in place.

f. Phased Inspections. Both aircraft undergo phased maintenance inspections based on the number of flying hours. Except for desiccant changes and a few electromechanical inspections, no avionics maintenance is performed in the course of these inspections.

4. Depot Support. Policy seems to differ locally as to how much access the shop chief has to the Item Manager in AFLC. In some cases there was good rapport and in others almost no rapport. There was some opinion that the quality of both depot organic and depot contractual work quality was declining, but this was by no means unanimous. There were also reports that budget cuts have forced elimination of some quality control inspections at depot level. Team members intend to follow up on this item.

5. Manning. Generally people complained about not having enough people to do the job. This situation was not uniform; however, some shops had received manning increases. Generally though, there have been manning cuts within the squadrons and more are projected for the coming summer. In several instances we found senior NCOs retiring at or shortly after the 20-year point. Projected replacements did not fill projected losses. The people questioned said there had been no perceptible decrease in flying hours but that there might have been an increase. This, combined with the aging weapons systems themselves, added up to a projected increase in workload. In some cases changes had been instituted to cut manning requirements but the manning had been reduced before the initiated changes could bear fruit. Most technicians were 5-level incoming. 3-level technicians seem to get trained up in short order. There were generally about two 7-level people to a shop, but this varied. There was usually a two-shift operation in force, 0730-1630 and 1600-2400.

6. Inspections. At Grissom the AMS people weren't bothered about inspections at all. The last ORI left them with a rare Excellent rating rather than the usual Satisfactory. At Kincheloe feelings were mixed. Receiving particularly vehement criticism was the Maintenance Standardization and Evaluation Team (MSET). The MSET, many shop chiefs and technicians felt was more concerned with cosmetics than actual maintenance problems. There were several reports of equipment which MSET had written up for superficial reason and not for failing to perform. Replacement of these items was costly and unnecessary as far as the people in the shops were concerned. There was much more evidence of the usual running battle which usually exists between the line troops and the inspectors. This also was reflected in the "average" attitudes of the people in the two squadrons. The people at Grissom seemed much more open and relaxed when they talked to us. It seemed a much happier place.

7. Training and Personnel Quality. There were mixed reports about the quality of technical training received by the incoming technicians. Some shop chiefs thought it was declining, while others thought not. Evidently some self-paced training is now being used in tech school and this has advantages and disadvantages. Generally the feeling was that for a four-year first-term enlistee only about one to two good years of work can be had from him. Six year enlistments are presently being tried and we received varying reports of the effectiveness of this method. There

was general consensus that the elimination of the draft has not decreased the quality of the avionics maintenance technicians coming in to these two squadrons. Consensus also was that avionics people are generally higher than average quality.

8. Effect of Seasonal Changes on Systems. There was a consensus that during the spring and fall is when the heaviest workloads occur. These are times of fluctuating temperatures. When the cold (or hot) weather comes to stay, the systems settle down and run better.

9. Information Work and Documentation Flow. Except on rare occasions equipment malfunctions are discovered by the aircrew during flight. Squawks are written up on the crew's debriefing form. It is usual for the command post to receive an abreviated malfunction code, relay it to job control which notifies the squadron which notifies the shop. The shop then sends a representative to the debriefing. If there is any doubt about the write-up, the shop representative questions the crew members until he feels he has sufficient information to go to the aircraft and isolate the LRU. The maintenance team then goes to the aircraft and tries to duplicate the malfunction on the aircraft. If the malfunction cannot be duplicated, the technician can

a. Write up a "cannot duplicate" on the work order form, AFTO Form 349.

b. Make a minor adjustment and record it on the form.

c. Pull the most likely LRU and take it back to the shop for bench check.

If the malfunction can be duplicated, the technicians pull the appropriate LRU. Once an LRU is removed, it is tagged with an AFTO Form 350, which contains a write-up of the malfunction transcribed from the AFTO Form 349 and more detail if it is available.

Manhours expended and action taken are recorded on the AFTO 349 and provide the inputs to the Maintenance Data Collection System. The AFTO Form 350 stays with the LRU if it goes to depot. Once at the shop the LRU is checked out further. If it is reparable on base, it is repaired if parts are available. If parts aren't available, they are ordered, or the next higher assembly to the failed component is ordered, or both. If the unit is not reparable on base, it is crated and shipped to depot.

10. Job Control. The nerve center of the maintenance operation is Job Control. It has one representative from the avionics maintenance squadron to dispatch avionics technicians from the various avionics shops to debriefings and on aircraft maintenance. It was located in the same building as the AMS at Kincheloe and in an adjacent building at Grissom. Job Control also prioritizes aircraft to be worked on.

11. Time Accounting. SAC is using a modified exception time accounting system which one of the NCOs in Analysis thought didn't accurately reflect how time is spent on such things as telephone alert at home and sitting in the "Redball" truck which is ready to make last minute repairs to aircraft ready to fly.

12. Cost Accounting. Almost without exception the people in both squadrons were extremely cost conscious with respect to parts and equipment costs. There is a monthly report which makes these costs highly visible. Nobody is very conscious, however, of the manpower costs involved in doing a job one way as opposed to another. Military are treated as a free, albeit limited, resource. Their salary does not come out of the squadrons' yearly budget. The Commander at Grissom said industrial funding would just make his job harder and he was not for it. Everyone in the squadrons implicitly depends on the cost-benefit analysis having been carried out at higher level and the results being implemented by policy. Management takes place within those constraints.

13. Maintenance Data Feedback. There seems to be little return to the maintenance technician, shop, or squadron on their investment of time in filling out the AFTO Forms 349. Any benefits must accrue at higher levels.

14. Housekeeping. We found the shops in what we would consider inspection condition. If there are junk drawers or miscellaneous parts lying around, they must have been hidden at home or in lockers. The labeling is as extensive as that shown in the Equipment Tiger Team slides. A lot of manhours must have been invested, but the lack of unnecessary spare parts must have helped the supply system budgets. This "lean" system seems to be working fairly well. The parts availability problem seems to be caused more by the age of the subsystems than by inefficiency in the supply system.

15. APN-59 radar. At Grissom this was the radar shop's biggest headache. It was also considered a dog by the shop at Kincheloe which also handled B-52 radars. They would love to have any kind of fairly modern replacement.

16. On-aircraft Avionics Accessibility. Most of the KC-135's avionics is readily accessible and working space is quite adequate. The B-52 on the other hand is really packed. Most of the B-52's avionics is removed inside the aircraft and there is precious little work space. In addition, it sits fairly high off the ground further complicating access. The fire control radar up in the tail section is a real bear to get at and work on, especially on a subzero windy night.

17. Observations. We are amazed that such ancient systems, from an electronics viewpoint, work as well as they do. The maintenance problems are increasing as the system ages. The problems are those typical of an old, non-automated

system. We expect the modern automated systems to have their own set of problems. The people seem highly professional and dedicated to doing the best they can with what they have to work with. There was a fair amount of frustration evident with the "system" but there were quite a few people both junior and senior who were downright enthusiastic about their jobs. Everybody seemed to really care about the quality of work turned out and to be interested in improving the system. We were impressed even when we discounted the probability that we were being treated as visiting firemen.

APPENDIX B

STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname and Grade)		TO	ACTION	SIGNATURE (Surname and Grade)
1	~~DHE~~		(Mr. Wagner) S. Wagner	6			
2	~~DHM~~		(Mr. Rees) D Rees	7			
3	DH		(Mr. Edwards)	8			
4				9			
5				10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INIT.	SUSPENSE DATE
PAUL R. OWENS, Maj, USAF	AFAL/DH	54998	gh	

SUBJECT	DATE
Trip Report - Homestead AFB, FL	6 April 1976

SUMMARY

Travelers: Maj P. R. Owens, Mr. M. R. St. John

Objective: To collect data for the Avionics Maintenance Study

Dates and Places: 11-12 Mar 76
31st AMS, Homestead AFB, FL
Lt Col Clack, Commander

Aircraft Maintained: F-4E

Discussion:

1. Age of the system. The F-4E is a fighter which dates from the early 1960s. Much of the avionics is discrete semiconductors although there were some LRUs using tubes and a few LRUs housing SST.

2. Parts availability. As with the rest of the places we visited, parts availability is a problem. Since the F-4E is a fairly modern mainline weapon system, the reason must be inadequate stocking or procurement of spares brought on by low budgets.

3. Maintenance Concepts Employed

a. Two tier structure. Again we found an essentially two tier structure. By this we mean one tier at base level, combining both flightline and base shop, and one tier at depot level.

b. Tail number scheduling. TAC is also using tail number scheduling. Opinions again varied on the value of the system.

c. On-base repair. Several people in some of the shops were not happy with the level of repair authorized. They felt they were doing work which could only be accomplished properly at depot.

d. Hot Mock-ups. Hot mockups were again the method used for isolating faults in removed LRUs. These mock-ups were again fairly unsophisticated equipment having no ability to simulate spikes on the power bus or any effects due to enrironment.

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e. Flightline AGE. Most shops carry out only simple test gear to the line. The calibration equipment for calibrating the Weapons Control System (WCS) radar is on the line in a nose dock. It is computer controlled though manually advanced through its steps. The calibration process is very time consuming.

f. Phased Inspections. Again, with the exception of ECM pods, no avionics was included in the phased inspections of the aircraft.

4. Depot Support. Shop chiefs seemed to talk rather frequently with their Item Managers in AFLC. Again we had reports of a fall-off in the quality of depot work.

5. Manning. With the exception of the Weapons Control Systems shops seemed adequately manned. The WCS, however, was in deep trouble. Two senior NCOs were retiring in the summer and there were no new senior NCOs scheduled in. WCS manning seems to be a real problem across TAC except for two bases where, with adequate manning, they have proved that WCS can be maintained. Since there is very little cross-training between shops, no end to the problem is in sight. This shop is being worked to death. There was two-shift operation with shifts flexible and geared to the flying schedule.

6. Inspections. Opinion was expressed that MSET (Maintenance Standardization and Evaluation Team) has outlived its usefulness. It evidently served a real purpose when instituted back in the early 60's. Shops varied widely and unnecessarily from base to base. Now, however, the opinion was expressed the MSET ties up too much skill in the senior NCOs on the teams. These skills could better be used in the field.

7. Training and Personnel Quality. Many complaints were voiced about the quality of technical school training being exhibited by new recruits. Almost unanimous was the opinion by shop chiefs that personnel quality was declining. We heard that several senior NCOs were retiring earlier than they might have had working conditions been more favorable. Recruits were evidently not being extensively trained on the equipment with which they would work and not receiving as much in the fundamentals of electronics as had been the case previously. Shop chiefs again said that the new people didn't get much time in tech school with test equipment such as scopes and multimeters. Training time to move from the 3-level to the 5-level was at least 6 months.

8. Effects of Seasonal Changes on Systems. Since there is no winter-summer gradient at Homestead, there were no associated effects. There was a change between the "rainy" and "dry" seasons, however. Particularly noted was the radio problem in the rainy season. The back seat canopy rails let water run off and drip onto the radios which sit under the back seat. This causes frequent necessity to pull the back seat and remove the radio.

9. Maintenance Data Feedback. Very little, if any, of the data input to the system by the shops comes back to help the people in the shops. Again, the data must be used at higher echelons or in AFLC.

10. Weapons Control System (WCS). The APQ-120 radar and its associated processing equipment are the biggest problem subsystem. The manning problem was referred to in para 5. Another piece of the problem with WCS revolves around calibration. The 307 test set used for calibration is advanced through go, no-go tests and requires manual action to correct no goes. The process takes over 20 manhours. The flying schedule sometimes requires that aircraft be buttoned up and flown before the calibration is complete. In other cases LRUs are pulled out of a partially calibrated aircraft and inserted into an aircraft which must fly soon (tail number scheduling). This negates the calibration performed since there is considerable interaction of LRUs. The result is many overtime hours and many weekends spent in working on the WCS. There seem to be no outstanding or easily fixed problems with the WCS itself except that its MTBF is too low for its maintenance force and that the calibration takes so long.

11. The ARC-164 UHF Radio. The F-4 fleet is slated to receive this radio. Opinion was expressed that it would be much better to put two radios in the aircraft rather than one radio and two control boxes. It was felt that decrease cabling and maintenance problems would pay for the cost of the extra radio. The radio will apparently fit where the control boxes are now, which will eliminate removing the back seat to replace the radio.

12. Accessibility of Avionics. With the exception of the radio and some LRUs on the WCS most of the LRUs are readily accessible. Doors in the side of the aircraft swing up and the boxes can be pulled fairly easily.

13. Observations. This system exhibits problems typical of a moderately aged system. Cabling and connectors are becoming a problem. Parts replacement problems are becoming more acute. The alignment problems of the WCS seems symptomatic of analog systems. Technical data is relatively mature and is not causing problems. On the other hand, the digital parts of the system were not free from problems. If the WCS problem can be alleviated by manning equipment fixes or equipment replacement, the problems of the 31st AMS would be much smaller than they are now.

STAFF SUMMARY SHEET

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1	DHE	SEW	(Mr. Wagner)	6			
2	DHM	DR	(Mr. Rees)	7			
3	DH	WE	(Mr. Edwards)	8			
4				9			
5				10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INIT.	SUSPENSE DATE
OWENS, P MAJ, USAF	DH	54998	gmh	

SUBJECT	DATE
Trip Report for trips to Langley AFB, Dover AFB, and Plattsburg AFB	21 April 1976

SUMMARY

Travelers: Maj P. R. Owens, Mr. M. R. St. John, and Mr. F. D. Lamb

Objective: To Gather data for the Avionics Maintenance Study

Dates and Places Visited: 28-30 Mar 76, Langley AFB, VA
30 Mar - 1 Apr 76, Dover AFB, VA
1-2 Apr 76, Plattsburg AFB, NY

Organizations covered in the interviews:
- 1st AMS, 1st Tactical Fighter Wing (TAC), Lt Col Caputo, Sq Cmdr, Langley
- 48th Fighter Interceptor (ADC), Lt Col Burnl, Sq Cmdr, Langley
- 38th Tactical Airlift Squadron (MAC), Langley
- 436th AMS, 436th Military Airlift Wing (MAC), Maj J. C. Smith, Sq Cmdr, Dover
- 380th AMS, 380th Bomb Wing (SAC), Plattsburg, Maj Thrasher, Sq Cmdr

Aircraft Maintained: F-15 (Langley)
F-106 (Langley)
C-130 (Langley)
C-5A (Dover)
FB-111 (Plattsburg)

Discussion

1. Ages of the Systems. Weapon systems covered on this trip range from the old F-106 and C-130 to the fairly new FB-111 and C-5A to the brand new F-15. These systems span roughly 20 years of technology. The F-106 has mostly tubes except for a few modified LRUs. The same is true for the C-130. The C-5A and FB-111 use both discrete solid state components and integrated circuits, while the F-15 is starting to use some large scale LSI. We think that planners of new technology should be aware that after their designs are finalized, their products will quite likely need spare parts for more than 20 years. This implies an emphasis on mainline, widely available parts with an eye to reprocurement of spares.

2. Parts Availability. People in each maintenance organization we have visited so far have complained of parts availability. One would expect this to be a problem with both very old or very new systems but not with supposedly mature mainline systems, other things being equal. Evidently other things are not equal and the Air Force is running as lean on spares as possible consistent with their operationally ready rates.

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3. Maintenance Concepts Employed.

a. Number of Levels. The F-15 and FB-111 have a definite three level maintenance structure (flight line, shop, depot). The C-130 has essentially a two tier structure, combining flightline and shop. The F-106 and C-5A maintenance organizations were a mixture. In some subsystems the same people worked both on the flightline and the shop and in others it was split out by the two levels.

b. Tail Number Scheduling. In all cases tail number scheduling was used. Opinions were again mixed about the efficacy of the concept as it impacted avionics. In particular, the FB-111 had a very high cannabalization rate.

c. On-base Repair

(1) F-15. On the F-15 repair was limited to removal and replacement of LRUs on the flightline and removal and replacment of modules (typically printed circuit boards) in the shop. Presently little, if any, replacement of components on boards is accomplished. Some modules are classified as throw-away, but they are generally being saved and sent to depot. Since the shop test stations and their associated software are only partially up and running, many LRUs are still being sent to the contractor for repair.

(2) FB-111, C-5A, C-130. In each case here only LRU removal and replacement is performed on the flightline. On the FB-111 and C-5A most of the shop maintenance consists of replacement of faulty modules, although some failed component parts are replaced (generally by agreement with depot). In the case of the C-130 and F-106 extensive piece part replacement is accomplished.

d. Hot mockups. Hot mockups are used exclusively in the F-106 and C-130. Again the simulation obtained is rudimentary and does not account for troubles induced by environmental stresses and voltage spikes. A few of the test stations in the C-5A system amount to hot mockups.

e. Automatic and Manual Test Stations. The F-15, FB-111 and C-5A all use a mixture of automatic and manual test stations. The manual test stations allow an LRU to be stepped through tests and have some branching capability for trouble-shooting. Voltages and sometimes waveforms may be monitored at test points. The F-15 manual test stations currently cannot handle all the LRUs for which they were designed. Simulations of inputs from related LRUs is limited and no environmental simulation is present.

(1) F-15 Automatic Test Stations. Only a few of the LRUs scheduled to run on the automatic test stations can actually be run. Software bugs are still being worked out. In some cases test tolerances may be set too close. Each of the three automated test stations contains its own minicomputer. The computer goes through its program serially and stops at the first fault. Until this fault is corrected, it will not go any further. Once the faulty module is replaced, the test begins again from the start. If another fault is detected in the LRU, the machine again stops. This process continues until all detected faults have been corrected. Both automatic and manual test stations were designed to catch 95% of probable faults (working from piece part reliabilities). Opinion so far has it that once the bugs are out, 80% of actual failures will be more nearly correct. The technical orders (TOs) published thus far tell the technicians in great detail how to operate

the test stations, but the TOs are not helpful in finding faults not detected by the automatic testers. It is the "trained monkey" approach. The technician has no flexibility in his interaction with the test station. The technicians for each test station are divided between those who operate the test station and those who maintain the test station and troubleshoot it. The present concept is that schematics and block and loop diagrams are not included in the TOs to aid the technician in troubleshooting. Moreover, the test station operators are not trained in the systems viewpoint of how different LRUs interact. They are trained in the LRU specific terms for troubleshooting using the test stations. Technicians are unhappy with this situation and would prefer schematics. Technicians particularly singled out the microwave area as unsuitable for the approach being used. They would much prefer to have a hot mockup in this area.

(2) FB-111 Automatic Test Stations. All the automatic test stations on the FB-111 system are controlled by a central computer. Consequently, when that computer "crashes," all of the test stations are out of business. This seems to be happening less frequently recently. Some of the hardware has been upgraded. There is some greater flexibility in tester operation since the technician doesn't always have to start the tester at the beginning of the test sequence. With the exception of choosing entry into the test sequence, however, the technician cannot interact with the computer. More tech data is available in terms of LRU schematics and data flow within the LRUs. Test station operators still do not have a system viewpoint however and are locked in to treating each LRU as a separate entity. At Plattsburg the FB-111 organization has a refrigerator and oven combination for cold/hot soaking LRUs. LRUs must be removed from the refrigerator or oven before test, however. A separate AGE Branch deals with the test station maintenance.

(3) C-5 Automatic Test Stations. The test stations for Inertial, Doppler Navagational Equipment (IDNE) and the Malfunction Analysis Detection and Reporting (MADAR) system were both controlled by computers which gave the technicians little flexibility in the testing process. They were not well liked by the technicians, who would prefer to take a more active part in troubleshooting. Technicians were assisted however by having on station the depot level TOs which gave them schematics of the LRUs. The autopilot and flight director subsystem LRUs were tested on a test station which used a Honeywell 1505 computer control. The shop chief and a technician interviewed were quite happy with the test station. The software allowed interaction between technician and computer to locate the problem module. Success rate was apparently high. A Honeywell technical representative was on station and considered most helpful in assisting with computer operation and LRU troubleshooting. I have since found that MAC Hq is going to request using similar test stations to replace the MADAR and IDNE testers. They felt the replacement cost plus maintenance would be less expensive than maintenance on the present test stations.

f. Built-In Test and Monitoring Equipment. The F-15, C-5A and FB-111 all had built in test (BIT) and/or automatic monitoring equipment on board the aircraft. The F-106 carries an oscillographic recorder for the radarscope. This is used both as a way of scoring intercepts and as an aid to troubleshooting malfunctions.

(1) F-15 BIT. The pilot has a status panel to tell him what systems BIT says are inoperable. Upon landing the crew chief will check in the equipment bays to see which LRUs are flagged (they have indicators which showed they failed BIT). If LRUs are reset and the flag does not reappear, it is assumed that a transient glitch was the problem. If the flag reappears, the LRU is pulled and taken to the shop. No permanent record is made of the indications on the status panel except as they are written up in the AFTO Forms 349. At this stage of development indications which do not reappear are very frequent. According to technicians the BIT indications are not always accurate with respect to the LRU to be pulled. Technicians must sometimes swap non-indicated boxes until the condition goes away.

(2) FB-111 BIT. FB-111 LRUs do not have BIT flags on them, so deciding which LRU to pull is accomplished by checking the BIT panel and trying to duplicate the malfunction on the ground. Again, no hard copy of the malfunction indications is automatically produced. Again, there was a lack of enthusiasm among the technicians who worked on the flightline removing and replacing LRUs. The technician evidently does not get enough information by BIT alone to go directly to the correct LRU "enough" of the time (whatever "enough" is).

(3) C-5A. The malfunction Analysis Detection and Reporting (MADAR) System performs the BIT functions. Not only does it monitor avionics but it also monitors the rest of the aircraft systems. There are about 800 monitoring stations on the aircraft multiplexed on a data bus so that each one is sampled at least once a second. Malfunctions detected are printed out on paper and stored on tape. The AFTO Forms 349 (job orders) and AFTO Forms 781 (Aircraft Discrepancy Log) are automatically generated from the tape. The tape is read into a data bank at Oklahoma ALC so that the information on any C-5A or all of them are available in near real time. The major problem with the MADAR system is that it is unreliable. It was considered the worst system on the aircraft by the avionics maintenance people at Dover. Of course when the MADAR is down the information flow into the automated system is impaired or stops altogether depending on what the nature of the MADAR failure is. MAC is aware of the problem and has recently decreed that C-5As will not fly unless MADAR is operational. The concept of MADAR in conjunction with the Ground Processing System (GPS) for using the data tapes to automatically produce the forms and enter information into the data bank is excellent. Shop chiefs for the C-5A said they got useful information out of the system. The analysis people in the squadron were highly pleased with the system. It is the best attempt seen so far at closing the information loop. We understand a similar concept is being used for the B-1. If implemented with reliable equipment (and good software), it can be a real boon not only to upper management and AFLC but also to the first and second line managers. Recognize that the foregoing is a big if.

g. Flightline AGE. The F-15, FB-111 and C-5 all had some specialized test sets which were used on the flightline in addition to use of multimeters and 'scopes. The FB-111 seemed to have more test sets than the others. None of the test sets were automated. The C-130's use a couple of specialized test sets.

h. Phased Inspections. The only evidence we found of phased avionics inspections on this trip was a program in the F-106 organization. The MA-1 fire control system LRUs were checked at 45 and 90 day intervals. Of particular interest are the relay banks. Each relay is resistance checked and relays with over 1 ohm resistance are replaced. The shop chief claimed that the extra time spent had paid off in much greater reliability. In all other cases avionics was repaired only as it malfunctioned.

i. Debriefing. All the bases visited on this trip used aircrew debriefing, but the methods differed.

(1) F-15 and F-106 pilots went to debriefing in a building in the maintenance complex. They were queried in turn by representatives from the major shops (one representative was present from avionics) regarding squawks on the systems.

(2) FB-111 crews were debriefed by avionics people in the cockpit in an effort to duplicate malfunction conditions before the aircraft cooled down from flight.

(3) C-5A crews were debriefed in a truck right by the aircraft. Avionics had one representative.

j. The "Big Apple" Truck. The FB-111 used a Big Apple truck which carried LRUs for most of the avionics systems likely to fail. Many of these LRUs were cannabalized from aircraft not scheduled to fly. This truck was used to insure the aircraft scheduled to fly got off on time (SAC places great emphasis on meeting scheduled take off times). The truck was also evidently used to isolate faulty LRUs immediately upon aircraft return during the avionics debriefing with the crew in the cockpit. The operation was similar to the "Red Ball" truck used at other SAC bases visited previously. The Red Ball truck has technicians on board from the major shops (one technician for avionics) the LRUs are not generally carried on the Red Ball trucks. Evidently the Big Apple concept is very effective in terms of meeting operational requirements. However it implies that the FB-111 electronics systems are a really big problem.

4. Depot Support. The FB-111 people said that depot support had been excellent. Other people were less enthusiastic, but there were no real complaints beyond the perennial parts availability complaints which are not really depot problems unless equipment turnaround at depot is slow.

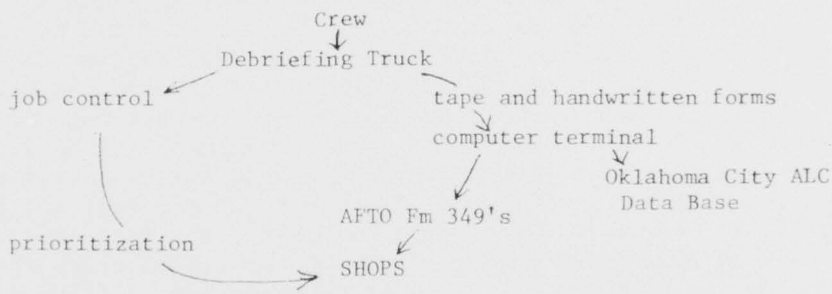
5. Manning. The only complaints encountered about manning concerned the gap between junior technicians and senior NCO in the FB-111 organization. We have encountered this problem before. Evidently the "middle" people get out creating possible future problems when the present senior NCOs retire. Presently people working in the F-15, F-111, and FB-111 have AFSCs unique to those three weapons systems. The people in the C-5A program are frozen to that weapon system because of its unique mode of operation.

6. Training and Personnel Quality. Generally shop chiefs were happy with the quality of people coming to their organizations. They saw no decline in the quality of the first termers in avionics. There were mixed reactions to the technical training given the new troops. However, Palace Eagle has created some problems. This program is designed to cross train airmen from other electronic career fields into the F-15 avionics maintenance system. Some of these people

do not have backgrounds in avionics maintenance and need reorientation according to F-15 "old timers." Then, too, the Career Development Course which the F-15 technicians are tested on for advancement is based on F-111 avionics systems.

8. Effects of Seasonal Changes. The people at Plattsburg and Dover reported increased maintenance problems when the seasons changed.

9. Information Flow. The only notable exception to the information flow previously reported was the C-5A's MADAR-GPS combination. The flow goes something like this



Once in the Oklahoma City ALC data bank the data is available back down to shop level in a number of formats which can be requested. LRUs can be tracked by serial number. Aircraft discrepancy logs can be automatically produced. This was the only closed loop system observed to date. That is the people in the shops saw the results of supplying information and benefited from the information supplied. In their opinion the equipment required for onboard installation in any kind of aircraft is neither heavy nor bulky. It bears further investigation.

10. Inspections. None of the organizations visited on this trip seemed to be overly concerned with Maintenance Standardization and Evaluation team findings.

11. Problem Systems. The F-106 stable platform and associated control electronics is a headache. This confirms findings of a previous trip to Tyndall AFB. The 0-41 Digital Processor on the F-15 radar is a high fail item. On the C-130s the APN-150 radar altimeter was a problem. On the FB-111 the converter sets cause a lot of maintenance. The C-5A Inertial and Doppler Navigation Equipment, the MADAR system, the radar altimeter, and the TACAN system all cause headaches. It seems that all automatic test equipment at the organizational level has problems. It is either too new, has bugs in the software or is down too much of the time or a combination of the above. The people working the APN-59 on the C-130's didn't think it was a big problem. However, we stopped in the KC-135 radar shop at Plattsburg and they thought it was a terrible system. Their opinion was that the biggest problem with the APN-59 is that the antenna is wearing out. Fuel sensors were a problem in all aircraft studied to date.

12. Plugs, Connectors, and Cabling. With the exception of the F-15 all the aircraft studied to date have plug, connector, and/or cabling problems. In no case were the problems caused by NAFI-type connectors. In cold weather ribbon cable gets brittle, so it apparently is not necessarily a better solution than regular wire.

13. <u>On-aircraft Avionics Accessibility</u>. Generally the LRUs are readily accessible on the aircraft seen on this trip. The FB-111 had some problems with cabling and antenna placement. The C-5A had several data sending units for the MADAR which were hard to reach. It also had one LRU which did not have the same latching system as the other LRUs but was bolted from the bottom. This necessitated removing several other LRUs to remove it.

14. <u>Observations</u>. We have seen almost all conceivable management structures at the base and flightline level including organizations where the people in some shops work both flightline and bench and in others are split into two groups. With the exception of the Honeywell 1505 test station on the C-5A all the ATE we have seen have problems. In some cases the equipment specs are set too tight. In others there are software bugs. In still others the BIT and the shop test station don't agree. Only the 1505 thus far lets the operator talk to it and use some judgment. Tech orders on the FB-111 and the F-15 are a real problem. In the case of the F-15 there are lots of initial mistakes and nothing in the way of schematics and flow diagrams. In the case of the FB-111 the contractor which built the test stations didn't write the tech data. The FB-111 and the C-5A should by now have the bugs worked out fairly well and should have experienced drops in maintenance actions. According to the people interviewed it hasn't happened. Both aircraft continue to have severe avionics maintenance problems. Prospects for the F-15 are brighter, but it is still too early to tell. Some people thought it a mistake to put people who work on LRUs in different pieces of the organization from those who pull the LRUs on the flightline. They feel data is lost in this division. Perhaps the systems are so complex that it is necessary for the technician to concentrate either on a broad systems viewpoint or a narrow subsystem viewpoint but not both. If true it will be quite possible for technicians to operate but they will have to operate more like trained monkeys than as true troubleshooters. So far we are impressed with the competence and professionalism we have seen and by the overall positive attitudes of people doing difficult jobs often under poor conditions.

APPENDIX D

STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname and Grade)		TO	ACTION	SIGNATURE (Surname and Grade)
1	DHE	SEW	(Mr. Wagner)	6			
2	DHM	DJR 19 Jun 76	(Mr. Rees)	7			
3	DH		(Mr. Edwards)	8			
4				9			
5				10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INIT.	SUSPENSE DATE
PAUL R. OWENS, MAJ, USAF	AFAL/DH	54998	gh	

SUBJECT Trip Report for Trips to Newark AFS, OH; Robins AFB, GA; and Reese AFB, TX.

DATE 14 May 1976

SUMMARY

Travelers: Maj P. R. Owens, Maj G. Pritchard (Robins AFB only), Mr. M. R. St. John, and Mr. F. D. Lamb

Objective: To gather data for the Avionics Maintenance Study

Dates and Places Visited: 9 Apr, Newark AFS, OH
12-14 Apr, Robins AFB, GA
14-16 Apr, Reese AFB, TX

Organizations Covered in the Interviews:

Aerospace Guidance and Metrology Center, (AFLC), Col. Elon Long, Director of Maintenance, Newark, Ohio
Warner Robins Air Logistics Center (AFLC), L/C Lerandeau, Avionics Director (within Maintenance Directorate)

64 Fighter Training Wing, 64 Field Maintenance Squadron (ATC), 1Lt Kerekes, Chief Avionics Branch.

Organizational Purposes:

64 FMS - Maintain avionics on T-37 and T-38
AGMC - Depot for AF Inertial navigation equipment
Warner Robins ALC - Depot for AF Avionics.

Discussion: Because of the difference in depot operations from field maintenance operations each will be treated separately.

A. 64th FMS

1. Ages of the Systems. The T-37 is over 15 years old and the T-38 is 10-15 years old. The avionics has LRUs using tubes, discrete semiconductors and some small scale integrated circuits.

2. Parts Availability. For the first time parts availability was not a major complaint. The only complaint regarded the new AFLC policy which prevents classing an LRU not reparable this station (NRTS) and sending it to depot without the Item Manager's approval. These LRUs are, instead, classed as Awaiting Parts (AWP) and

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counted as LRUs possessed by the organization. If components don't come in, the organization winds up owning a lot of useless LRUs. This condition has been noted in previous reports. It encourages cannibalization of components from LRUs and results in the LRU which is sent to depot being used as little more than suitcases for defective components and printed circuit boards (PCBs). AFLC policy is to maximum stock bits and pieces and shop replaceable units (SRUs) at base level and to minimum stock LRUs at base level. So far the policy has not been a success but perhaps things will smooth out in a few months.

3. Maintenance Concepts Employed.

a. Two tier Structure. The same people work both on the flightline and in the shop at Reese, so we have another example of two tier maintenance - base and depot.

b. Tail Number Scheduling. Tail number scheduling was in effect at Reese as at all bases visited to date. Cannibalization actions were frequent partly because of the policy.

c. Hot Mock-ups. All in-shop maintenance was performed using hot mock-ups; there was no automatic test equipment.

d. Flightline AGE. There was no dedicated flightline AGE. Scopes and meters are sometimes used on the flightlines or in the hangars for on aircraft trouble-shooting.

e. Phased Inspections. The aircraft undergo phased inspections, but the avionics do not. All avionics maintenance is fixed upon failure.

f. On-base Repair. Repair on many LRUs goes to the component level, although some circuit boards must be repaired at depot level.

g. Debriefing. There was no person-to-person debriefing procedure. The sole means of communication between pilots and the maintenance was the debriefing form filled out after each flight. The reason for this was as follows: Each day there are about 200 sorties flown with about 50-75 aircraft. This means that a lot of maintenance must be accomplished in a short time to turn the aircraft for the next sorties. With the maintenance manning available it has not proved practical to debrief pilots in person. It was admitted that the situation was undesirable. Probably many of the write-ups are due to student pilots incorrectly operating equipment. This could be curtailed more quickly if maintenance people could discuss write-ups with the pilots. No relief is in sight for the problem.

4. Depot Support. There were no complaints about the quality of depot support.

5. Manning. Manning levels have been cut but not severely. Somewhat alleviating the manning problem is the fact that the new airmen are not moved as frequently as in the Viet Nam War era. The practice used to be to send an airman in fresh out of tech school, let him stay a year to get trained up, and then ship him over to Southeast Asia. There is at least one civilian in each shop. The

stability lent by the civilians is valuable in providing a steady core of capability for training the new people. We also found this practice in effect at Dover in the C-5A maintenance. The disadvantages of using civilians are that they rarely work overtime since they are paid extra for overtime while GIs aren't and they usually earn more than the GIs, causing some resentment. On balance, however, both organizations strongly believed in using a limited number of civilians in avionics maintenance. Normal operation was two shifts, six days a week.

6. Training and Personnel Quality. At Reese there were no complaints about the quality of new technicians. On the contrary there was great praise of both the aptitude and attitude of the people recently arrived. Tech school training was deemed adequate background for the job.

7. Inspections. People within the Avionics Branch did not appear to be "inspected to death." There were no complaints about nit-picking.

8. Effects of Weather. The only effects of weather noted were that when it rains the IFF control box gets wet and often causes malfunctions and fuel quantity systems usually malfunction in rainy weather.

9. Undergraduate Pilot Training Environment. As noted in 3g about 200 sorties per day are flown with 50-75 operationally ready aircraft (about 200 aircraft are assigned). This means the average operational aircraft is turned around between two and three times in a day. This turnaround rate results in about 30 minutes of aircraft availability for maintenance on each turnaround. Of course the T-37 and T-38 do not have highly sophisticated avionics suites, but even so the required maintenance must be performed swiftly and accurately to maintain the flying schedule.

10. Time Accounting. As at other bases the time accounting system does not accurately reflect training conducted while performing maintenance. This means that the manhour data in the 66-1 system is probably good for sensitivity analysis and other analyses where absolute magnitudes are not required.

11. Cost Accounting. At Reese as at other bases the enlisted technicians are treated as free resources by local commanders and supervisors. The costs related to their salaries and benefits are not traded against capabilities for performing maintenance at base level rather than depot.

12. Maintenance Data Feedback. At Reese as at all other bases except Dover there is little or no useful data returned to the shop chief or branch chief by the 66-1 data collection system.

13. Problem Systems. The ARC-34 radio was the worst performing subsystem. However in the past 18 months the MTBF had been pushed up to 100 hours, the MTTR had dropped from 15 hours to 5 hours while the people doing the work had dropped from five to three. For the Precision Measuring Equipment Laboratory (PMEL) the two worst pieces of test gear were the TACAN test set and the IFF flightline test set. The Air Force currently has a better TACAN test set and one is on order at Reese. As with other aircraft the wiring is a problem.

14. On-Aircraft Equipment Accessibility. Both aircraft had generally good accessibility to the avionics with the exception of the ARC-34 radio. In each case the radio was hard to remove and replace. This is particularly unfortunate since the radio is the highest failure rate item on each aircraft.

15. Technical Orders (TOs). The TOs were said to be difficult to use for some tasks. Often information for a task was located in more than one place. There was also a lack of good logic tree diagrams for trouble-shooting.

16. Trainers. The avionics organizations are now responsible for trainers Air Force-wide. This change of responsibility from operations to maintenance occurred in the fall of 1975. For all of the trainer facilities this has created problems, but it is particularly true at Reese. When the trainers were under operations maintenance was not run according to AFM 66-1, and the shift required adjustments. Reese was particularly hard hit among the bases we visited because, being an ATC base, it has a lot of trainers (over 30). The shop chief felt they were undermanned. They had been receiving some close inspections designed to bring them up to required standards for 66-1. Periodic inspections were a big headache. The shop chief also said the configuration of the trainers was not close enough to the configuration of the aircraft they were simulating. There was under construction at Reese a complex to house several sophisticated flight simulator cockpits which will be "flown" with the help of a large terrain board similar to the one at AF Flight Dynamics Laboratory. The cockpits will have motion simulation along with the visual simulation. This is the first evidence we have seen of the AF emphasis on flight simulators to substitute for aircraft flying hours. It looks like an expensive investment.

17. Observations. For trainers such as the ones for the T-37 and T-38 which are produced in relatively high quantities and which have a large number of repetitive boxes the standard module approach looks like a natural. We feel face-to-face debriefing would cut down on the number of maintenance actions required. Unfortunately we have no suggestion for implementing this procedure which would not strain the existing manning.

B. AGMC and Warner Robins ALC.

1. Responsibilities. Aerospace Guidance and Metrology Center (AGMC) is the depot for AF inertial guidance systems and precision measuring equipment (PME). Warner Robins Air Logistics Center (ALC) is the depot for AF avionics. It is probable these two places will become the depot operations for their respective areas DOD-wide within a few years. Already each handles equipment from the other services. It would be a mistake, however, to conclude that all avionics depot work is the responsibility of Warner-Robins ALC. In actuality various pieces of avionics depot work are ongoing at the other ALCs. There is even a contractor-run mini depot for the F-111 at Cannon AFB. We found no particular reason for this situation. The preponderance of avionics depot work, however, is accomplished at Warner Robins ALC.

2. Capabilities. Both depots have extensive facilities and people to accomplish their respective tasks.

a. At AFGMC there are highly automated test stations for testing inertial measurement units. Most of the facilities relate to the mechanical components. There is one major shop, however, whose sole function is to check and correct the associated electronics boards. Equipment is available for combined environmental (temperature and humidity) and electrical tests on these boards. The electronics testers are computer controlled and much more flexible than those associated with the F-111 and F-15 intermediate maintenance operations. PC board conformal coatings can be stripped and reapplied. Components can be replaced down to the bit and piece level.

b. The Airborne Electronics Division of Warner Robins ALC performs the depot maintenance of avionics. This division has many sections which are functionally oriented, e.g., electronic warfare, weapons control, and radar navigation. Some of the electronics can be tested on "universal testers" which are computer controlled test stations which can be reconfigured by software and hardware to test a wide variety of LRUs. Other test stations are specific automatic test stations, while still others amount to hot mock-ups or general purpose test instrumentation such as signal generators, multimeters and oscilloscopes. Here, too, conformal coatings can be stripped and reapplied and replacement of components can occur at the bit and piece level. In a few cases thermal and humidity environments can be simulated while electrical testing is in progress. The dominant form of testing, however, is in a bench environment with cooling air attached when called for in the aircraft installation.

3. Work Flows. There is no one work flow which is followed in all instances, but let us follow a "typical" LRU through the depot and point out some of the possible branch points along the way. The LRU arrives, is unpacked and is binned awaiting testing. Next, the LRU might be tested on an automatic or manual tester for fault isolation to specific subassemblies, e.g., printed circuit board, with the LRU. In the case of LRUs from such troublesome systems as the APN-59 this step would be bypassed since past experience has shown that each of the subassemblies will need work. If malfunctions do appear the subassemblies requiring fault correction will be removed and worked separately. In some cases testers are available to test separate PC boards. In other cases generalized test instrumentation will be used. Workers are highly specialized with one or more workers concentrating on a particular subassembly typical. At AGMC technicians operating automatic testers for IMUs are rotated among test stations to avoid boredom. At Warner Robins ALC this is rarely the case because of the nature of the testers and the nature of the subassemblies. In the electronics shop at AGMC there is less compartmentalization because the IMUs have relatively less electronics. Faulty components are removed and replaced with new components, and a functional check of the subassembly is run. The LRU is reassembled and functionally checked manually or automatically. It is then binned. When a request is generated for the LRU, it goes to packing and shipping. Because obtaining parts is a problem for the depot as well as for the bases, if several LRUs of the same type are awaiting parts for different subassemblies, cannibalization may occur, i.e., missing subassemblies

for LRU "A" may be obtained from LRUs "B" and "C" in order to ship LRU "A" to a base which has requested this type of LRU. In general it should not be assumed that a particular subassembly will stay with a particular LRU.

14. Data Flows. When an LRU arrives at the depot, it has the AFTO Form 350 attached which was filled out at the base level shop. AGMC uses the 350 and feeds data back to the base of origin on what was found at AGMC. At Warner Robins, however, the 350's are regarded as useless and no feedback to the bases is made. The reason for this is that quite often the bases use the LRU case as a "suitcase for failed PC boards." That is, other LRUs at base level which are awaiting parts are given good PC boards or other subassemblies from the LRU being shipped to depot with failed subassemblies being inserted (or sometimes omitted entirely). When this happens the information on the AFTO Form 350 is totally useless. Schedulers in each section and unit allot the work to the technicians who document actions taken on each LRU and subassembly on AFTO Forms 349. Parts consumed are fed into the computer for cost accounting and restocking. Workhours are accounted for in different ways for each installation and will be treated under para 15, Cost Accounting. A detailed account of actions taken is not fed into the computer, but forms accompany each subassembly as it is checked, fixed and fed into reassembly into LRUs. Unsatisfactory Reports (URs) generated at base level which are sent back in conjunction with inoperable equipment received at base from depot are answered by message. Some people we have talked to at base level feel that depot responses to URs tend to be perfunctory and don't really help correct sloppy work. This perceived attitude tends to discourage the paperwork required to document URs. Depot people, on the other hand, maintain that URs are scrupulously investigated.

15. Cost Accounting. Cost accounting procedures are different at AGMC and Warner Robins ALC. For both costs incurred are charged to the various Item Managers (IMs) who are responsible for the equipment being repaired. This charge is burdened with the depot overhead.

a. In the case of Warner Robins both materials standards and labor standards are used to calculate the charges to the IM. The materials standard is found by dividing the total parts cost during, say, the previous quarter or year for repairing a given type subassembly by the total number of that type subassemblies repaired during the same previous period. This represents the average cost of materials per subassembly. The labor standard is computed in similar fashion by dividing the total direct labor cost for a previous period by the number of subassemblies repaired during that period. These costs are then burdened with the various overheads, combined, burdened with management overhead, and charged to the IM.

b. In the case of AGMC a different system is in use and the bugs are currently being worked out. Under this system actual labor costs are charged rather than using labor standards. An employee clocks in by inserting his badge and a job order card into a one-way computer terminal. The computer then assumes he is working on the unit or units listed on the job order card until he clocks in again with another job order card or until the shift ends, whichever is first. If more than one unit is covered by the job order card (an IBM-type punched card) his time is prorated among the units. The computer, which has stored in it his wage rate, can compute the direct labor cost on the units processed by any technician. I believe materials standards are still being used at this point. The direct labor charges are burdened with the various types of overhead and charged to the IM. This cost accounting procedure is a proving ground for the AFLC. By DOD directive the services will go to an actual cost system for depot maintenance within the next few years. It remains to be seen whether this close accounting of costs will result in savings or in extra expenses for the cost accounting system.

16. Planning for New Equipment Maintenance. When a new avionic subsystem is acquired, depot maintenance is planned roughly as follows: The planner first analyzes the AGE requirements. He takes into account the prime contractor's data and recommendations and previous experience on similar subsystems. Working with projected failure rate data and past experience with similar systems the planner estimates workloads and manning required. In conjunction with people from engineering floorspace, power and other facility requirements are calculated. The entire analysis goes forward to Hq AFLC for blessing. As far as we could determine, no computer aids were used in this process. All calculations were performed by hand. Once blessed the "prototyping" phase begins. In this phase the various procedures to be used at the depot for fixing the subsystem are test run. Labor standards are estimated from the data collected and previous experience. Finally, the full process becomes operational. Another duty of the planners is validation of material costs which leads to an update of the materials standards. Data from which to develop trends in parts consumption is available, but no use seems to be made of this data for triggering failure analysis on parts with rising consumption trends.

17. Quality Control. Inspection of finished work is on a sampling basis with the exception of UR exhibits. Both AGMC and Warner Robins claim the expense of 100% inspection is prohibitive. There were 90 people in the Quality Branch and about 2450 in the Production Branch at Warner Robins. There have been reports at a couple of the bases we visited complaining about lack of quality control in the depot products. Obviously the 90 people will be hard pressed to keep up with the over 2000 production people.

18. Training. The civilian electronics technicians at Warner Robins go through a training program which stretches over two years at on the order of five hours per week. Subjects covered are tailored to the area of specialization. Both classroom and on the job instruction is given.

19. Problem Systems. It was agreed that the APN-59 Radar and the APQ-120 Radar (the Weapons Control System on the F-4E) were two of the biggest problem systems at Warner Robins. Because of the AFAL interest in the APN-59 and the importance of the APQ-120 and the problems discovered by us at Homestead, we examined the depot maintenance of these two radars in some detail. The APQ-120 was one of the first solid state radar systems built. The computer is the sore spot in terms of failures. Some of the other

problem areas are magnetron pulling frequency; SCR failures in LRU-5; high fail servo platform in LRU-I, and poor case, connector, jackscrew design. We were shown examples of field mistreatment of equipment including PC boards which had obviously been hammered into place and an LRU case which bore the imprint of a ball peen hammer. PC board designs had not been outstanding in all cases. There are several instances of power resistors mounted on the boards with no standoffs. Some severe charring and vaporization of metal runs have occurred. Extensive board refurbishing is accomplished at Warner Robins. Additionally, the cooling design is not up to current standards since in some cases air is blown directly over the components. The test equipment furnished the depot is quite old now in comparison to the test equipment furnished the Military Assistance Program countries. The depot is considering modifying their test equipment to bring it up to the recent configuration. Problems have occurred in trying to put APQ-120 LRUs on the General Purpose Analysis and Test System (GPATS) which is a computer controlled tester. The LRUs were not designed with testability in mind and need to have more test points and parallel paths for efficient fault isolation. For example, LRU-1 test time is 19 hours! Westinghouse is working on the software-hardware problem and thinks the test time can be cut to 6-7 hours. An IFF capability is being added now by a traveling team from the depot. Under development are an air combat computer mod and a digital automatic acquisition mod. Technical data has been a problem with a definite mismatch between the field and the depot. Some checks were possible in the field and weren't possible at depot. LRUs are being manually tracked by serial number, and so far it does not appear that a few "bad actors" within each LRU type are causing the problems. Mr. St. John and Mr. Lamb have detailed information concerning APN-59 problems.

20. Other Problem Areas.

a. Software. On the order of 40 people are working on automatic test station software. We gathered this was partly due to software bugs and partly due to efforts to improve tester efficiency or effectiveness.

b. The ARC-133 and ARC-90 UHR Radios. These sets are scheduled to be replaced by the ARC-164. The depot experience tallies with experience at the bases in that all agree the sets should be replaced.

c. ADI/HSI. There is an opportunity to replace the electromechanical Altitude Direction Indicator/Horizontal Situation Indicator with an all electronic unit. We will have to check with DAIS to see if this is being done. In general it was felt that the more mechanical assemblies which could be eliminated in favor of electronic assemblies the better off the Air Force would be.

d. TWTs. Traveling wave tubes are a high fail item across a number of systems.

e. Connectors and Cabling. These are perennial problem areas because cabling receives flexing each time an LRU is attached or removed and connectors receive both aircraft vibration and abuse from insertion and retraction. Almost no LRUs examined had the tuning fork and blade connector used by NAFI. In those LRUs where this connector was used the technicians' opinion was that there were few connector problems. AFGMC was particularly having problems with the A-7 connectors.

f. Parts Availability. Even though mountains of data is available on parts consumption, it is still a problem to obtain enough bits and pieces to fix the systems. Part of the problem is budget, of course. IMs want to spend as little as possible in a very lean Air Force. Another problem is that many piece parts either were nonstandard from the start or are no longer produced in volume. Furthermore, the Air Force often does not reprocure in sufficient volume to take advantage of economies of scale. In some cases the initial lay-in of spares was insufficient even for the projected period. In other cases the spares laid in are disposed of before the parts on the original equipment starts to fail. When failures do start the parts must be reprocured. Very little failure analysis is conducted to determine whether substitute parts are advisable or if small modifications are in order.

21. Comments

a. Information. It seemed to us that it was difficult for the manager to get the information he needs. There is no lack of information. Printouts abound but it is necessary to pour over long busy printouts to extract the useful information. Quite possibly a data base management system such as Information Central's should be considered. It also seemed that more use might be made of data already available. For instance, the data on parts consumption which the planner validated could be used not only to trigger adjustments in stock levels for the coming period but also to trigger failure analysis.

b. Engineering. There were 25 engineers available in the Engineering Services Section at Warner Robins. These people were used mainly to plan facilities modification to accommodate new equipment support. Almost nobody is present to find out why parts start failing or what might alleviate the problems of a chronically poor LRU. Probably the budget and the industrial funding structure doesn't allow for it. Somebody should be working the problem whether in AFLC or AFSC.

c. Cross-fertilization. It struck us that a possible source of help for the bases having problem systems such as the APQ-120 (which has an experience gap at several bases) would be some of the civilians who work on the system at depot. In exchange some GIs might have a chance to see the maintenance from a depot point of view and get some thorough insight into important pieces of some of their systems. The management was not enthusiastic about the idea. The opinion was that the people in the field were more systems oriented and less subassembly oriented compared to depot people. We still think this may be partially true but not universally so. We still think the idea has merit and should be explored further.

d. Item Managers. We asked the people at Warner Robins if it wouldn't make sense to have the Item Managers located at the place where depot maintenance is conducted. They agreed it would save time and money and ease communications. Currently the IMs are all over the country and the depot people frequently have to talk with the IM via telephone. Since reorganizations are common within AFLC, we think this one might be worth pursuing.

APPENDIX E

STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname and Grade)		TO	ACTION	SIGNATURE (Surname and Grade)
1	Mr. Wagner DHE	SKW	Stanley Wagner	6			
2	DHM (Mr. Rees)		D Rees 14 June 76	7			
3	DH (Mr. Edwards)			8			
4				9			
5				10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INIT.	SUSPENSE DATE
PAUL R. OWENS, Major, USAF	AFAL/DH	54998	gmh	

SUBJECT Trip Report for Trips to McClellan AFB, Travis AFB, and Luke AFB

DATE 1 June 1976

SUMMARY

Travelers: Maj P. R. Owens, Mr. M. R. St. John, and Mr. F. D. Lamb

Dates and Places Visited: 28-29 Apr 76 McClellan AFB, CA
29-30 Apr 76 Travis AFB, CA
3-4 May 76 Luke AFB, AZ (Owens only).

Organizations covered in the interviews:
Sacramento ALC (AFLC), MMEP and MMF - McClellan AFB
60th AMS (MAC), Lt Col Hollingsworth, Sq Cmdr, Travis AFB
58AMS (TAC), Lt Col May, Sq Cmdr, Luke AFB

Aircraft Maintained
F-4C (Luke)
F-15 (Luke)
F-111 (McClellan)
C-5A (Travis)
C-141 (Travis)

Discussion

Since the depot operation is fundamentally different from the avionics maintenance squadrons' operation, each will be discussed in a separate section.

A. Sacramento ALC. Avionics depot maintenance is not the main business of Sacramento ALC. We concentrated on the limited depot operation for the F-111 and the Avionics Integrated Support Facility, which is a full hot mockup of the F-111 avionics suites.

1. F-111 Maintenance Concept and How It Changed. In the beginning it was decided there would be no depot maintenance for the F-111. An attempt was made to provide enough test equipment at base level to remove the necessity for further work at depot. No depot level AGE was designed. After the Air Force started operating the F-111 it became apparent that the base level test equipment operated by enlisted people was not sufficient to maintain the operationally ready rate required. First, the test equipment did not sufficiently fault isolate in many cases. The level of simulation was not as good as it was on hot mockups (which were not available). Additionally, the average experience level of the enlisted technicians remained relatively low because of turnover. Partly related to the maintenance problems was the software problem. The operational flight programs (OFPs) and the automatic tester software were both inadequate. Something had to be done. Four things were done: (1) A set of base level test equipment was installed at Sacramento ALC and manned with (low turnover) civilian technicians. (2) Fully integrated hot mockups and some subsystem hot

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mockups were installed at Sacramento ALC and manned by both civilian technicians and (Autonetics) contractor personnel. (3) A dynamic avionics simulator was installed at Sacramento ALC for checking, debugging, and modifying the OFPs. (4) A contractor run (General Dynamics) "mini depot" was installed at Cannon AFB, the first F-111 base. The "mini depot" is now in the phase down process but the other operations are going strong.

2. Work flow. When a LRU comes in which can't be fixed at base level, it goes first to the test stations (the duplicates of those used at base level). In many cases the more experienced technicians can isolate the problem. Only removal and replacement of SRUs are done. Work does not proceed to the bit and piece level except for such things as cables, connectors and cases. If the fault cannot be located on the test stations, the LRU is sent to the Avionics Integrated Support Facility (integrated hot mockup). Since input signals are better simulated on the mockup, intermittent failures are easier to locate even though dynamic flight profiles cannot be run. A refrigerator is sometimes used to cold soak the LRUs before running them. The AISF has a 96% success rate of isolating faults on LRUs for which the test stations could locate no fault. A set of "shop standards" (known good boards) is maintained to assist in fault Isolation. Again, corrective action is limited to replacing defective SRUs.

3. Documentation Flow. The AFTO Form 350 information is used but it often must be supplemented by a phone call to the base from which the LRU came. The actions taken and faults located at each step are documented and kept with the LRU as it moves from place to place. The information is fed back to the base which sent the LRU. The information is also sent to Analysis.

4. Problem Subsystems. The two main problems are with the computers and the analog to digital converters. At least originally the A/D converter solder connections were a big problem. This has since been alleviated but the converters remain a high fail item. The navigational computer unit (NCU) has a tendency to memory scramble. They are currently working to find out why. About 10% of the NCU cases need major rework. Connectors are also a problem with this unit both internally and externally.

5. Other problems.

a. Flexible printed cabling which is used extensively in the avionics is failure prone. Under cold conditions it is often brittle. There are separation problems between eyelets used to connect to components. It is hard to jumper realiably.

b. Technical data quality is uneven. Some TOs are well organized but with some subsystems it is necessary to refer to two or three TOs during a trouble-shooting sequence.

c. It is not always possible to tell whether a troubleshooting problem lies with the LRU or the test equipment. The ATE is failure prone.

d. Parts problems are severe in this depot operation. Because both bases and the depot basically replace SRUs the bases have first call on the SRUs. This results in approximately 60% of the LRUs at depot being in awaiting parts status. Item Managers must be cajoled to send SRUs to Sacramento. This happens because this

AD-A042 568 AIR FORCE AVIONICS LAB WRIGHT-PATTERSON AFB OHIO F/G 9/3

AVIONICS MAINTENANCE STUDY.(U)

JUN 77 P R OWENS, M R ST. JOHN, F D LAMB

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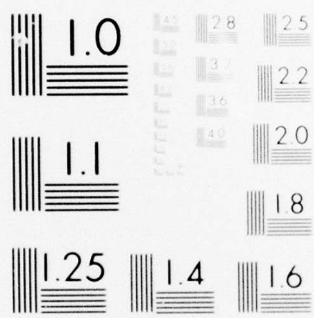

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

depot operation is not officially a depot operation. It was organized to work itself out of business by solving what was thought to be a set of growing pains. But there is no sign of the problem going away.

e. The built in test equipment often tests to tighter specs than the shop testers. These areas are being resolved as time goes on but they still cause problems.

6. Software Problems

a. Operational Flight Programs (OFPs). There are seven OFPs per aircraft - three each for the two general purpose computers and one shared between the two computers. Most of the original bugs from the 1974 baseline OFP are now fixed. Current efforts are devoted to (1) improved capabilities which can be achieved through reprogramming and (2) reprogramming to meet changing requirements. With the existing onboard equipment tradeoffs must be made on what the software is to do since currently there are only 100 spare words of memory and the computer duty cycle is about 95%. Thus including one capability means excluding some other capability. The dynamic simulators are used to verify software. Eventually the integrated mockup may be hooked up to the dynamic simulator so that flight profiles may be simulated on the full avionics suite. Data for the simulator comes from instrumented test aircraft. The recorded signals can be fed to the aircraft computer to see if the program under test processes the data correctly and send out the proper response signals. They have PRAMPO money to develop a diagnostic program which can be loaded on the aircraft computer on the flightline to isolate a malfunction to one LRU more accurately than the BIT presently does.

b. Automatic Test Equipment (ATE) Software. There are presently 100 open projects on software. The average resource requirement for one change is over 90 workhours plus 0.2 hour of mainframe computer time. It was agreed that technicians would welcome more easily human readable output from the ATE computer. It was not thought that an interactive system was likely to ease maintenance problems. The average test time per SRU now is 2 hours. Part of the testing problem deals with the design of the equipment being tested. As it is now, one test point sometimes monitors as many as 19 components. Design for testability is extremely important. Another part of the testing problem is the lack of an efficient automatic test pattern generator (for digital circuitry). The F-111 people have three test pattern generators available and none is really satisfactory. Some problems would be eased if one had a basic test system which was used from weapon system to weapon system. The problem is that the field is not that mature and rapid changes in software techniques as well as hardware are in progress. We are still in the beginnings of writing software specs. San Antonio ALC is evidently working on software specs for ATE.

c. General Software Problems. Once a contractor has sold a software-hardware package he sometimes loses interest in maintaining the software. This is analogous to problems of obtaining replacements for obsolete parts. Right now General Dynamics wants to take people off F-111 software maintenance and put them on the F-16 software generation. Without some organic capabilities the Air Force would be lost. Money and people are in short supply for F-111 software support. A 50-50 military-civilian mix is desirable. Right now the majority are civilians. It is easier to turn electronics engineers into useful programmers than to get programmers to turn out programs useful on electronic systems. This opinion was also expressed in the Computer Aided Design study.

7. Comments. The present arrangement for the F-111 at Sacramento appears to be a lash-up which should be legitimized. The problem with SRU priorities is the biggest problem.

B. 58th and 60th AMS Visits.

1. Ages of the Systems. Oldest is the F-4C (early '60s). Next comes the C-141 (mid '60s). Then comes the C-5A (late 60s), and newest is the F-15 (early 70s). Older electronics uses some tubes and many discretes. The latest electronics uses SSI, MSI and some LSI.

2. Parts Availability. Once again parts availability was considered a major problem. The AFLC policy of requiring Item Manager approval before shipping LRUs to depot was not liked. Cannabalization was frequently the only way to meet flying requirements.

3. Maintenance Concepts Employed.

a. Number of Maintenance Tiers. The AMS at Travis (C-5A & C-141) used the same people for flightline and shop work. The same people worked on C-5As and C-141s. A separate shop maintained the C-5A shop automatic test equipment. It was essentially a two-tier structure (base and depot). The AMS at Luke was split into two physically separated pieces, the F-4C piece and the F-15 piece. In each case the organization was further subdivided into flightline and shop branches, resulting in a three-tier structure. There was no transfer of people between flightline and shop.

b. Tail Number Scheduling. As at each base we have visited, tail number scheduling was used.

c. On-base Repair

(1) F-15. Repair is limited to removal and replacement of LRUs on the flightline and removal and replacement of shop replaceable units (SRUs), e.g., PC boards in the shop.

(2) F-4C, C-141, and C-5A. In these systems LRUs are removed and replaced on the flightline. Repair in the shop sometimes only proceeds to replacement of SRUs, but often goes to the bit and piece replacement on the SRU. The level to which repair proceeds is directed by the Item Manager.

d. Hot Mockups. All F-4C and C-141 avionics and some C-5A avionics are bench checked on hot mockups. Simulation of electrical inputs to the equipment under test is thus complete except for lack of simulation of transients induced by aircraft power switching and signals which would be modified by flight profiles. No environmental simulation is used.

e. Manual Test Stations. The F-15 uses three manual test stations to handle several of the LRUs. Luke is further along than Langley in that all the manual test stations can now test each LRU for which they were designed. Electrical simulation of input signals to the LRU under test is not as complete as is the case with a hot mockup. However, each section of the LRU is systematically checked by the test sequence. If, in sequencing through the test, the technician reads out a malfunction he must take the corrective action indicated and start the sequence from step one. In addition to this disadvantage intermittent faults or faults arising from combinations of signals are less likely to be detected. Test stations malfunction fairly often, but this appears to be a training problem.

f. Automatic Test Stations. These test stations are used on both the F-15 and the C-5A. Operation is similar to the manual test stations, but sequencing is under computer control. As reported at Dover AFB the test station for the autopilot seems to be well liked because it is more flexible than the other test stations used in both weapon systems. A similar station with different software is planned to replace the present C-5A Identification and Navigation Equipment test station. The F-15 automatic test stations at Luke AFB can presently test 19 of the 28 LRUs for which they were designed. The LRUs which cannot be tested are handled on a "work around" basis by Boeing. Dissatisfaction was particularly evident in the ATE shop at Luke. As at Langley the trained monkey approach to use of technicians is resented. The people felt that the junior technician would adapt to the new way of doing things quicker than the senior NCOs who were used to traditional trouble-shooting techniques using the hot mockups.

g. Built-in Test and Monitoring Equipment. F-15 and C-5A equipment has been discussed in a previous trip report. The C-141 has no on board test and monitoring equipment other than the instruments and flight recorders. The F-4C has a scope camera which produces data useful in troubleshooting.

h. Flightline AGE. The F-4C has an automated radar calibration test set which is used in a dock. Approximately one aircraft radar per day can be calibrated. The C-5A uses some special portable test sets and some fault isolation is accomplished on all aircraft using oscilloscopes and multimeters. Aside from radar calibration of the F-4Cs and some instrument work very little on aircraft avionics maintenance is performed beyond the removal and replacement of LRUs.

i. Avionics Preflight. At Travis we encountered a policy not present elsewhere. If an aircraft had been on the ground more than 15 days, its avionics went through a preflight inspection.

j. Debriefing. At Travis crews were not always debriefed in person. At Luke one technician was present at debriefing for F-4Cs. For F-15s at Luke one avionics technician from each of the three flightline avionics sections was present at debriefing. Note that there are about 70 F-4C sorties/day with about 90 aircraft assigned resulting in 20-40 aircraft turning around for a second sortie in a day. The F-15 flying schedule is less strenuous.

k. Production Oriented Maintenance Organization (POMO). See attached slipping. The POMO is essentially an expanded crew chief team. Evidently the intent of the experimental program is to cut down on maintenance manning. The avionics people were leery of the POMO. One senior NCO asked, "What happens when they don't have the avionics aces around to back them up?" If enough aces are kept around to back them up, however, the POMO might be a better way to go. Certainly the extreme specialization does tend to cut involvement and diffuse responsibility for getting aircraft flyable.

4. Depot Support. People at both Travis and Luke had some criticism of depot handling of URs. They said the paperwork required was discouraging when coupled with what they considered perfunctory responses. They thought that material failure and shipping damage was too often cited as reason for failure by depots. In their opinions LRUs leaving the depot should be 100% checked to at least the level checkable in the field. We received the impression that some technicians and supervisors give up on URs because they feel it is unproductive effort.

5. Manning. The Travis AMS had no apparent manning problems although apparently a downgrading of skill level requirements was in progress. As at Dover there were a fair number of civilians in the organization to provide stability. About 20% were civilians. There were a few civilians in the F-4C organization at Luke but none in the F-15 organization (although tech reps were present). The F-15 organization is probably overmanned for the current schedule, but will be at about the right strength when the full number of aircraft are received. The F-4C organization is getting low on senior NCOs. There is some evidence of a downward trend in retirement age for senior people. In addition, the coming combination of Instrument and Autopilot shops in the F-4C is resulting in a 50% manning cut in October, but cross-training will not be complete by then.

6. Training and Personnel Quality. Opinions were universal on this trip that the first termers arriving are smarter and have better attitudes than recruits from the Vietnam era. There was a complaint about tech school preparation of recruits from one or two supervisors but generally no major problems. As has been the case in all the bases visited, supervisors were happy with the Field Training Detachments' work. The F-4C organization was trying out a set of slide and cassette training aids and were happy with them. There were several cross trainees into F-15 avionics maintenance from other career fields. The supervisor thought they were working out well. He thought that people from ground electronics career fields were quicker to learn than those from non-electronic career fields. At present the F-15 career development courses taken by technicians to upgrade their skill levels are still mostly based on the F-111, C-5A and A-7 test stations rather than on the F-15 stations. This causes quite a bit of unhappiness.

7. Environmental Effects. At Luke the malfunction rate shoots up during the summer especially on the Weapons Control System (WCS). The cooling air is not really adequate on the ground and, if a pilot fires up the radar to check it out before takeoff, it is likely to malfunction because of overheating. The WCS also tends to malfunction during cold periods at Luke. The F-15 antennas and UHF tend to fail in hot weather.

8. Maintenance Documentation. The people at Travis did not seem as enthusiastic about the automated data system as people in their sister wing at Dover. This may be due to not having a terminal in the shop area and not having a close working relationship with the computer people who process the data. At Luke MMICS is in Phase II and the paperwork flow has become a problem. Each AFTO Form 349 must be

closed out at midnight whether the corrective action is complete or not. If the corrective action is not complete a new 349 must be generated. This makes it hard to track progress of a LRU and leaves the possibility open to errors of both omission and commission.

9. Inspections. The opinion of one NCO at Luke was that local Maintenance Standardization Evaluation Program teams were OK but the higher headquarters teams were a waste. Another problem was getting resolution of different interpretations of the same directive by different inspectors.

10. Problem Systems.

a. F-4C. The major problem system on the F-4C is the Weapons Control System (WCS), although the C model does not use the APQ-120 radar in the WCS. The cannot duplicate (CND) rate is about 40% for the WCS. The overheating problem has been mentioned above. Wiring harnesses are high fail items. The calibration problem is eased at Luke because of an excellent team chief for the calibration dock. The TACAN set and its test set were also high fail items. Fifty percent of the inertial navigation assets were in awaiting parts status.

b. F-15. The highest failure rates occurred on the inertial measurement unit, the radar data processor, the radar receiver and the digital computer. Some of the highest failure rate LRUs cannot presently be tested on the ATE. The testers themselves are also high fail items. The technical data does not give adequate notes on checking for tester malfunction when a fault is apparently located. The software for checking out the automated testers is far from perfect. About the time the bugs for a given test tape are documented in a Procedural Change Request (similar to an AFTO Form 22) a new tape comes in with the same mistakes.

c. C-5A. The MADAR (on-board systems test and monitoring system) is the biggest problem at Travis as it was at Dover. There are problems with the multimode radar antenna. The CDIPR, a station keeping Ku-band doppler unit, is located near the Ku-band multimode radar antenna which is trying to radiate through an X-band radome. Consequently the CDIPR is a high fail item.

d. C-141. There seem to be no major problems with the 141. This may be by contrast with the C-5A, however.

e. Connectors and Cabling. Throughout the systems connectors and cabling have been sore spots. This was also true at Travis and Luke.

11. Technical Data. In general tech data is a problem area at Luke and Travis. Particularly bad so far are the Technical Orders (TOs) for the F-15 which do not have schematics for the electronics. Some logic trees are starting to appear in the TO changes for the F-15, so things are improving a bit. The test equipment is supposed to catch 95% of all problems (although opinon has it that 50% is closer to the truth). In any case the possible failures not checked by the test equipment are not covered adequately by the TOs. Since there is precious little experience base with the F-15, this gap is a real problem.

12. F-15 test Equipment vs Hot Mockup. The people at Luke said there is a full hot mockup of the F-15 at Edwards AFB. Figures they have show the following CND rates:

~10% for manual test stations (Luke)
10%-20% for automatic test stations (Luke)
~40% for the hot mockup (Edwards).

Of course the automatic test stations cannot presently handle some of the highest failure rate LRUs. It seems likely that the hot mockup will eventually reside in a depot in an operation similar to the F-111 hot mockup.

13. Troubleshooting Around LRUs and SRUs Available. For the F-15 there is a tendency to try replacement of an LRU or SRU on hand even if this replacement is not indicated, but the one on hand could conceivably be causing the problem. This arises out of: (1) a desire to fix the aircraft. (2) a shortage of LRUs and SRUs, and (3) present inadequacy of the test stations. This causes a skew of maintenance data since recorded actions taken could indicate a unit was failing when, in fact, no such indication is available.

Comments. It was again apparent that the automatic test system-technician problem must be attacked. Apparently the assumption was made that the all volunteer force would attract people of lower abilities than the force in being during the Vietnam era. The attempt was made to design test equipment which could be operated by someone who could do little more than read and understand a checklist. This assumption seriously underestimated the quality of recruits appearing in the force and placed a great burden on the programmers who wrote the software for the test equipment. The opinion of the vast majority of supervisors interviewed is that the new technicians in the force are at least as smart as those of previous years. They are frustrated at being assigned to the USAF's newest first line fighter and used as trained monkeys. The programmer must write software which catches 95% of the failures in a system. When engineering changes, insufficient emphasis on design for testability, and the inevitable software bugs are factored in it is no wonder that the system does not operate as it was intended to. More interaction between man and machine is necessary. The automatic tester for the C-5A autopilot is an excellent example of what can be done. That MAC is using the same approach to replace the IDNE tester is support for this point of view. On the brighter side, people are far happier with the F-15 than they are with the F-4. It appears we are making progress.

The article below appeared in TALLYHO (LAFB Base Newspaper), dated 30 April 1976, Vol. 2, No. 17, page 3, and was entitled "Streamlined Maintenance Program Tested Here" by A1C Dave Morrissette:

There was a time when the crew chief was the person responsible for virtually all the maintenance his airplane needed. All that changed with the jet age as systems and aircraft became so complex that maintenance personnel specialized into distinct maintenance career fields.

But there might be a day when that may change once again.

POMO -- the Production Oriented Maintenance Organization — is a test program designed to streamline aircraft maintenance by training crew chiefs and specialists into each other's fields.

"We use a despecialized concept," says the NCOIC, SMSgt. Martin Diggs. "Instead of calling a specialist to handle a job, we use one of our own men who is familiar with the system."

Fifty-five people in 13 separate AFSCs (Air Force Specialty Codes) started working with POMO in August 1975 using six F-15s. POMO has since expanded to eight aircraft.

According to Sergeant Diggs, the intent of POMO is threefold. First, to provide a more varied job environment. Second, to reduce waiting and "lag" time for crew chiefs and specialists, and third, to reduce the overhead structure required to manage aircraft maintenance.

Sergeant Diggs said the POMO personnel were drawn from the munitions, field and organizational maintenance squadrons, avionics, electronics, engines, environmental control systems (ECS), egress, fuels, hydraulics and sheet metal. "We scrutinize every single item we want a guy trained in," he added. "We use them where we need them."

When it comes to saving time, said TSgt John Downs, a POMO supervisor, "We just kill 'em. When we had a problem with one of the egress systems one day," said Sergeant Downs, "our egress man happened to be working as a crew chief, so he fixed it on the spot."

"The best thing about POMO is that we're working as a team," said Sgt Jim Owens, one of POMO's sheet metal specialists. "Most of us feel a lot more involved with the overall operation than we did before we came here."

APPENDIX F
AVIONICS MAINTENANCE STUDY

1. Traveler: Franklin D. Lamb

2. Subject: Report on visit to the Naval Air Station, North Island, San Diego, CA

3. Organizations/Support: AMID shore-based intermediate shop - Maintained avionics on the S-2 and S-3 aircraft system along with various ASW heliocopters.

   VS-21 flight line shop - supports 10 S-3 aircraft

   VS-41 flight line shop - supports 31 S-3 trainer aircraft systems

   AMID ship-board intermediate shop (U.S.S. Constellation) - supports a total of 70 aircraft systems of various nomenclature.

4. Work Flow/Documentation: Both the base and the USS Constellation operated using a two tier maintenance structure, that is, the flight line shops, and the intermediate shops were physically separated and controlled by different shop supervisors. The shops were further broken down into separate groups each assigned to a specific responsibility for avionics maintenance.

   After an aircraft has been recovered, the flight crew is debriefed by the flight line technicians and the maintenance data forms initiated (the maintenance data form is called VIDS/MAF, a sample copy is attached). When the problem with the failed equipment has been found and repaired the VIDS/MAF form is completed by the technician and reviewed by the shop supervisor then routed to a computer center. At the same time, a new VIDS/MAF form is initiated and sent along with the failed LRU to Production Control at the intermediate shop. Production control screens the LRUs to determine which group within the intermediate shop has the capability to repair the unit. When the responsible shop is determined, a copy of the VIDS/MAF is pulled and placed on the production control required work board and a copy sent to the computer center. The LRU is delivered to the awaiting work bins assigned to the designated shop where the supervisor pulls another copy of the VIDS/MAF and places it in his production required board. When a technician becomes available he will pull the VIDS/MAF copy and pick up the unit. When the LRU is repaired, a new VIDS/MAF form will be completed, reviewed by the shop supervisor, and the VIDS/MAF/LRU routed back to production control. The LRU is then placed in the supply system, work boards updated, and VIDS/MAF form sent to the computer center. If an LRU cannot be repaired due to lack of parts again a VIDS/MAF form is initiated indicating the required part and both the form and LRU routed to supply. At supply the date the part was ordered will be placed on the VIDS/MAF form, the LRU stored, and copies of the VIDS/MAF sent to the shop, production control, and the computer center. When the part is received, it is recorded on the VIDS/MAF form and LRU/part routed back to the group for repair. The VIDS/MAF is a relatively new form and the shop supervisors indicated it had increased their paperwork requirements due to the necessity of transferring information from one form to another; however, they have heard rumors that eventually the VIDS/MAF format would become an automated system with a terminal in each individual shop. Each shop supervisor gets a daily readout from the computer center indicating the status of their shops. Apparently, the daily readouts were usually late and of little value; but monthly readouts were useful in performance of their management function. It should also be noted that the personnel indicated the maintenance manhours filled out on the forms were rough estimates.

5. Manning: The manning at the base intermediate shop consisted of both permanently assigned personnel, and technicians assigned to aircraft carriers in port. Whenever a ship returns to port, no avionics maintenance is performed on the ship; therefore, both the flight line and intermediate shops' personnel are temporarily assigned to the base. A small crew is left on board the ship to keep up the test stations and perform general housekeeping. This concept can be a problem in a case such as existed with the USS Constellation. This ship had just returned from a two-year stay in the shipyards, thus, personnel assigned to the ship have been trained and working at the base shops for a relatively long period of time. When the USS Constellation goes to sea, the base shops will lose the personnel assigned to the ship and could inadvertently find themselves in a position where they have no one trained on a particular piece of equipment. To overcome this problem, extensive cross training exists within the shops. The base intermediate shop employed a few civilians. Again the supervisor stated that this provided stability to their organization. All shops used three shifts plus a weekend shift of four days.

6. Parts Availability: Parts availability had just begun to be a problem and was directly related to lack of money. The senior personnel indicated that this was a normal problem that always occurred toward the end of the fiscal year. The only exception was the spare LRUs/SRUs for the avionics suite on board the S-3 aircraft. This was a new weapon system and minimum spares were procured causing a high cannabalization rate, and, in fact, two aircraft were in the hanger fairly well stripped of LRUs. Apparently the Navy is gathering field reliability data to determine the required spare level to support the systems prior to commitment of a large amount of funds.

7. Intermediate Shops:

a. Special soldering facility: This shop was manned by technicians trained both in electronics and soldering techniques. Some shops also had personnel trained on soldering techniques, thus, when bad components were found, the shop supervisor would determine if the components could be replaced by his personnel. He usually based his decision upon the component density and mounting technique used on the SRU. However, all the shops indicated that made extensive use of the equipment/expertise that existed within the special soldering facility.

b. VAST: Five VAST (Versatile Avionics System Test) were located at the base and 3-1/2 systems had just been installed on the U.S.S. Constellation: The VAST concept has existed within the Navy for approximately 15 years and the systems installed on the U.S.S. Constellation represent the second generation. A VAST system consists of several LRU referred to as building blocks and functions to dynamically test/troubleshoot a LRU by simulating interface signals. The shipboard VAST systems are capable of testing 130 LRUs and usually isolated the problem down to three or less SRUs. It also had the capability of troubleshooting 103 SRUs again isolating the problem down to a group of three components or less. The VAST concept differs from the Air Forces automated test stations in various ways. First the VAST station is used for a fairly wide range of new and old systems as well as tactical and ASW systems. However, the VAST personnel stated that performance is better on the newer system where the VAST concept was incorporated into the system design. Probably the unique difference was that within the VAST shop there were three levels of maintenance technicians. (1) A computer operator who could interface the LRU to the VAST system and troubleshoot in the automatic mode only, (2) A limited maintenance operator who could use the VAST system in a manual mode, reprogram to a certain extent, and perform limited manual maintenance (use scope, meters, etc.) to isolate a problem, and (3) A maintenance technician responsible for upkeep of the test station. It was estimated that 60% of the time, VAST, in the automatic mode, would fund the problem in a LRU/SRU. The VAST shop used the special soldering facility for all component replacements.

The biggest problem with VAST appeared to be the time required to test an LRU. Base shop personnel indicated that it took on the average 5.6 hours to test/troubleshoot one LRU. The majority of this time was consumed in setting up the interface and loading the necessary programs. A more efficient test station design would allow for interfacing more than one LRU and time sharing the computer. It should be noted that there was one other automated test station installed on the U.S.S. Constellation. This station was specifically designed for the APS-120 radar system and isolated problems both in the LRUs and SRUs. Again the technicians were not limited to using the test station in the automatic mode. Apparently, there is a continuing development effort within the Navy on the VAST concept and they are also investigating methods to shorten the LRU/SRU test times associated with the present systems.

c. Comm-Nav Aids: This shop used hot mock-up for troubleshooting and repaired all systems, except one still under Vendor contract, down to the component level. Very little higher level support was required and usually consisted of chassis repair. The shop was having the same problem with the TACAN test set as existed on the Air Force bases. In addition, the IFF power supply (xmtr) was a headache to troubleshoot.

This power supply consisted of several stacked SRUs mounted in a small volume such that it was impossible to use scopes/meter for troubleshooting. To find the fault required disassembly of the power supply, R&R of the suspected SRU, reassembly and then conducting the system tests. Most likely this problem was not noted at the Air Force bases since the power supply itself could be considered as a SRU. This was not a high fail item and the IFF system both in the Navy and Air Force appear to be highly reliable.

d. Radar: This shop had a cross-section of age. All the older systems used hot mockups for troubleshooting. Manual test stations existed for the APS-116 and the FLIR aboard the S-3 aircraft. Both of these systems were also supported by the VAST shop, however, as of yet the software problems have not been solved. Their biggest problem was that the tech orders had not been published and they were using preliminary manuals which were not complete or corrected. From the limited data, it appears that the scan converter for the APS-116 will be one of the high fail items.

e. Instrument Shop: The instrument shop had very few complaints This shop differs from the Air Force in that it is manned by Electricians instead of Electronic Technicians.

9. Flight Line Shops VS-21 & VS-41: Both of these shops supported S-3 aircraft with the biggest problem being lack of spares causing a large amount of cannabalization (refer to item 6). The S-3 has an on board computer that performs, among other functions, an in-flight BIT. Further, both maintenance and operational tapes exist for use by the flight line technicians. The VS-41 shop indicated that they had little use for the maintenance tapes and have found the operational tapes to be more effective. Also, the S-3 system had an in-flight recorder that would record when a LRU failed and other pertinent data associated with the aircraft. It did not monitor the status of aircraft power when the failure occurred. Again, the flight line technicians found this to be of little value. It appeared both flight line shops still depended upon experience for fault isolation.

10. S-3 Accessibility: The LRUs on the S-3 are readily accessible with the majority of the units mounted in a pressurized compartment behind the aircrew. All the LRUs were slide mounted with permanent connector on the back plate. They have experienced some wiring problems but only a few bent pins.

11. Tail Number Scheduling: Like the Air Force tail number scheduling was employed. Again, it was felt that this increased the cannabalization rate.

COPY 3

MAINTENANCE / PRODUCTION CONTROL VIDS REGISTER COPY

5 PART FORM

USE BALL-POINT PEN PRESS HARD

ENTRIES REQUIRED SIGNATURE

NONE LOGS REC

VIDS/MAF OPNAV 4790/60 (12-75) S/N 0107-LF-047-9300

REFERENCE/LOCAL USE

ACCUMULATED WORK HOURS

NAME/SHIFT	DATE	MAN HOURS	ELAPSED M/T

ACCUMULATED AWM HOURS

DATE	TIME	REASON	HOURS

(H-Z) FAILED/REQUIRED MATERIAL

79 INDEX	08 F/P	09 AWP	10 A/T	11 MAL	14 MFGR	19 PART NUMBER	34 REF SYMBOL	41 QTY	43 PRI	45 DATE ORD	49 REQ NO	53 DATE REC

-FOLD-

A22 WORK UNIT CODE | A24 ACTION ORG | A32 TRANS | A34 MAINT L | A35 ACT TAKEN | A36 MAL CODE | A39 ITEMS P | A41 MAN HOURS | A45 ELAPSED M/T

TECHNICAL DIRECTIVE IDENTIFICATION

F08 INTERIM | F09 CODE | F11 BASIC NO | F15 RV | F16 AM | F17 PART | F19 KIT

A48 TYPE EQUIP | A52 BU/SER NUMBER | A58 DISCD | A59 T/M | A60 POSIT | A62 FID | UNSAT MAT'L REPORT A65 A66 SERIAL | G.S.E. A70 RRC A71 STA | A72

INVENTORY TRANSACTION

F21 | F22 HOURS | F26 PERM UNIT CODE | F32

REPAIR CYCLE

	DATE	TIME	AOC
RECEIVED	B08	B12	B16
IN WORK	B19	B23	B27
COMPLETED	B30	B34	

AWAITING MAINTENANCE

B38 E39 HOURS | B43 B44 HOURS | B48 B49 HOURS

MAINTENANCE/SUPPLY RECORD

JOB STATUS	DATE	TIME	AOC
B53	B54	B58	B62
B65	B66	B70	B74
C08	C09	C13	C17
C20	C21	C25	C29
C32	C33	C37	C41
C44	C45	C49	C53
C56	C57	C61	C65
D08	D09	D13	D17

JOB CONTROL NUMBER

A08 ORG | A11 DAY | A14 SER | A17 SUF | D25 WORK CENTER

REMOVED/OLD ITEM

E08 MFGR *(tec if eng)* | E13 SERIAL NUMBER

E23 PART NUMBER *(leave blank if engine)* | E38 DATE REMOVED

E42 TIME/CYCLES | E47 TIME/CYCLES | E52 TIME/CYCLES

INSTALLED/NEW ITEM

G08 MFGR *(tec if eng)* | G13 SERIAL NUMBER

G23 PART NUMBER *(leave blank if engine)*

G38 TIME/CYCLES | G43 TIME/CYCLES | G48 TIME/CYCLES

DISCREPANCY

CORRECTIVE ACTION

CF REQ | QA REQ

TURN-IN DOCUMENT

INSPECTED BY

CORRECTED BY

SUPERVISOR

☆ U. S. GOVERNMENT PRINTING OFFICE: 1977 — 757-001/544