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AD 852 107

PROJECT PIMO FINAL REPORT

TROUBLESHOOTING AID PREPARATION GUIDELINES

PREPARED BY:

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George S. Dibelka

SERENDIPITY, INC.

FOREWORD

This report (Volume I through Volume VIII) represents the final phase of a study and test which was initiated in September 1964 to explore newly developed techniques and devices for presenting T. O. (Technical Order) type instructions and information. The eight volumes of data contain the result of a test conducted in an operational environment using concepts developed during an earlier phase under Contract AF 04(694)-729 and documented in BSD-TR-65-456. Both the early phase and final phases which were accomplished under Contract AF 04(694)-984, Project 1316, "Presentation of Information for Maintenance and Operation (PIMO)", were started in June 1966 and completed in April 1969. This final report was submitted in May 1969.

The original program documentation was prepared by Mr. C. L. Schaffer, SMTE, in 1964. He subsequently functioned as the Air Force Program Director and Chairman of a Working Group which monitored all development throughout the life of the project. This Group was composed of individuals from various Air Force commands (AFLC, MAC, ATC, ADC, AFSC) and the Army Command (AMCPM, AXMLE) knowledgeable in the various maintenance disciplines and all facets of the T. O. system. Capt. Don Tetemeyer, the Project Scientist during the formulative stages of the Program was largely responsible for the basic test structure. Mr. John Saunders was the monitor for all contractual aspects until his reassignment in 1968.

Any success one may attribute to the project must be shared by numerous individuals; however, major credit and appreciation are due General Howell M. Estes, Jr., Commander of the Military Airlift Command, who provided the C-141A aircraft and the bases at Charleston, Dover and Norton for the operational test. Sharing in the credit for the MAC contributions are Lt. Col. Don Watt and his staff at Hq. MAC, and Col. Foreman, Col. Henzi, W/O Van Riper and all the personnel at Charleston Air Force Base and also at Dover and Norton who participated in the test. The hardships imposed on their organizations are recognized, and we sincerely appreciate the special efforts put forth to overcome all obstacles. The test could never have been conducted without the cooperation and competent performance of these many individuals.

We are especially indebted to the Air Force Human Resources Laboratory, Wright-Patterson Air Force Base for their financial contributions at a critical point in the project; and also to the Army Materiel Command, who believed the test potential of sufficient magnitude to warrant the expenditure of their funds. We are most grateful for their confidence and assistance. It is most assuredly the primary factor that permitted completion of the test.

This technical report has been reviewed and is approved.

D A Cook

D. A. Cook, Lt. Col. USAF
Hq. AFSC (SCS-2)

ABSTRACT

This report describes the latest phase in the program to develop and evaluate PIMO (Presentation of Information for Maintenance and Operation); a job guide concept applied to maintenance. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Three immediate behavioral effects were expected: 1) reduction in maintenance time, 2) reduction in maintenance errors, and 3) allow usage of inexperienced technicians with no significant penalty. Experienced and inexperienced Air Force technicians performed maintenance on C-141A aircraft using PIMO Job Guides presented in audio-visual and booklet modes. Performance was measured in terms of time to perform and procedural errors. The performance was compared with the performance on the same jobs by a control group, i.e., experienced technicians performing in the normal manner. The following conclusions were drawn from the test results: 1) after initial learning trials, both experienced and inexperienced technicians using PIMO can perform error-free maintenance within the same time as experienced technicians performing in the normal manner, 2) inexperienced technicians perform as well as experienced technicians when both use PIMO, 3) there is no significant difference between audio-visual and booklet modes, 4) the users revealed an overwhelmingly positive reaction to PIMO, and 5) the performance improvements provide the capabilities to significantly improve system performance defined in terms of departure reliability, time-in-maintenance, and operational readiness. This report also presents a description of the recommended operational system, specifications and guidelines for PIMO format development, including troubleshooting.

PREFACE

This report was prepared under Contract AF04(694)-984. It is submitted as partial fulfillment of Contract Data Requirement List (CDRL) Item 29.

It is used to support specifications presented in

PIMO
Troubleshooting
Aid Specification
TR 315-69-14 (U) Volume VII

This portion of the final report presents a recommended approach to the development of troubleshooting manuals. These recommendations were arrived at through intensive analysis conducted over a two-year period.

Although the primary function of this portion of the project was to develop troubleshooting aids (TSA's), it became evident that specification of an end product does not necessarily insure its effective production.

The type of TSA's used on PIMO are somewhat new. And, as with any new system, there are a certain number of false starts (often referred to as the learning curve) and subsequent iterations in bringing the technique into operation.

The manuals were developed by both Serendipity personnel and technical writers currently employed by a major aircraft manufacturer. The reason for this approach was to take advantage of technical capabilities inherent in both groups. However, the problems associated with the development of TSA's became evident in a very short time. Therefore, these guidelines are intended to aid the developers of TSA's and have resulted as a by-product of recognizing the associated problems, together with the development of an appropriate solution to those problems.

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SECTION I

INTRODUCTION TO GUIDE

A. GENERAL

This document presents a set of guidelines for the development of improved troubleshooting aids in conformance with proposed specifications set forth in FIMO Troubleshooting Aid Specifications, Volume V.

Prior to presenting the guidelines, certain key terms are defined. These terms must be clearly understood if the concepts, criteria and resultant guidelines are to be perceived and used properly.

B. GLOSSARY OF TERMS

1. Constraints

Constraints are restrictions placed upon the means that implement a function. Constraints are the result of living in a real, practical world. Statements of constraints in terms of money, man-hours, materials, etc., generally force compromises to be made when implementing a function. Constraints, together with expressions of state pairs, may be considered as major factors that motivate trade-off studies as part of the systems analysis effort.

2. Criteria

The term criteria, the plural of criterion, is defined as standards by which a correct judgment or measurement can be made. The criteria must exist prior to any specific analytical effort, and all analysis must be compared to the criteria in order to determine that the analysis is relevant and lawful.

3. Function

An operational definition of the term function, as used in this document, is: an occurrence which continues until a required output state is achieved, given the requisite initiating input state. Thus, a function can be defined by state pairs, input and output.

Definitions of function and system often are quite similar. In fact, they can be the same. For the purpose of this document, the term system will be used two ways, both within the definition of the term. When the term is used without an adjective, it will mean the highest order of functions or physical means (primarily equipment) of concern. In other words, a given function or equipment will be a part of the SYSTEM. When an adjective is used (e.g., Aileron System), it will refer to a subgroup of equipment entities which are a part of the larger SYSTEM and implement a particular function.

An existing SYSTEM, such as a multi-engine transport, can be characterized in terms of its functional elements and/or physical elements. Both the functional and physical elements exist in a hierarchy. To avoid confusion, the hierarchy of functions will be labeled only in terms of levels, i.e., Level I, II, or III (see definition of Hierarchy).

4. Functional Unit

Functional unit is a term used to describe a general grouping of hardware elements that implement a common functional requirement. Generally, each grouping represents a hardware system, subsystem, or segment. Each functional unit implements a functional requirement and is readily bounded. It conforms to the criteria which are specified for aircraft partitioning. It may be used interchangeably with the term troubleshooting unit in this document.

5. Hierarchy

Originally, the term hierarchy was used to denote the arrangement of successive groups of clergy of a church according to rank. The term is now commonly used to denote a series of groups having commonality arranged by rank. The concept of hierarchy is fundamental to functions analysis and systems engineering.

The application of the hierarchical concept to functions permits one to express the highest level function in greater detail by successively partitioning the higher level functions into state pairs. These state pairs must possess commonality and, as a group, encompass the entirety of the higher level function. The functional hierarchy used to analyze an aircraft, for example, is as follows:

a. Level 0 Function -- the occurrence that describes the state change required at the major level of concern, e.g., the fundamental state changes of the aircraft that are necessary to achieve its mission, such as "control aircraft during flight".

b. Level I Function -- the occurrences that together describe the state changes required within a Level 0 Function, e.g., "control the attitude of the aircraft during flight".

c. Level II Function -- the occurrences that together describe the state changes required within a Level I Function; e.g., "control the aircraft attitude in pitch during flight".

d. Level III Function -- the occurrences that together describe the state changes required within a Level II Function; e.g., "control the aircraft in pitch by airspeed compensation".

Aircraft Type A can be grouped with other types of aircraft whose purpose is to transport material, thus the Type A system is a subsystem (a rank lower than system) of a logistics system. Similarly, the aircraft flight control system is ranked lower than the aircraft system and is therefore a subsystem of the logistics system.

Use of terms such as system, subsystem, segment, and entity will be noted frequently in this document. They describe the equipment hierarchy that is to be used during development of the troubleshooting aids. The levels are frequently dictated by the function a particular grouping of equipment serves. There will be cases when the grouping is not compatible with the way the equipment is packaged. In these cases, the adjective used to define the grouping (system, subsystem, etc.) is based on the function(s) the grouping is to serve. These terms are defined as follows:

a. System -- a grouping of equipment that provides a means of effecting a basic functional requirement, such as control attitude of aircraft. Generally, the term system can be correlated to a Level I function as previously defined. Do not confuse with the term SYSTEM, which refers to the major system under analysis and for which requirements have already been defined.

b. Subsystem -- a grouping of equipment that provides a means of effecting a functional performance required for aircraft operation. Subsystems are the next lower level indenture to system; however, in some cases where no further partitioning of the system is feasible, the two are synonymous. The subsystem, therefore, can be correlated to a Level II function as previously defined.

c. Segment -- This term may be used to denote a further partitioning of the subsystem for the purposes of troubleshooting aid presentation or to denote a specific use of the equipment making up the subsystem, such as operational modes. It is the smallest partition of the aircraft for which a troubleshooting aid is identified. It is similar to the segments developed for operational checkout. Segments can be correlated to Level III functions.

d. Entity -- Normally the term entity refers to any specific equipment within the equipment hierarchy. In this document it is used as notation for any identifiable equipment within a segment, whether it is a removable unit or a component comprising that unit. Entity can be usually associated with a Level IV function.

e. Removable Unit -- This term describes an entity that is removable at the on-aircraft maintenance level.

f. Component -- Component is used to denote an entity within a higher equipment echelon that cannot be further subdivided.

g. Means -- The physical entity (e.g., people, equipment, data, etc.) used to meet the requirements of a function or system.

6. Interface

Interface is a term used to indicate a discontinuity. In systems terminology interface means the point, line, or plane of separation where a distinction between systems or portions of systems can be made. Often, it is the point at which an energy transfer takes place. In functions analysis, this distinction is made by indicating the interrelation of one function to another. Identifying system interfaces in terms of prerequisite inputs such as electrical or hydraulic energy, mechanical motion, etc. assists in establishing the boundaries of lower ranking systems. Additional definition is required to identify the components between which the boundary is defined; however, it will be along the energy path indicated by the input commodities or conditions.

7. Signal

The definition of the term signal is: an indication, event, or cue conveying information. When signal is used in this document, it refers to an observable or measurable indication of an action or event. Signal flow denotes that the signal has an origin and a destination. An example of signal flow is the electrical voltage carried by circuits from a pressure transducer to a panel meter. The indication of pressure is a result of the signal "flowing" from the sensor.

8. State

The term state is defined as the condition of existence of something at a particular time and place. Consider the use of state in the expression, "ice is water in the solid state." Note that the state of the water is described as solid without reference to its temperature, density or salinity. These descriptors are parameters, or measures, of the state.

9. State Pairs

Two states forming an input-output boundary for a process or function. The two states represent the basic requirement for the function, i.e., change the state of an arbitrary parameter from the input state to the output state. Thus, the requirement for a function termed TRANSPORT could be to change the location state of people x from Los Angeles to San Francisco.

10. System

Many definitions of the term system can be found in the open literature on systems engineering, systems analysis, and other related subjects. The following definitions illustrate three distinct concepts of what a system is.

a. A system is a collection of rules, such as a system to win at blackjack. This definition is based upon rules of behavior.

b. A system is a collection or aggregation of similar things such as a system of highways or the solar system. This definition is based on composition.

c. A system is a collection of entities (animate and/or inanimate) which receives certain inputs and acts upon them in concert within constraints to produce certain outputs.

All are correct; however, the third definition is more closely aligned with complex military systems and is accepted for this document.

Each system has a certain integrity; i.e., all of the parts comprising it have some common purpose and contribute, in some sense, towards the accomplishment of that purpose. It is this concept -- commonality of purpose -- that permits system hierarchies to be developed.

SECTION II

AIRCRAFT PARTITIONING

A. GENERAL

An aircraft is obviously a complex SYSTEM comprised of many interacting components. Effective troubleshooting cannot be performed on the aircraft as a whole (neither can design, development, nor production). Thus, there is a requirement to partition the system into smaller, more manageable segments that lend themselves to ready identification and manipulation. This section has as an objective the development of an aircraft structure comprised of segments termed "troubleshooting units". It is anticipated that each of these troubleshooting units will be treated by a troubleshooting aid so that a malfunction of the aircraft can be efficiently isolated to the removable unit level. Although the U.S.Air Force C-141A was used to illustrate the application of the partitioning guidelines, they can be similarly applied to any aerospace system.

B. CRITERIA FOR PARTITIONING

The objectives that should be met as a result of the partitioning activity are as follows:

- An inclusive set of troubleshooting units for the aircraft should be identified so that it permits a troubleshooter to "enter", given a malfunction indication; has a high probability of containing the malfunction indicated by the symptom.
- The boundaries of each troubleshooting unit should be defined.
- The relationship between troubleshooting units should be indicated.
- The base on which troubleshooting aid development can be initiated should be standardized.

Criteria to guide the partitioning of the aircraft were developed from these stated objectives. Some of the criteria were explicit, while others were implied. Their application required a considerable amount of judgment on the part of the partitioner. Some of the criteria for developing the set of troubleshooting units were:

1. Relatability of a Troubleshooting Unit to a Function

This criterion stipulates that the resultant troubleshooting unit (a grouping of equipment items) must perform a specific function. Since the troubleshooting unit is to be identified by its functional performance, the aircraft must originally be partitioned on a functional basis. It is anticipated that equipment complexity is not in direct proportion to the functional level; therefore, troubleshooting units are expected at various functional levels.

2. Identifiability of Troubleshooting Unit Boundaries

The boundaries of a troubleshooting unit must be identified by establishing the elements that comprise it. If the boundary is between components, these must be identified. In defining the boundaries, an attempt should be made to minimize the interfaces (all other things being equal).

3. Measurability of Relationship Between Troubleshooting Units

The relationship between troubleshooting units must be amenable to test or measurement. This implies that the interface is either directly or indirectly testable. The interface must be specified so that it is clear what action, energy, signal, etc., pass the troubleshooting unit boundaries. This relationship is, thus, determined by identifying the input and output states of the function that the troubleshooting unit implements.

4. Relatability of Troubleshooting Unit to Indicated Malfunction

Since the troubleshooting unit (and the resultant aid covering it) must be associated with the malfunction indication with which the technician begins, the troubleshooting unit must incorporate the elements of the aircraft that present the indication. For example, instrumentation indicating a malfunction must be contained within the equipment grouping defined as a troubleshooting unit.

5. Acceptability of Nomenclature by Personnel Using Aids

The personnel using the troubleshooting aids may not readily accept them if the nomenclature of the troubleshooting unit (or the equipment it contains) creates interpretive problems. For example, describing the troubleshooting unit in functional terms may not expedite the technician's association with the hardware it represents. The nomenclature should assist the troubleshooting function, not retard it. It is expected that conventional nomenclature will usually meet this criteria.

6. Consistency of Troubleshooting Unit Set with Other Maintenance Materials

The total set of maintenance material covers many operational and maintenance functions. Those functions that interface with the troubleshooting function occur in a serial fashion, i.e., troubleshooting is sandwiched between functions for which other aids will be available. This may be illustrated by a typical sequence of events as follows: A malfunction indication, e.g., "effort required to control aircraft in pitch is excessive," is noted during flight by the copilot. He relays this information to the flight chief who writes the indication down on a Form 781A, e.g., "wheel force in pitch excessive". This information is collected by ground personnel and transcribed to a Form 992. This information is given to a technician on a copy of the Form 992. The technician is assigned the task of locating and fixing the cause of the "stubborn" wheel. At this point, upon reading the malfunction indication, he requires an aid. This aid is made accessible by an index relating the indication directly or indirectly to the aid. The aid is not necessarily a troubleshooting aid at this point -- it may be classed as an operational check or inspection guide. The troubleshooting aids should be compatible with the aids used for these other maintenance functions. This is particularly so for the operational check function.

If systems or units are segmented for operational checks, a similar segmentation should be considered in developing the troubleshooting aids. If the source of the malfunction is not readily apparent, the index is referred to for the proper troubleshooting aid. With this aid, it is assumed that the malfunctioning element (removable end item or unit in the case of on-aircraft maintenance) is located and identified. An index is now required to make available the store of maintenance aids which can bring the system back to a "go" state.

7. Compatibility of Troubleshooting Unit with Troubleshooting Aid

Although one type of troubleshooting aid may be constructed for all segments of an aircraft, it is anticipated that different troubleshooting aids should be employed. The proper employment will be a function of both the troubleshooting unit and the troubleshooting aid characteristics. The resulting set of troubleshooting aids will then be a mix of different techniques where each troubleshooting unit is treated by an aid best suited for isolating the cause of a malfunction in that unit. Criteria for matching the aid and the unit are based upon the characteristics of the malfunctions possible within the unit, properties of the troubleshooting aid, the user requirements, and constraints on aid development.

8. Inclusiveness of Aircraft Removable Units Within Set of Troubleshooting Units

The entire aircraft does not require formal troubleshooting aids. Certain faults are noted with the malfunction, e.g., a flat tire, a leaking seal, a broken windscreen, a dent in the fuselage. There are some portions of the aircraft that do not need troubleshooting aids and therefore are not classed into troubleshooting units. Those elements of the aircraft that are selected as troubleshooting units must include all components that may be potential sources of malfunctions. The aid representing the unit, however, need only detail the equipment to the removable unit level.

C. PARTITIONS AND FUNCTIONAL UNIT IDENTIFICATION

Although the C-141A aircraft has been designed, fabricated, and is in an operational status, analysis of it in terms of functions is expected to provide a valid basis for the identification of equipment groupings for troubleshooting. This analysis was conducted by determining the changes of state (at various functional levels) necessary to accomplish the objectives of the C-141A aircraft. A review of the gross segments of the mission profile indicates that it can be separated into three phases: preflight, delivery, and postflight.

- Preflight consists of both aircraft and ground support activities which prepare the aircraft for operation. It ceases when the aircraft is capable of moving under its own power, and the doors and hatches are closed. Loading, fueling and preflight checkout are included in this phase.

- Delivery includes taxi, take-off, ascent, cruise, descent and landing. This phase ends when the engines are shut down, and doors and hatches are opened.

- Postflight consists of cargo discharge, postflight maintenance, etc. It actually dovetails into the preflight phase, since aircraft missions are cyclic.

The mission profile reveals that the aircraft goes through three distinct operational regimes. They are: (a) the stationary regime, which encompasses provisioning, loading, preflight checkout, and other preparatory activities conducted while the aircraft is in a stationary state at the ramp; (b) the ground motion regime, encompassing taxi operations, take-off run, and landing runout; and (c) the flight regime, encompassing aircraft flight maneuvers, navigational operations, and other in-flight operations. The (a) and (b) regimes support the flight regime.

Examination of the flight regime portion of the mission profile reveals that the aircraft undergoes various state changes in transporting material from Site X to Site Y. The major changes of state necessary to achieve this mission are shown in the figure below.

1. A/C LOCATION a) Latitude = Ramp A, b) Longitude Site X c) Altitude = 0 2. A/C ATTITUDE a) Roll = Level b) Pitch c) Yaw = α	FLY AIRCRAFT	1. A/C LOCATION a) Latitude = Ramp B, b) Longitude Site Y c) Altitude = 0 2. A/C ATTITUDE a) Roll = Level b) Pitch c) Yaw = β

These changes of state are achieved by the combined performance of numerous aircraft functions. This function can be partitioned into state pairs which reveal the requirements for lower level functional systems. These state pairs are depicted diagrammatically in Figure 2-1. The state pairs shown in this figure were derived by first examining the state classes used to bound the system and then defining the processes required to meet the state-change requirements. Note that the partition is essentially a parallel one, i.e., the functions are not in series. However, the functions are not independent. The dependency of the functions upon each other is not shown since it was not necessary for the partitioning.

The functions required to meet the over-all state-change requirements of the system represent the primary functions. Additional partitioning required consideration of generic means used in large jet transports to meet the requirements of the primary functions. Two additional functions were identified by considering generic means used in the secondary functions. Examination of the functions thus defined indicated that the functions were quite generic, although it was necessary to go to the third level of derivation. More important, additional partitioning required consideration of specific means. Therefore, it was decided to treat the functions identified up to this time as the level 0 function for the SYSTEM.

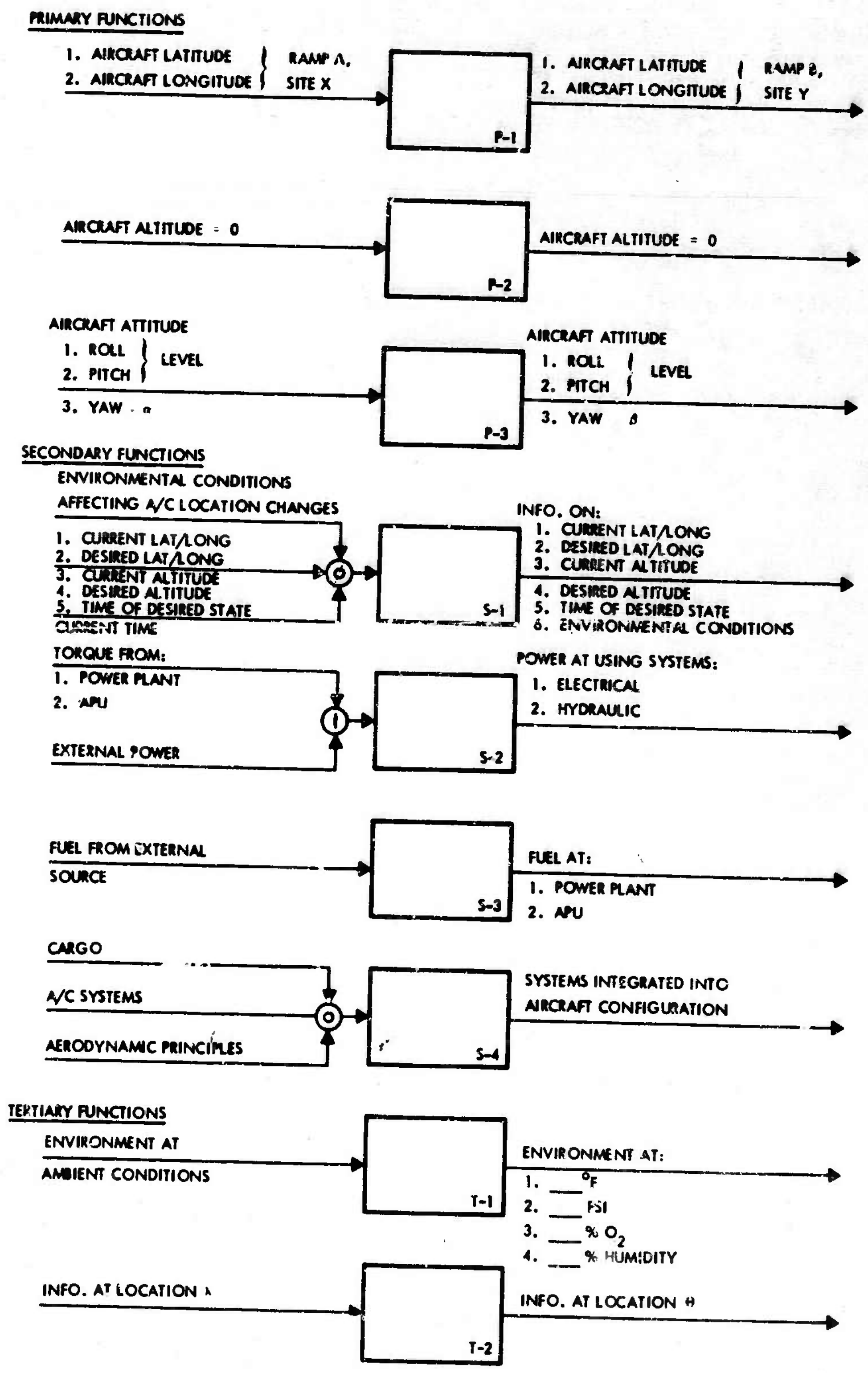


Figure 2-1. Basic C-141A Aircraft State Change Requirements

It should again be noted that the dependencies of the functions are not shown on the diagram. For example, the outputs of P-1, P-2, and P-3 are basic inputs to S-1. The output of S-1 in turn, is a required input for P-1, P-2, and P-3, if the function is to be controlled. The interdependencies are omitted solely for the safe of simplicity.

The state-change requirements shown above can be re-expressed in terms of functional objectives by examining the type of state changes required. The primary objectives are:

1. Provide aircraft translational capability.

2. Provide aircraft lifting capability.

3. Provide aircraft orientation capability.

In addition to these, the objectives termed "supportive" must be met during the mission. These supportive objectives are accomplished by secondary and tertiary functions. A list of the major supportive functional objectives follows:

1. Provide a navigational capability.

2. Provide power to execute all functions.

3. Provide fuel to produce power and/or translating force.

4. Provide an integrating structure.

5. Provide a controlled environment.

6. Provide a communications capability.

Taking the C-141A aircraft as an example, equipment was selected to implement the required performances; in other words, hardware systems were associated with functional objectives. This was accomplished by reviewing the Technical Orders and manuals pertaining to the C-141A aircraft. The grouping of equipment items is somewhat arbitrary, but they tend to represent a commonality of purpose within each group. A matrix of the primary and supportive functions versus the selected hardware systems was constructed to determine whether additional or revised partitioning of the top-level function (Level 0) into Level I functions, was required. This matrix is shown as Figure 2-2. Note that Function A requires a means to translate on the ground surface and a means to change the rate of translation, both ground and airborne. The hardware which is required to accomplish these translational objectives is not easily bounded when treated as a single system. Three hardware systems were selected for Function A; namely, the wheels and braking portions of the landing gear system, the wing flaps of the lift/drag system, and the thrusting portion of the propulsion (or power plant) system.

Function B requires both fixed and movable aerodynamic surfaces to meet its functional objectives. The fixed portion is contained in a system termed airframe, while the movable portion (wing flaps) is classed as a portion of the lift/drag system.

Orientation of the aircraft, Function C, is accomplished by the landing gear braking and steering subsystems while on the ground, and movable aerodynamic surface while in flight. Ground orientation is accomplished by a subsystem of the landing gear system, while the flight orientation hardware is an independent system.

Implementation of the navigational function, Function D, is accomplished by a well-bounded set of hardware subsystems; however, Function E is implemented by two on-board systems, the power plant and the auxiliary-propulsion unit-driven power generation equipment. The APU, for this function, serves as a redundant source of energy. The power requirement is fulfilled by means of electricity and hydraulic fluid. They were considered as separate hardware systems, even though they are functional subsystems of the power system, because of their unique boundaries. The reason for coding the Propulsion System and the APU System is that they generate pneumatic power. Functionally, a pneumatic system exists; however, the

HARDWARE SYSTEMS \ LEVEL I FUNCTIONS	A TRANSLATE AIRCRAFT	B LIFT AIRCRAFT	C ORIENT AIRCRAFT	D NAVIGATE AIRCRAFT	E POWER AIRCRAFT SYS.	F FUEL AIRCRAFT SYS.	G INTEGRATE A/C SYSTEMS	H CONTROL ENVIRONMENT	I TRANSFER INFORMATION
1.0 AIRFRAME		●					●		
2.0 LANDING GEAR	●		●						
3.0 LIFT/DRAG	●	●							
4.0 ATTITUDE CONTROL			●						
5.0 PROPULSION	●				●				
6.0 APU					●				
7.0 FUEL						●			
8.0 ELECTRICAL					●				
9.0 HYDRAULIC					●				
10.0 ENVIRONMENTAL CONTROL								●	
11.0 COMMUNICATIONS									●
12.0 NAVIGATIONAL				●					
13.0 MAN	●	●	●	●				●	●

Figure 2-2. Level I Function - Hardware System Matrix

hardware associated with it appears as a subsystem of hardware systems 5.0, 6.0, 10.0.

The aircraft fuel storage and distribution function is accomplished by the fuel system, Function F, and lends itself to explicit definition. The requirement to tie together all aircraft components into a unified structure is accomplished by the system termed airframe. This system satisfies the requirements of Function G. Except for the access panels, doors, ramps, etc., the airframe is the integrating nonremovable structure giving the aircraft its form and cohesiveness.

Function H is accomplished by the environmental control system. The transfer or exchange of information, Function I, within and between the aircraft and other receiving and transmitting stations is implemented by the communication system. Man is listed as a hardware system since he acts as an observational, computational, and actuational system.

A review of the Technical Orders was made to ascertain that each aircraft component fitted into one (and only one) designated hardware system. No omission was noted. The selected systems appear to meet most of the criteria previously set forth for troubleshooting units.

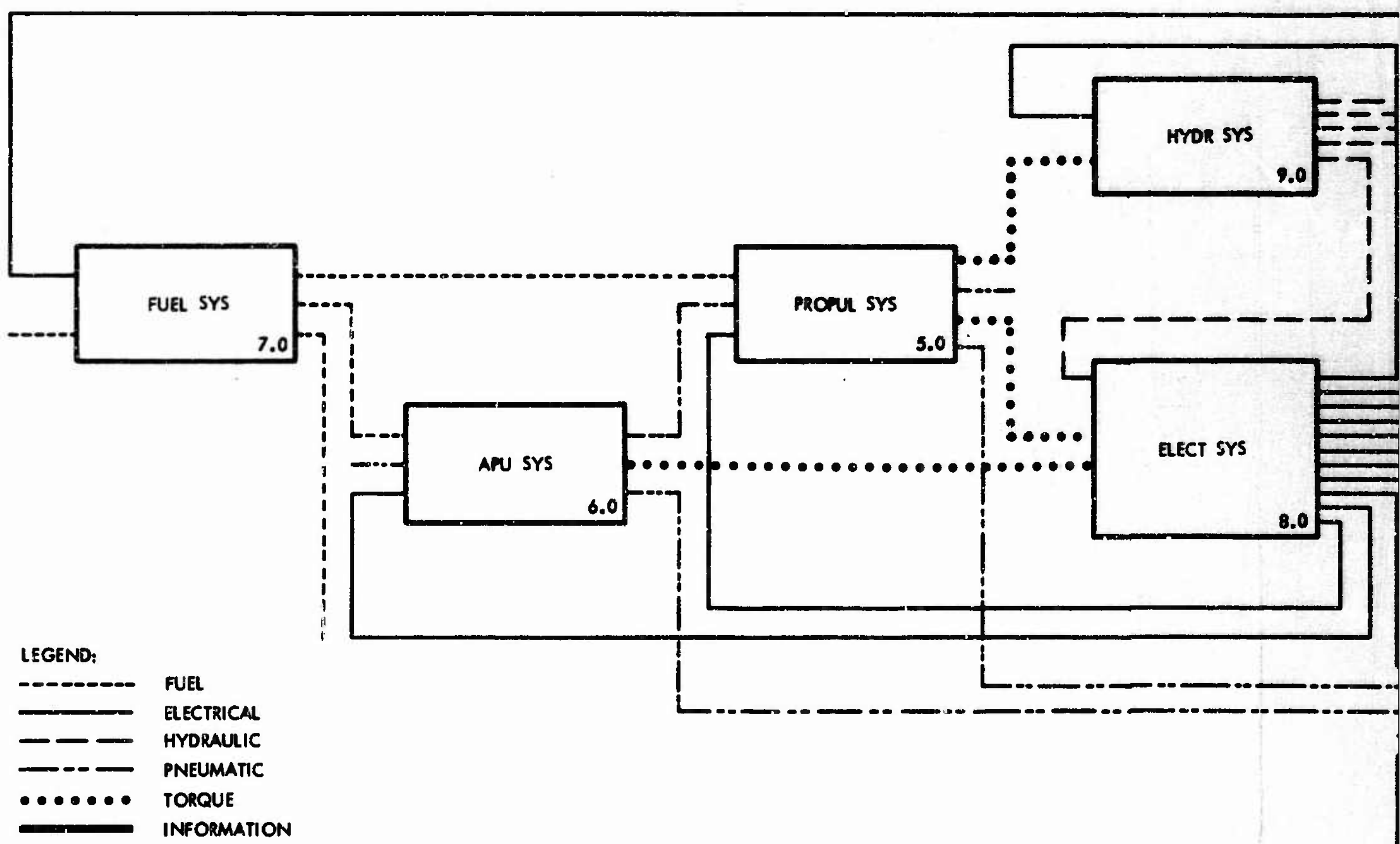
The boundary between systems was identified by indicating the point (or general area) where an output of another system has singularity of purpose; i.e., it is the input to only the system in question. For example, the fuel required for the engines and the APU cannot be distinguished as engine fuel or APU fuel until the fuel crosses a boundary where the fuel has a unique destination. Fuel in the tanks is not unique to an engine; however, fuel beyond the fuel isolation valve in an engine nacelle can only be used by that functional unit.

As mentioned previously, the equipment groupings were selected for commonality within each group. Although the nomenclature is hardware, each grouping represents a functional unit since the common purpose is a functional purpose, i.e., a class of state change required. Thus, the groupings will be treated as the Level I functions.

The systems associated with the Level I functions and the energy flow between them are illustrated on Figure 2-3. This diagram represents only those portions of the C-141A which are expected to require attention during on-aircraft troubleshooting. It does not show the structure tieing all systems together. Diagrammatically, this can be viewed as the paper on which the blocks are drawn. The figure does not show man nor the information and control interfaces with him. It does, however, represent the interdependence of the aircraft systems that have been designed to meet the top-level functional requirements.

The hardware systems making up the C-141A aircraft that appeared to meet the required functional performances are shown in Table 2-1, C-141A Aircraft Systems - Level I. Each aircraft system is briefly described by a short statement of performance requirement, the major output state to be achieved, and the requisite inputs. Most of the systems require man as an input to actuate controls and to monitor the output of the system. The Level I system and the Level I functional requirements, were then examined in greater detail by inquiring into aircraft specifications, the technical orders and other similar aircraft and space vehicle functions analyses. This examination was to determine which equipment of the C-141 made a contribution to the Level I functions. The activity of deriving functions by the state-change process was continued until a means specific to an aircraft had to be selected as implementing the function. This stop-blocking criterion permits the functions analysis to be generic to any cargo transport aircraft. The result of this analysis was the isolation of functional units. The term functional unit is used to denote a grouping of equipment that adheres to the partitioning criteria and may be considered as a candidate for either a hardware subsystem or segment. It may be considered as synonymous with the previously discussed troubleshooting unit for this study.

The functional units derived by the analysis along with performance and boundary descriptions are tabulated in Table 2-2, entitled C-141A Aircraft



FUEL SYS
7.0
APU SYS
6.0
PROPUL SYS
5.0
HYDR SYS
9.0
ELECT SYS
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LEGEND:
FUEL
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A

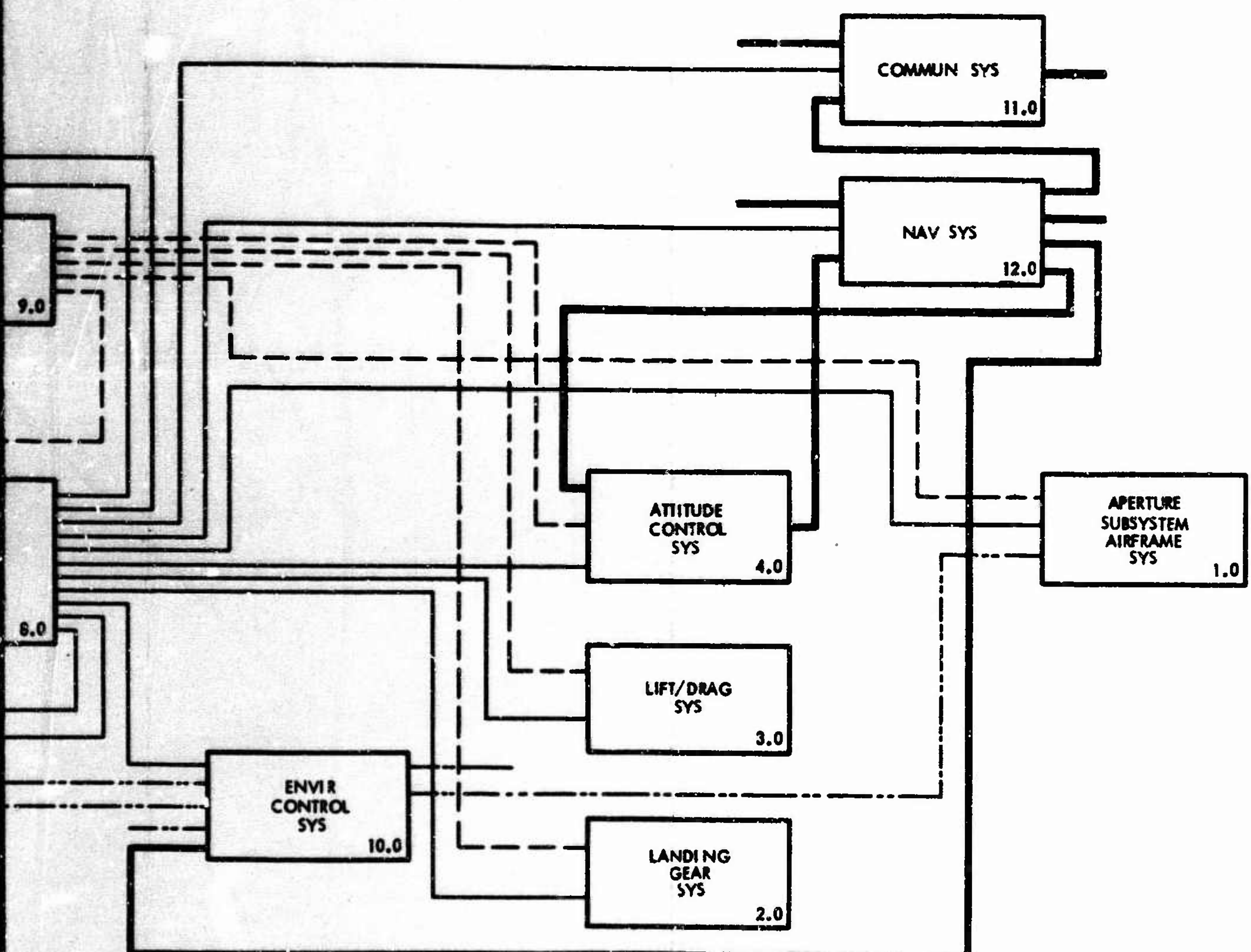

Figure 2-3. Energy Flow Between Hardware Systems

B

A/C SYSTEMS	PERFORMANCE	OUTPUT STATE	INPUTS
1.0 AIRFRAME	Integrate A/C Systems, provide basic lifting and steering surfaces, and provide access to internal elements	• Cargo/hardware system space and access to spaces • All A/C systems fastened together • A/C aerodynamically operational	• Structural • Aerodynamic surfaces • Access openings • Elect. energy • Hydr. energy
2.0 LANDING GEAR	Provide platform for and control over ground mobility	• Landing gear up or down • Brakes/anti-skid active • A/C oriented in yaw	• Hydraulic power • Elect. power
3.0 LIFT/DRAG	Alter A/C lift/drag characteristics	• Flaps extended/retracted x^o • Spoiler deployed x^o	• Hydraulic power • Elec power
4.0 ATTITUDE CONTROL	Provide capability to orient A/C	• A/C elevator, aileron, rudder oriented to produce: 1. Roll 2. Yaw 3. Pitch	• Hydraulic power • Elect. power
5.0 PROPULSION	Provide translational thrust Provide mechanical energy Provide pneumatic fluid	• Thrusting force on airframe • Torque at CSD • Bleed air at envir. control • Torque at hyd. sys. pumps	• Fuel • Elect. energy • Starting air
6.0 APU	Provide pneumatic fluid Provide mechanical energy	• Air at engine starter • Air at envir. control system • Torque at elect. sys. gen.	• Fuel • Hydraulic pressure • Elect. energy
7.0 FUEL	Store/distribute fuel	• Fuel at engines • Fuel at APU • Fuel overboard	• Elect energy • Fuel from external source
8.0 ELECTRICAL	Provide electrical power to operate systems	• AC power at circuit breaker panels/trans. • DC power at circuit breaker panels/trans.	• Torque at CSD from engine • External elect. energy • Torque from hydr. sys. • Torque from APU
9.0 HYDRAULIC	Provide hydraulic power to operate systems	• Hydraulic pressure at manifolds/actuators for: 1. L.G. sys. 2. Att. cont. 3. Lift/drag. 4. Elec power 5. Airframe	• Engine torque • Electrical power
10.0 ENVIRONMENTAL CONTROL	Control condition of external surfaces and internal environment	• A/C internal compartments at x psi, x% O_2 x% humid, x^oF • A/C external surface free of ice • Adequate illumination level provided	• Bleed air from APU/engine • Ram air from environment • Elect. power
11.0 COMMUNICATIONS	Provide information exchange	• Information (voice) received at crew/cargo stns. • Info transmitted to internal/external receivers	• Elect. energy • Received voice signals
12.0 NAVIGATIONAL	Provide aids to navigational problems	• Reference information at crew station • Radar/radio emissions to ground/air stations	• Elect. energy • Received RF signals
13.0 MAN	Performs observational, computational, and actuational activities	• Controls actuated • Calculations performed • Info exchanged	• Visual info • Audio info • Tactual info

Table 2-1 C-141A Aircraft Systems for Level 1 Functions

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT NUMBER	FUNCTIONAL UNIT NOMENCLATURE	FUNCTIONAL SYSTEM	BOUNDARIES: OUTPUT STATE	BOUNDARIES: INPUT STATE	PERFORMANCE DESCRIPTION	AID TYPE
1.1 1.1.1	DOORS/RAMPS CARGO RAMP/ PRESSURE DOOR/ PETAL DOORS	AIRFRAME	Opening clear to load and unload and Cargo compartment at ambient pressure or Opening closed and Cargo compartment pressurized	Electric power Hyd pwr from: 1. No. 3 hyd subsys 2. Hyd handpump Control actuation	Ramp/door operation required to load/ unload and airdrop cargo/paratroops. Functional unit includes all controls and indicators associated with this unit.	MDC
1.2	ELECTRICAL SERVICE	AIRFRAME	115/200 volts, 400 cps 3 phase electrical power to: 1. Crew galley 2. Cargo winch 3. Lavatory 4. Six service outlets 115 VDC electrical pwr to shaver outlet 28 VDC electrical pwr to: 1. Iron lungs 2. Pilots signal light 3. Copilots signal light 4. Avionics test receptacles 115 volts, 400 cps electrical power to Avionics test receptacles	Electrical power	This functional unit includes all controls, indicators, and circuiting to provide electrical service to support personnel comfort, cargo loading/unloading, and ground test equipment.	MDC
1.3 1.3.1	SPECIAL PURPOSE KITS GENERAL CARGO KIT	AIRFRAME	Cargo loaded and restrained for flight or Cargo released and unloaded	Electrical power Cargo	This functional unit includes all mechanisms and controls involved in general cargo loading, restraint, unloading/ airdropping; and provisioning for passenger needs during normal flight and emergency conditions.	MDC
1.3.2	AIRDROP KIT		Cargo/paratroops restrained for flight or Cargo/paratroops airdropped.	Electrical power Cargo or Paratroops		
1.3.3	TROOP KIT		Oxygen for 460 man-hours at cruise altitude and Troops restrained for flight and/or Comfort pallet in use or Life rafts deployed with survival kits	Electrical power Troops		

Table 2-2 C-141A Aircraft Functional Units
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C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
1.3.4	AEROMEDICAL KIT		Therapeutic oxygen available and/or Iron lungs in use and/or Patients restrained for flight	Electrical power Medical patients		
1.4 1.4.1 1.4.2	FUSELAGE EQUIPMENT GENERAL EQUIPMENT MISC. EQUIPMENT	AIRFRAME	Loose equipment restrained for flight and Flight crew restrained for flight and/or Galley in use and/or Lavatory in use	Electrical power Food Water Communications Special purpose kits	This functional unit includes all equipment necessary to support the flight crew during normal flight and emergency non-flight conditions.	MDC OR NONE
1.4.3	EMERGENCY EQUIPMENT		First aid kit in use or Fire extinguisher and/or smoke mask in use or Escape equipment in use or Survival equipment in use or Emergency radio transmitter in use	Emergency Conditions		
2.1	LANDING GEAR EXTENSION/ RETRACTION	LANDING GEAR	Landing gear in 1. Extended position and locked 2. Retracted position and locked	Landing gear touchdown relays closed Elec power Stall warning/prevention relays normal Hyd power 1. No. 2 hyd subsystem 2. Hyd handpump Control actuation	Include controls/indicators associated with this functional unit for all modes of operation for landing gear extension/ retraction, braking and steering.	MDC
2.2	LANDING GEAR BRAKING/ ANTI-SKID	LANDING GEAR	Differential braking force at landing gear wheels, at less than 120 rpm	Elec power Hyd power 1. No. 2 Hyd subsystem 2. No. 3 Hyd subsystem Rudder pedal movement	Normal braking operations as well as emergency (using hyd subsystem No. 3) and parking brake operations including controls and indicators.	MDC

Table 2-2 C-141A Aircraft Functional Units
(Sheet 2 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT NUMBER	FUNCTIONAL UNIT NOMENCLATURE	FUNCTIONAL SYSTEM	BOUNDARIES: OUTPUT STATE	BOUNDARIES: INPUT STATE	PERFORMANCE DESCRIPTION	AID TYPE
			Equal braking force applied to wheels at 120 rpm (A/C stable in yaw during braking)	Elec power Control actuation Hyd power Rudder pedal movement Touchdown relay closed	Anti-skid to prevent high-speed yawing during landing	
2.3	LANDING GEAR STEERING	LANDING GEAR	A/C nose gear turned ____° yaw relative to longitudinal axis	Hyd power, No. 2 hyd subsystem Steering wheel motion or Rudder pedal movement	Required to steer aircraft during taxi operations	MDC
3.1	WING FLAP	LIFT/DRAG CONTROL	Wing flaps in 1. Retracted position or 2. Extended to ____°	Elec power Hyd power, subsystem No. 3/No. 2 Control actuation or Flap asymmetry	Wing flap subsystem provided to increase aerodynamic lift when extended. Include indicators and warning devices associated with wing flap functional unit.	MDC
3.2	WING SPOILER	LIFT/DRAG CONTROL	Wing spoilers in 1. Retracted position or 2. Deployed to ____°	Elec power Hyd power, subsystem No. 2/No. 3 Control actuation or Touchdown switches closed and Throttles in reject take-off position or Spoiler asymmetry	Wing spoilers decreased lift and increase drag when deployed. Included in this functional unit are asymmetry test panel, asymmetry detection circuitry, indicators, and warning devices.	MDC
4.1	AILERON CONTROL AND TRIM	ATTITUDE CONTROL (ROLL)	Ailerons moved: 1. Up ____° 2. Down ____°	Autopilot signal Elec power Hyd power, subsystem No. 1/No. 2/No. 3 or Control wheel rotation or Servo tab movement during flight Aileron trim control switch position	The roll functional unit includes the mechanisms linking the controls and the ailerons as well as the artificial feel, aileron trim, autopilot input, and associated indicators.	MDC
			Ailerons tabs moved 1. Up ____° 2. Down ____°	Control wheel rotation Elec power Hyd power, subsystem No. 1/No. 2		

Table 2-2 C-141A Aircraft Functional Units
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C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
4.2.1	ELEVATOR CONTROL	ATTITUDE CONTROL (PITCH)	Elevators moved: 1. Up ____° 2. Down ____°	Elec Power Hyd power subsystem No. 1/No. 2/ No. 3 Control column fore and aft movements or Autopilot signal Impending stall	The pitch functional unit includes an artificial feel servomechanism, elevator computer and servo, control column shaker, limit switches, and associated indicators as well as the mach trim compensator. Show role of CADC in this functional unit as related to mach trim compensation.	MDC
4.2.2	PITCH TRIM		Horizontal stabilizer moved: 1. Up 4° 2. Down 12.5°	Elec power Hyd power subsystem No. 2 Trim control switch operation or Control lever actuation or Autopilot signal or Mach trim compensator signal		
4.2.3	MACH TRIM COMPENSATOR					
4.3	RUDDER CONTROL & TRIM	ATTITUDE CONTROL (YAW)	Rudder movement: 1. Right ____° 2. Left ____°	Elec power Hyd power subsystem No. 1/No. 2 Rudder pedal movement or Autopilot signal or Rudder pedal movement via mech. linkage alone or Rudder trim control switch operation	The yaw functional unit contains the yaw damper servos, linkage, and all associated controls and indicators.	MDC
4.4	STALL WARNING/ PREVENTION	ATTITUDE CONTROL	Control column is shaken Control column moved forward Underspeed light flashing Max speed warn horn activated	Elec power Hyd power subsystem No. 2/No. 3 Angle-of-attack vane relationship to air flow Yaw rate Mach No. Control surface positions Landing gear position	The stall warning/prevention functional unit includes all controls, indicators, limit switches associated with its operation. The CADC and autopilot's role must be included. The stall prevention computers are an integral part of this unit.	MDC

Table 2-2 C-141A Aircraft Functional Units
(Sheet 4 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
4.5	TAKE-OFF WARNING	ATTITUDE CONTROL	Aircraft in normal take-off conditions illuminates green TAKE-OFF light.	AC power available 1. Isol avionics bus 2. Isol AC bus DC power available 1. Main DC bus No. 1 2. Main DC bus No. 2 Spoilers closed and locked Thrust reverser closed and locked Flap in take-off approach position Autopilot off Cargo doors closed One hydraulic pitch trim lever button depressed and released Touchdown relay No. 9 actuated	This functional unit senses the satisfaction of the go state of various systems prior to take-off.	MDC or S
4.6	AUTOMATIC FLIGHT CONTROL SYSTEM	ATTITUDE CONTROL	Control signals to execute 1. Roll motion 2. Pitch motion 3. Yaw motion	Elec power Rate signals 1. Roll 2. Pitch 3. Yaw Manual actuation of: 1. Switches 2. Control wheel No. 1 CADC signal on: 1. Static pressure 2. Dynamic pressure Navigation signal from: 1. TACAN 2. VOR 3. Localizer 4. ASN-24 5. ASN-35 6. Pilot HSI 7. C-12 Compass, No. 1	This functional unit includes the components from the acceptance of an input signal to the servos that are part of the attitude control functional units. All controls and indicators associated with the autopilot, its checkout, or its troubleshooting are to be incorporated. Include rate gyros, CADC role, computers, warning indicators, and control panels. Note: The autopilot functional unit must include those attitude control mechanisms not a part of functional units 4.1, 4.2, 4.3, and 4.4. Interface at point where attitude control execution is independent of signal source.	MDC
5.1	ENGINE POWER	PROPULSION	Engine thrust at exhaust Engine torque at accessory drive gear box Bleed air at bleed air shutoff valve Bleed air at engine anti-icing shutoff valve Bleed air at nacelle anti-icing shutoff valve	Electrical power Starting torque to N_2 turbine Starting air Fuel Bearing lubrication Control actuation	The engine power functional unit consists of the compressor, combuster, and turbine stages and the indicators associated with its operation. It is supported by the engine fuel, starter, thrust reverser, oil, CSD and bleed air subsystems. All engine indications associated with operation included. The engine power functional unit interfaces with the engine fuel system at the fuel nozzles, the hydraulic system at the hydraulic pump gear box, the starter system at the accessory gear box, the electrical system at the CSD and circuit breaker panels, the environmental control system at the bleed air shutoff valve, the anti-icing system at the anti-icing shutoff valves, and the airframe system at mounting structure and access panels.	

Table 2-2 C-141A Aircraft Functional Units
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C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
5.2	ENGINE OIL	PROPULSION	Engine oil at engine bearings Pressurization in system	Engine oil Torque to drive oil pumps Blood air Electrical power	The engine oil functional unit includes indicators associated with operation. It also includes the breather pressure system.	
5.3	ENGINE FUEL & ENGINE CONTROL	PROPULSION	Metered fuel at engine nozzles	Fuel at nacelle shutoff valve Torque for fuel control drive Torque for fuel pumps Bleed air for fuel heating Electrical power Control actuation	The engine fuel and engine control functional unit includes the indicators and controls associated with starting, operation, and shutdown. The engine fuel system interfaces with the oil system at the fuel oil cooler, with the engine bleed air system at the fuel de-icer.	
5.4	ENGINE STARTER	PROPULSION	Starting torque to N_2 turbine Electrical power to igniters	Bleed air from APU, external source or other engine Electrical power Control actuation	The engine starter functional unit includes the indicators and controls associated with starting, operation and shutdown and also includes the ignition system. It interfaces with the engine at the accessory drive gearbox and at the igniters. It interfaces with the bleed air system at the starter control valve.	
5.5	THRUST REVERSER	PROPULSION	Directed thrust at exhaust	Electrical power CSD oil Control actuation Torque to drive thrust reverser valve	The thrust reverser functional unit includes the indicators and controls associated with its operation. It interfaces with the engine at the exhaust nozzle and at the accessory drive gearbox with the engine control system at the throttle quadrant and with the engine fuel at the fuel control.	
5.6	ENGINE HEATING & ANTI-ICING	PROPULSION	Bleed air in nacelle Bleed air in inlet fan Bleed air in nacelle cowl Electrical heating at pressure probe	Electrical power Bleed air at nacelle pre-heat shutoff valve Bleed air at engine anti-icing shutoff valve Bleed air at nacelle anti-icing shutoff valve Control actuation	The engine heating and anti-icing functional unit includes the indicators and controls associated with its operation. It interfaces with the engine at the anti-icing shutoff valves and with the bleed air system at the nacelle pre-heat shutoff valve.	
5.7	ENGINE FIRE WARNING/ EMERGENCY SHUTDOWN	PROPULSION	Fire warning light Audible fire alarm Liquid extinguisher in nacelle Fuel shutoff valve closed Zone II cooling vent closed Hydraulic system shutoff	Electrical power	The engine fire warning/emergency shutdown functional unit includes the indicators and controls with its operation. It warns the flight crew of a fire condition existing in any of the engines, and permits the flight crew to shut down, interrupt the flow of combustibles, and apply a fire extinguishing agent to the specific engine in which the fire condition exists.	

Table 2-2 C-141A Aircraft Functional Units
(Sheet 6 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
6.0	APU	APU	Air at engine starter Bleed air at bleed load control valve Torque at APU generator	Elec power - battery Hyd power subsystem No. 3 Fuel Control actuation	The APU functional unit included controls and indicators associated with starting, operation, and shutdown.	MDC
7.0	FUEL	FUEL	Fuel at engines Fuel at APU Fuel overboard	Elec power Fuel in tanks Control actuation	The fuel functional unit includes the fuel tanks with fuel quantity indicators, the fuel tank vent subsystem, the fuel jettison subsystem, the fuel boost pumps, cross feeds, and associated controls and indicators.	MDC
8.1	EXTERNAL POWER	ELECTRICAL	AC elec power, 200/115 volts, 3 phase, 400 cycles, at: 1. Main AC Bus No. 1 2. Main AC Bus No. 2 3. Main AC Bus No. 3 4. Main AC Bus No. 4 5. Main AC tie bus	External AC power at A/C receptacle at: 1. 200/115 volts 2. 3 phase 3. 400 cycles Control actuation	This functional unit includes the power selector switch, the bus protection panel, relays, circuit breakers, controls, and indicators from the external power source to the main AC buses and the main AC tie bus.	MDC
8.2	APU GENERATOR	ELECTRICAL	AC elec power, 200/115 volts, 3 phase, 400 cycles, 40/50 kva at: 1. Main AC bus No. 1 2. Main AC bus No. 4 3. Main AC tie bus	APU generator at 6000 rpm Control actuation	This functional unit includes the power selector switch, the override switches, bus protection panels circuit breakers, relays, controls, and indicators from the APU generator to the main AC tie bus.	MDC
8.3	AC GENERATOR NO. 1	ELECTRICAL	AC elec power, 200/115 volts, 3 phase, 400 cycles, 40/50 kva at: 1. Main AC bus No. 1 2. Main AC tie bus	Generator No. 1 at 6000 rpm Control actuation	This functional unit includes the CSD controls and indicators the generator controls and indicators, circuit breakers, relays, protection panels, and switches from the generator to the main AC tie bus.	MDC
8.4	AC GENERATOR NO. 2	ELECTRICAL	AC elec power, 200/115 volts, 3 phase, 400 cycles, 40/50 kva at: 1. Main AC bus No. 2 2. Main AC tie bus	Generator No. 2 at 6000 rpm Control actuation	This functional unit includes the CSD controls and indicators, the generator controls and indicators, circuit breakers, relays, protection panels, and switches from the generator to the main AC tie bus.	MDC
8.5	AC GENERATOR NO. 3	ELECTRICAL	AC elec power, 200/115 volts, 3 phase, 400 cyles, 40/50 kva at: 1. Main AC bus No. 3 2. Main AC tie bus	Generator No. 3 at 6000 rpm Control actuation	This functional unit includes the CSD controls and indicators, the generator controls and indicators, circuit breakers, relays, protection panels, and switches from the generator to the main AC tie bus.	MDC
8.6	AC GENERATOR NO. 4	ELECTRICAL	AC elec power, 200/115 volts, 3 phase, 400 cycles, 40/50 kva at: 1. Main AC bus No. 4 2. Main AC tie bus	Generator No. 4 at 6000 rpm Control actuation	This functional unit includes the CSD controls and indicators, the generator controls and indicators, circuit breakers, relays, protection panels, and switches from the generator to the main AC tie bus.	MDC
8.7	AC DISTRIBUTION	ELECTRICAL	AC elec power, ______ volts, ______ phase, ______ cycles at: 1. Circuit breaker panels 2. Transformer/rectifiers	AC elec power at the main AC tie bus 1. 200/115 volts 2. 3 phase 3. 400 cycles	This functional unit includes the AC essential buses, AC avionics buses, AC isol buses, emer AC buses, AC navigation buses, input to circuit breaker panels and transformers, and control and indicators associated with AC power distribution.	MDC

Table 2-2 C-141A Aircraft Functional Units
(Sheet 7 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
8.8	EMERGENCY GENERATOR	ELECTRICAL	AC elec power, 200/115 volts, 3 phase, 400 cycles, 2 kva at: 1. Emer AC bus 2. Isol AC buses 3. Isol AC avionics bus DC elec power, ______ volts, ______ amps at: 1. Emer DC bus 2. Isol DC bus 3. Isol DC avionics bus	Hyd power at emer generator hydraulic motor, hyd subsystem No. 2 Emer generator at 12,000 rpm Control actuation	This functional unit includes the emergency general load reduction switch, relays and circuit breakers between the essential AC bus No. 1 and the isol AC bus and between the main DC bus No. 1 and the isol DC bus, and controls, and indicators for the emergency circuit as well as the emergency generator and hydraulic motor driving it. Show battery in this functional unit.	MDC
8.9	DC DISTRIBUTION	ELECTRICAL	DC elec power at circuit breaker panels: 1. 28 volts 2. ______ amps	AC elec power at transformer/rectifier: 1. ______ volts 2. ______ amps 3. ______ cycles or 24 vdc battery power at 1. Isol DC buses 2. Emer DC bus or DC elec power, ______ volts, ______ amps at: 1. Isol DC buses 2. Isol DC avionic bus 3. Emer DC bus from emer generator	Included in this functional unit are the main DC buses, main DC avionics buses, isol DC avionics buses, isol DC buses, emer DC bus, circuit breakers, relays, transformer/rectifiers, controls and indicators. Note that the alternate inputs do not exercise the entire DC circuitry; however, it must be shown here and those active elements repeated under functional unit 8.7 that pertain to the emer mode. The battery may be repeated here.	MDC
9.1	NO. 1 HYDRAULIC	HYDRAULIC	Hydraulic pressure of 2950/3000 psi Hydraulic flow rate of 0/26 gpm at: 1. Aileron actuator 2. Rudder actuator 3. Elevator actuator	Torque from No. 3 and No. 4 engines at accessory gear box Hydraulic fluid Elec power at suction boost pump Control actuation	This functional unit includes the pumps, reservoirs, valves, relays, circuit breaker panels, controls, indicators, and lines between the engine driven pumps and the using functional unit.	MDC
9.2	NO. 2 HYDRAULIC	HYDRAULIC	Hydraulic pressure of 2950/3000 psi Hydraulic flow rate of 0/26 gpm at: 1. Aileron actuator 2. Rudder actuator 3. Elevator actuator 4. Emer gen motor 5. Flap drive motor 6. Spoiler actuator 7. Pitch trim motor 8. Landing gear functional unit	Torque from No. 1 and No. 2 engines at accessory gear box Hydraulic fluid Elec power at suction boost pump Control actuation	This functional unit includes the pumps, reservoirs, valves, relays, circuit breaker panels, controls, indicators, and lines between the engine driven pumps and the using functional unit. Interconnect valves define the interface between No. 2 and No. 3 hydraulic functional units.	MDC

Table 2-2 C-141A Aircraft Functional Units
(Sheet 8 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
9.3	NO. 3 HYDRAULIC	HYDRAULIC	Hydraulic pressure of 3000 psi Hydraulic flow rate of 0/26 gpm at: 1. Spoiler actuator 2. Spoiler cable servo 3. Flap drive motor 4. Elevator emer actuator 5. Aileron tab lockout 6. Emerg brakes 7. APU starter motor 8. Cargo door actuators 9. Ramp actuators 10. Pedal door actuators 11. Control column pusher 2 - 400 cubic inch accumulators charged to 3000 psi	Elec power to (2) elec driven hyd pumps Hydraulic fluid Control actuation	This functional unit includes the pumps, reservoirs, valves, relays, circuit breaker panels, controls, indicators, and lines between the electrically driven pumps and the using functional unit. Interconnect valves define the interface between No. 2 and No. 3 hydraulic functional units, to permit the pressurization of either hydraulic system from the others.	MDC
10.1	BLEED AIR SUBSYSTEM	ENVIRONMENTAL CONTROL	Bleed air at ______°F and ______ psia at 1. Engine Bleed Air S.O. Valve a) No. 1 b) No. 2 c) No. 3 d) No. 4 2. Anti-ice module valve 3. Cargo floor heat mod & S.O. Valve 4. Jet pump press reg. 5. Air condition flow control & S.O. Valve 6. Rain removal press reg & S.O. Valve (2) 7. Overboard downstream of ejector S.O. Valve (2)	Bleed air @ ______°F and ______ psia at: 1. Engine Bleed Air S.O. Valve a) No. 1 b) No. 2 c) No. 3 d) No. 4 2. APU Bleed Air Check Valve 3. Ground Test Connection Check Valve	The Bleed air functional unit includes pressure transmitters, indicators, restrictors, check valves, control valves, and ducting to supply air pressure to the engine starter subsystems and environmental control system. The source of bleed air before engines are started is either the APU or a ground source. After engines are started, the source is the engine.	MDC
10.2	AIR CONDITIONING/ PRESSURIZATION	ENVIRONMENTAL CONTROL	Aircraft compartments at: 1. 11.8 psi 2. ______ % humidity 3. ______ °F	Air via ram air duct at: 1. ______ °F 2. ______ psi 3. ______ % humidity Air via bleed air duct at: 1. ______ °F 2. ______ psi 3. ______ % humidity Elec power at circuit breaker panel Signal from CADC on pressure of atmosphere Control actuation	This functional unit includes the heat exchangers, valves, sensors, relays, circuit breakers, filters, refrigeration units, water separators, switches, and other controls and indicators appropriate to interior conditioning and pressurization. The ram air ventilation subsystem, cargo floor heat subsystem, cooling fans, and cabin pressurization subsystems, are integral elements of the environmental control of the aircraft interior. Interfaces exist with the bleed air subsystem and APU air conditioning pressure regulator valves, cargo floor heat modulating/shutoff valves; with elec subsystem at circuit breaker panels; and with the external environment through press release valves, air inlets, and door/window seals.	MDC

Table 2-2 C-141A Aircraft Functional Units
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C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
10.2.1	CARGO COMPARTMENT SMOKE DETECT SYSTEM	DISCONDITIONING/ PRESSURIZATION	Aircraft compartment at less than ______ particles per m^3 air	Warning lights on: 1. Flight engineer panel off 2. Ammunition panel off	This warning system includes five detectors, circuitry, amplifier, test selector switch, and warning lights at flight engineer panel and ammunition panel.	MDC
10.3	CREW OXYGEN SUPPLY	ENVIRONMENTAL CONTROL	Air with ______% oxygen at crew station	Elec power at circuit breaker panel Liquid oxygen Control actuation	The crew oxygen supply functional unit includes all elements from oxygen source to crew station outlet such as heat exchanger, vents, check valves, regulators, probes, controls, and indicators.	MDC
10.4	TROOP OXYGEN SUPPLY	ENVIRONMENTAL CONTROL	Air with ______% oxygen at troop station	Elec power at circuit breaker panel Liquid oxygen Control actuation	The troop oxygen supply functional unit includes all elements from oxygen source to crew station outlet such as heat exchanger, vents, check valves, regulators, probes, controls, and indicators.	MDC
10.5	ANTI-ICING/RAIN REMOVAL	ENVIRONMENTAL CONTROL	External surfaces free of ice Fuel free of ice Windshield free of ice/rain/fog Ram air pressure probes free of ice Angle-of-attack vanes free of ice	Bleed air on: 1. Anti-ice mod valve 2. Rain removal pressure regulator Elec power at circuit breaker panel Control actuation	The anti-icing/rain removal functional unit includes wing leading edge, and empennage ice detection and removal elements such as valves, servos, relays, heaters, regulators, sensors, switches, and indicators. The rain removal subsystem uses regulated bleed air and included in this functional unit. Interfaces between the bleed air subsystem are at the anti-ice module valve and rain removal pressure regulator where bleed air is unique to anti-icing/rain removal.	MDC
10.6	INTERIOR ILLUMINATION /LIGHTING	ENVIRONMENTAL CONTROL	Cargo compartments illuminated to ______ lumens Crew stations illuminated to ______ lumens Indicators/panels illuminated to ______ lumens	Elec power at circuit breaker panels Control actuation	Interior illumination (lighting) includes the wheel well lights, area lights, door lights, panel lighting and dimming, circuits, relays, circuit breakers, and controls. The primary interface is with the elec system at circuit breaker panels.	S
10.7	EXTERIOR ILLUMINATION /LIGHTING	ENVIRONMENTAL CONTROL	Wheel wells illuminated to ______ lumens Frontal area illuminated to ______ lumens at ______ feet Aircraft lighted for: 1. Navigation 2. Anti-collision 3. Formation	Elec power at circuit breaker panels Control actuation	This functional unit includes the controls, indicators, relays, circuit breakers, fixtures, bulbs, and wiring associated with navigation lights, anti-collision lights, running lights, taxi lights, and landing lights.	S

Table 2-2 C-141A Aircraft Functional Units
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C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
11.1	INTERPHONE	COMMUNICATIONS	Voice information at any crew member (RCU) RF signal at any crew member (non-voice) RF signal at radio transmitter	Voice from any crew member Input from 1. Public address 2. Marker beacon receiver 3. TACAN receiver 4. VHF nav receiver 5. ADF receiver 6. All radio receivers Elec power at circuit breaker panel (CBP) Control actuation	Crew voice intercommunications, the functional unit includes the controls, indicators, circuit breakers, and wiring as well as the jacks associated with interphone and intercommunications.	MDC
11.2	PUBLIC ADDRESS	COMMUNICATIONS	Information at cargo area	Voice from any crew member Control actuation Elec power at CBP	One-way communications to cargo area. This functional unit includes speakers, circuitry, controls, and indicators.	MDC
11.3	HF COMMUNICATION	COMMUNICATIONS	Voice information at any crew member Voice information to radio transmitter	Voice information from source external to A/C Control actuation Elec power at CBP	Two-way voice-communication 100-2500 miles, this functional unit includes transmitter receiver, antenna, controls, and indicators. There are two of these systems.	MDC
11.4	VHF COMMUNICATION	COMMUNICATIONS	Voice information at any crew member Voice information to radio transmitter	Voice information from source external to A/C Control actuation Elec power at CBP	Two-way voice communication line-of-sight, this functional unit includes transmitter receiver, antenna, controls, and indicators. There are two of these systems.	MDC
11.5	UHF COMMUNICATION	COMMUNICATIONS	Voice information at any crew member Voice information to radio transmitter	Voice information from source external to A/C Control actuation Elec power at CBP	Two-way voice communication line-of-sight, this functional unit includes transmitter, receiver, antenna, controls, and indicators. There are two of these systems.	MDC
11.6	FLIGHT DATA RECORDER	COMMUNICATIONS	Record of four in-flight parameters	Elec power at CBP A/C heading info from No. 1 C-12 compass Pitot pressure Vertical acceleration, -3G to +6G Static pressure	Provide record of aircraft parameters	P
11.7	TROOP JUMP LIGHT SYSTEM	COMMUNICATIONS	Lights on at: 1. Loadmaster jump master's panel 2. Navigator's panel 3. Pilot's side console	DC elec power at CB panel (flight engineer No. 4) AC elec power at 28 VAC and 9 VAC bus Control actuation	This functional unit communicates the jump status of the paratroop onboard the aircraft via a system of lights.	MDC

Table 2-2 C-141A Aircraft Functional Units
(Sheet 11 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT NUMBER	FUNCTIONAL UNIT NOMENCLATURE	FUNCTIONAL SYSTEM	BOUNDARIES: OUTPUT STATE	BOUNDARIES: INPUT STATE	PERFORMANCE DESCRIPTION	AID TYPE
11.8	IFF RADAR AN/APX-64	COMMUNICATIONS	Coded signal of given frequency at interrogating facility on A/C identification RF signal at interrogating station of A/C altitude	Elec power at circuit breaker panel Coded interrogation signal from A/C, ship, ground transmitter	Transmitters A/C ID and alt, line of sight capability, this functional unit includes transmitter, receiver, encoder, decoder, antenna, controls, indicators, and circuit breakers	MDC
11.9	CRASH POSITION INDICATOR	COMMUNICATIONS	RF distress signal	Fracture of frangible switch or Manual switch actuation Deployment from aircraft (to transmitter) Trickle charge (elec) to self contained battery (while onboard)	The CPI includes the release mechanism, test circuit, and associated test controls and indicators as well as the batteries.	P
11.10	STATIC DISCHARGE	COMMUNICATIONS	Static electricity dissipated into atmosphere	Static electricity from the airframe	The static discharge functional unit is comprised of all circuitry between equipment ground connections, airframe bonding, and the static dischargers. This functional unit permits the discharge of static electricity which otherwise would effect radio frequency reception.	S-C
12.1	RADAR ALTIMETER	NAVIGATION, ALTITUDE	Radar pulse of transmitter Altitude signal at indicator	Reflected signal from ground at antenna Elec power at circuit breaker panel Control actuation	This functional unit provides information on A/C alt, above ground, 0-5000' range. It includes transmitter, receiver circuit breakers, controls, displays, antennas, and indicators.	MDC
12.2	GLIDESLOPE	NAVIGATION, ALTITUDE	Vertical displacement signal to: 1. FDS computer 2. ADI	Elec power at circuit breaker panel LOC frequency emission from runway transmitter Control actuation Signal from VHF navigation in localizer mode	This functional unit when used with VHF nav. not only gives vertical displacement around angle of glide, 15 miles range, but lateral displacement as well. There are two of these systems. The VHF nav functional units should be combined with these units for troubleshooting.	MDC
12.3	VHF NAVIGATION	NAVIGATION, DIRECTION	VOR (VHF Omnirange Info) at BDHI Localizer info at receiver for ILS landing 1. Glideslope Indicator 2. Autopilot	VHF signal from VOR station at antenna LOC signal from LOC station at antenna Elec power at circuit breaker panel Control actuation	This functional unit is to receive VOR info and localize LOC info at 45 and 200 mile ranges, and includes antennas, receivers, controls, indicators, and associated elements. The VOR/ILS mode of the VHF nav functional unit should be troubleshot along with the glideslope. There are two of these systems.	MDC
12.4	ADF RADIO	NAVIGATION, DIRECTION	Voice/code info to: 1. Intercom 2. Public address Bearing info on BDHI	Elec power at circuit breaker panel 190-1750 kc signal at antenna from ground transmitter Control actuation	This functional unit is to receive voice/code homing/bearing info, 20-200 mile range, and provided info on the relative bearing between the A/C and transmitter ground at an audio output or the BDHI. It includes receiver, sense antenna, loop antenna, antenna coupler, quadrantal error corrector, transmission lines, controls, and indicators. There are two of these systems.	MDC

Table 2-2 C-141A Aircraft Functional Units (Sheet 12 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
12.5	COMPASS, C-12	NAVIGATION, DIRECTION	Directional reference info at: 1. HSI 2. BDHI 3. Tacan 4. VHF nav 5. Autopilot 6. Nav Comp 7. Dop radar 8. Flight recorder 9. Search radar	Magnetic field, or Directional gyro Elec power at circuit breaker panel	This functional unit provides directional info on 360° azimuth. It includes magnetic azimuth detector, remote, magnetic compensator, directional gyro, digital controller, power supply, and amplifier as well as controls and indicators.	MDC
12.6	TACAN	NAVIGATION, LOCATION	Bearing, course displacement, distance info at: 1. Autopilot 2. BDHI 3. HSI 4. FD Computer 5. Nav Computer	RF signal from selected ground transmitters Elec power at circuit breaker panel Control actuation Directional reference from C-12 compass	This functional unit is to receive and display bearing/distance info, up to 195 miles range, line-of-sight. It includes receiver, transmitter, coupler antenna, antenna selector, switches, indicators, and associated circuitry.	MDC
12.7	LORAN	NAVIGATION, LOCATION	Digital readout of time differences of RF signals at LORAN receiver panel Visual display on oscilloscope of LORAN waveform	Elec power at circuit breaker panel Control actuation RF signal at antenna from landbased transmitter	This functional unit receives and processes signals to determine geographic position of A/C, 2500 miles range. It includes receiver, power supply, antenna, antenna coupler, interlock relay, panel, controls, and indicators. Note that operation of malfunctioning high frequency transmitters may give indication of malfunction in LORAN functional unit.	MDC
12.8	MARKER BEACON	NAVIGATION, LOCATION	Audio signal at interphone (400 cps to 3000 cps) Visual signal at flight station by lights	75 mc AM signal from ground transmitter at antenna of A/C Elec power at circuit breaker panel Control actuation	This functional unit includes the receiver, antenna, light assembly and switch. It is used for navigation where the A/C flies a directional RF beam.	MDC
12.9	NAVIGATIONAL COMPUTER	NAVIGATION, LOCATION	A/C position Remaining distance Crosstrack deviation distance at: 1. Autopilot 2. HSI 3. ADI Direct readouts: 1. Distance to go 2. Distance crosstrack 3. Range/bearing of destination 4. Declination/altitude/azimuth of 57 stars	Magnetic Heading True airspeed (CADC) Doppler drift X Doppler ground speed Distance to station, TACAN Elec power at circuit breaker panel Control actuation	This functional unit is essentially a general purpose serial digital computer. It consists of the computer, power supply, computer controls, latitude-longitude controls and indicators range-bearing controls and indicators, along track-crosstrack controls and indicators, Celestial data controls and indicators, initial conditions controls and indicators, mode control, selector controls, and test elements.	MDC

Table 2-2 C-141A Aircraft Functional Units
(Sheet 13 of 15)

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C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
12.10	SEARCH RADAR	NAVIGATION, RANGE	Radar pulse emissions at antenna Visual cues of weather and surface features at radar screen Azimuth-range of observed feature at flight station indicators	Elec power at circuit breaker panel Reflected signals from targets at antenna Control actuation or RACON signals from ground beacon Directional reference from C-12 compass	The search radar functional unit receives and displays info on weather, surface and features, 3-240 miles range. The functional unit includes the radar pressurization subsystem, receiver/transmitter/antenna, stabilization data generator electronic control amplifier, sync control, synchronizer, az/range indicator, power supply, venturi fan, marker generator, antenna and generator control, and associated controls, relays circuit breakers, and indicators.	MDC
12.11	DOPPLER COMPUTER	NAVIGATION, RANGE	Distance-to-go info at control indicator Cross track deviation info at cross-track indicator Distance crosstrack at control indicator Track angle error at HSI	Track angle info from doppler radar Ground speed info from doppler radar Directional reference from C-12 compass Elec power at circuit breaker panel Control actuation	This functional unit is close associated with the doppler radar and is dependent upon its operation. The doppler computer functional unit includes computer, control indicator, test switch, controls, and indicators.	MDC
12.12	DOPPLER RADAR	NAVIGATION, SPEED	Radar signal (to ground) at antenna Drift angle info at: 1. Doppler radar indicator 2. Doppler computer 3. Navigation computer Ground speed info at: 1. Doppler radar indicator 2. Doppler computer 3. Navigation computer 4. C-12 compass	Elec power at circuit breaker panel Control actuation Reflected radar pulse from ground	The Doppler radar functional unit consists of transceiver, antenna, waveguides, frequency tracker, control panels, adapters, and associated electronic elements. The doppler radar and doppler computer should be considered together in one troubleshooting unit.	MDC
12.13	FLIGHT DIRECTOR SYSTEM	NAVIGATION	Info displayed on HSI 1. Heading 2. Distance 3. Course Deviation 4. Bearing or track angle error 5. Ambiguity 6. Signal/power failure warning Info displayed on ADI 1. Glideslope deviation 2. A/C rate-of-turn 3. Turn coordination 4. Roll attitude 5. Pitch attitude 6. Lateral computed guidance 7. Vertical computed guidance 8. Signal/power failure warning	Electrical power at avionics circuit breaker panel Control activation Signals from: 1. C-12 compass 2. Tacan 3. VOR/ILS (VHF Nav) 4. Glideslope 5. ASN-35 6. ASN-24	The flight direction functional unit consists of a FDS computer, nav selector panels, attitude gyros, rate gyros, and associated elements. The ADI and HSI must be integrated into this unit as indicators of the processed information. There are two FDS systems on the aircraft.	MDC

Table 2-2 C-141A Aircraft Functional Units
(Sheet 14 of 15)

C-141A AIRCRAFT FUNCTIONAL UNITS

FUNCTIONAL UNIT		FUNCTIONAL SYSTEM	BOUNDARIES		PERFORMANCE DESCRIPTION	AID TYPE
NUMBER	NOMENCLATURE		OUTPUT STATE	INPUT STATE		
12.14	PITOT STATIC	NAVIGATION, (SPEED ALTITUDE)	Indicated altitude on: 1. Engineers altimeter 2. Navigators altimeter Pitot and static pressure at: 1. Flight data recorder 2. CADC No. 1 and No. 2	Static press at static inlet Dynamic press at pitot inlet Electrical power	The pitot-static functional unit includes the pitot-static sensors, plumbing, and pitot-static de-icing circuitry.	MDC
12.15	TOTAL TEMPERATURE	NAVIGATION, SPEED	Total temp indications: 1. Pilot's indicator 2. Flight engineer indicator 3. CADC No. 1 and No. 2	Elec power at CB panel Ambient temperature Raw temperature	The total temperature system includes the probe de-ice circuits. There are two identical total air temperature systems.	MDC
12.16	VERTICAL NAVIGATION	NAVIGATION	CADC FDS Autopilot	ASN 35 computer Radar altitude ASN 24 Go around computer CADC Elec @ Control		
13.0	CADC	CENTRAL AIR DATA COMPUTER (CADC)	Synchro signal or AC voltage at instruments representing: 1. True air speed 2. Indicated air speed 3. Mach no. 4. Pressure altitude 5. Vertical speed	Pitot-static 1. Total pressure 2. Static pressure Total temperature Elec power at circuit breaker panels	The Central Air Data Computer (No. 1 and No. 2) input or output should appear in each functional unit for which it is a requirement inasmuch as the troubleshooting of that unit is involved. The instruments on which CADC processed data are displayed are a part of this functional unit. They include Include Nav's TAS indicator, altitude vertical velocity and AS-Mach indicator. The Pitot static and the temperature sensing components provide inputs to the CADC functional unit. Total temperature probe is used to support CADC as well as a separate indicator. The overspeed warning circuits are to be included here as well as safe speed computer.	

Table 2-2 C-141A Aircraft Functional Units
(Sheet 15 of 15)

Functional Units. The functional unit, a hardware system or subsystem, is given a number and a name in the first two columns. The first numeral refers to the system and the second to the subsystem. A third number should identify multiple segments within a subsystem if additional breakdown is required. The "parent" system is listed in the third column. The fourth and fifth columns give state information regarding each functional unit to help bound it as well as to provide interface information. The column designated Performance Description gives a brief summation of the need for, and the elements comprising, the functional unit. All functional units must be treated as closed-loop systems where all inputs and outputs are considered. The last column, Aid Type, lists a recommendation for the type of troubleshooting aid to treat the hardware grouping that is described. Abbreviations used in this column are: MDC - Maintenance Dependency Chart; S - Schematic Diagram; P - Narrative Procedure; and S-C - Symptom Cause Diagram. Additional analysis, as outlined in Section III, is required to confirm these recommendations. It should be noted that all aircraft components are not included in this tabulation. Those that are not listed are considered as posing little difficulty in troubleshooting so that existing methods of malfunction isolation may be adequate. Any indications to the contrary should be observed during the actual development of troubleshooting aids.

The functional units described in Table 2-2 are presented in the form of a matrix in Figure 2-4, Functional Unit Interface Matrix. These functional units are at the system and subsystem level; therefore, they represent hardware that implements Level I and II functions. This matrix indicates that a dependency exists between the functional units intersecting at a cell which has a dot entry. Table 2-2 in concert with the matrix should permit the analysts to determine the boundaries of most aircraft equipment groupings.

Some of the functional units contained in Table 2-2 may require further segmentation during the troubleshooting aid development process. It is also probable that during the course of developing aids, that revisions to the nomenclature originally used will be recommended. Additional

	CARGO RMP, PRESS DR, PETAL DR	LANDING GEAR	WING FLAP	WING SPOILER	ROLL	PITCH	YAW	STALL WARN/PREVENTION	AUTOPILOT	POWER PLANT	APU	FUEL	AC GENERATOR NO. 1	AC GENERATOR NO. 2	AC GENERATOR NO. 3	AC GENERATOR NO. 4	APU GENERATOR	EXTERNAL POWER	EMERGENCY GENERATOR	AC DISTRIBUTION	DC DISTRIBUTION	NO. 1 HYDRAULIC	NO. 2 HYDRAULIC	NO. 3 HYDRAULIC	AIR COND/PRESSURIZATION	CREW OXYGEN SUPPLY	TROOP OXYGEN SUPPLY	ANTI-ICING/RAIN REMOVAL	INTERIOR ILLUM./LIGHTING	EXTERIOR ILLUM./LIGHTING	INTERPHONE	PUBLIC ADDRESS	HF COMMUNICATION	VHF COMMUNICATION	UHF COMMUNICATION	FLIGHT DATA RECORDER	IFF RADAR AN/APX-46	IFF RADAR AN/APX-64	CRASH POSITION INDICATOR	STATIC DISCHARGE	RADAR ALTIMETER	GLIDESCO	
CARGO RMP, PRESS DR, PETAL DR																					●			●																			
LANDING GEAR		●		●				●													●		●	●																			
WING FLAP			●																	●	●		●	●																			
WING SPOILER		●		●																●	●		●	●																			
ROLL					●				●											●	●	●	●	●																			
PITCH						●	●	●	●											●	●	●	●	●																			
YAW						●	●	●	●											●	●	●	●																				
STALL WARN/PREVENTION		●				●	●	●	●											●	●		●	●																			
AUTOPILOT					●	●	●	●	●											●	●																					●	●
POWER PLANT										●	●	●	●	●	●	●				●	●	●	●	●	●			●															
APU										●	●	●					●			●	●			●	●			●															
FUEL										●	●	●								●	●																						
AC GENERATOR NO. 1										●			●							●																							
AC GENERATOR NO. 2										●				●						●																							
AC GENERATOR NO. 3										●					●					●																							
AC GENERATOR NO. 4										●						●				●																							
APU GENERATOR											●						●			●	●																						
EXTERNAL POWER																		●		●																							
EMERGENCY GENERATOR																			●	●	●		●																				
AC DISTRIBUTION			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●		●		●	●			●		●
DC DISTRIBUTION	●	●	●	●	●	●	●	●	●	●	●	●					●		●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●
NO. 1 HYDRAULIC					●	●	●			●										●	●	●																					
NO. 2 HYDRAULIC		●	●	●	●	●	●	●		●									●	●	●		●	●																			
NO. 3 HYDRAULIC	●	●	●	●	●	●		●		●	●									●	●		●	●																			
AIR COND/PRESSURIZATION										●	●									●	●				●			●															
CREW OXYGEN SUPPLY																				●						●																	
TROOP OXYGEN SUPPLY																				●	●						●																
ANTI-ICING/RAIN REMOVAL										●	●									●	●				●			●															
INTERIOR ILLUM./LIGHTING																				●	●								●														
EXTERIOR ILLUM./LIGHTING																				●	●									●													
INTERPHONE																					●										●	●	●	●	●								●
PUBLIC ADDRESS																					●										●	●											
HF COMMUNICATION																				●	●										●		●										
VHF COMMUNICATION																					●										●			●									
UHF COMMUNICATION																				●	●										●				●								
FLIGHT DATA RECORDER																					●															●							
IFF RADAR AN/APX-46																				●	●																●						
IFF RADAR AN/APX-64																				●	●																	●					
CRASH POSITION INDICATOR																					●																		●				
STATIC DISCHARGE																																								●			
RADAR ALTIMETER																				●	●																				●		
GLIDESCOPE									●												●																					●	●
VHF NAVIGATION									●											●	●										●											●	●
ADF RADIO																				●	●										●	●											
COMPASS, C-12									●											●																●							●
TACAN									●											●	●										●												
LORAN																				●	●																						
MARKER BEACON																					●										●												
NAVIGATIONAL COMPUTER									●											●	●																						
SEARCH RADAR																				●	●																						
DOPPLER COMPUTER									●											●	●																						
DOPPLER RADAR																				●	●																						
CADC					●	●	●	●	●											●	●				●											●							
FLIGHT DIRECTOR SYS																				●	●																					●	●

Figure 2-4 Funct

A

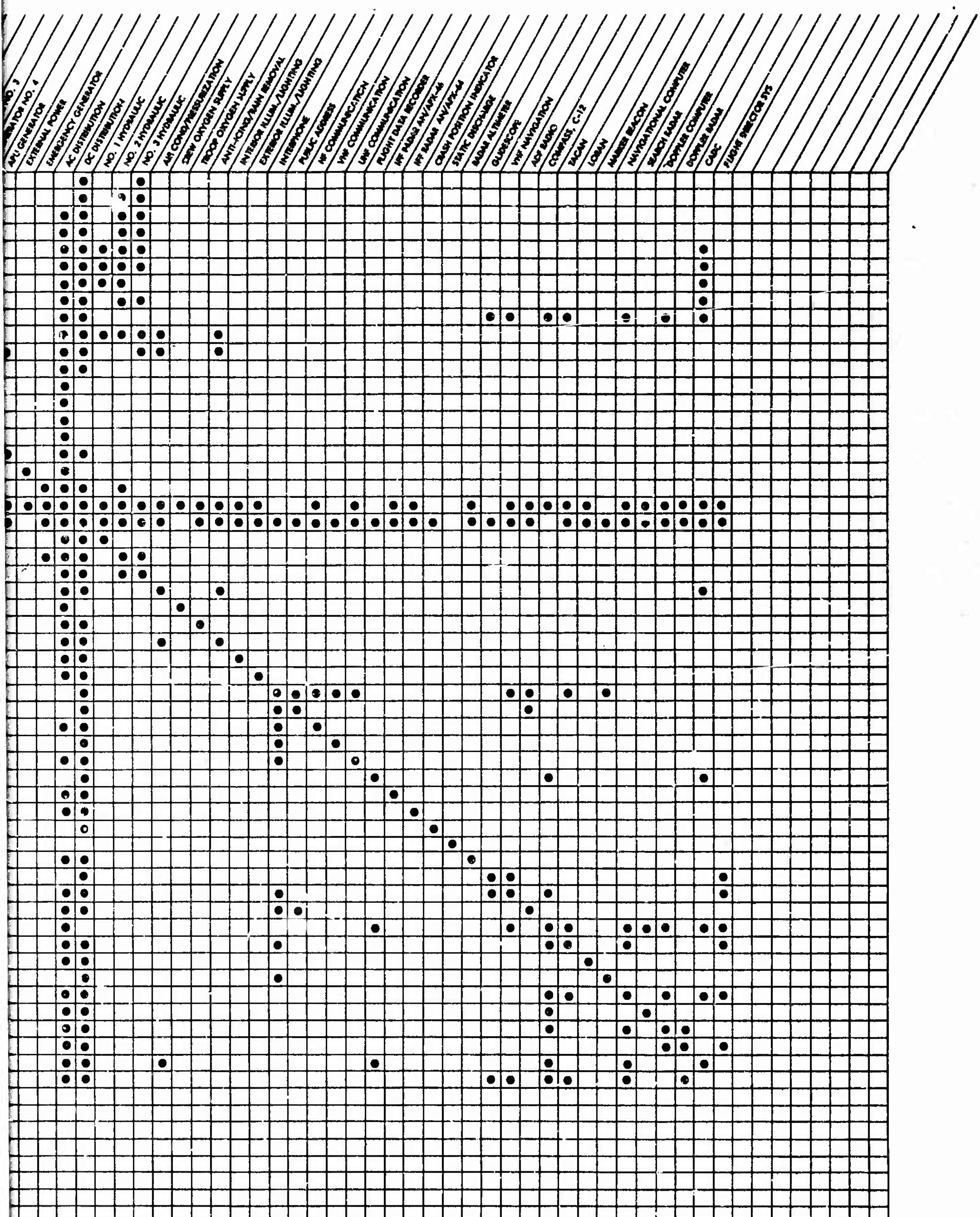


Figure 2-4 Functional Unit Interface Matrix

B

hardware groupings may be discovered that should be covered by troubleshooting aids. Iteration is common in activities of this type. Ideas to improve the partitions presented may be discovered by participating personnel.

Any changes or additions should conform to the same criteria used in the original partitioning process. Discovery of supplemental criteria or a ranking of the existing criteria during aid development should be reported and should be incorporated into the over-all guide.

The following procedures are recommended to be followed so that innovations and improvements can be recognized and incorporated uniformly into the troubleshooting aid set by all personnel. The originator of the recommended change should document the recommendation by:

- Example.
- Written explanation.

The originator should then present the recommendation to his supervisor who is to:

- Review the proposal.
- Add any pertinent comments.
- Inform affected personnel of the change (if accepted).

SECTION III

DEVELOPMENT OF TROUBLESHOOTING AIDS

A. GENERAL

This section consists of a discussion of some practical considerations and specific guidelines for the development of adequate troubleshooting aids. Adequacy is defined in terms of the criteria imposed upon the development of each portion of the troubleshooting aid, and is presented in the discussion of each step in the development procedure. The terms "system" and "functional unit" will both be used to mean the same level of system partition throughout this discussion.

B. CONSIDERATIONS FOR TROUBLESHOOTING AID DEVELOPMENT

The over-all consideration for any maintenance aid is the intent of such an aid. In the case of the troubleshooting aid, the intent is to provide the technician with the information necessary to isolate the cause of a malfunction with the highest degree of accuracy in the shortest time, and with minimum effort. Consequently, both the person generating the troubleshooting aid and the technician using it should be aware of the following considerations:

1. Considerations for Troubleshooting Aid Development

a. Troubleshooting is the name given to the activity concerned with identifying the specific cause of a system malfunction. The specific troubleshooting actions to be performed depend upon the malfunction symptom, but always within the context of all the interrelated parts that work together to perform the system function that has failed.

b. Symptom is the name given to the indication that some part in the system has malfunctioned, or has failed to perform properly a system function.

c. It is possible for a malfunction to occur with no symptom directly observed, or with the symptom observed in the function of some associated system. That is, a pump failure in the hydraulic system may not be observed as a hydraulic system malfunction, but as a flight control malfunction due to a requirement to exert excessive force on the control wheel.

d. In order to localize and isolate the defective part, the malfunctioning system should be operated to verify the performance of all interrelated parts associated with the symptom. Exceptions to system operation would be when a danger to other system parts may result from additional system operation, or where the symptom-cause relationship is plainly evident. It is necessary to specifically identify these exceptions for the troubleshooter.

e. Some symptoms may be observed only during system operation in a specific environment or under specific conditions. That is, an engine may always function properly at 10,000 feet, but may malfunction at 30,000 feet, or it may perform properly at all throttle settings except full thrust.

f. It may be difficult or impossible to duplicate exactly the environment in which the malfunction was observed, assuming that the characteristics of the environment were reported with the malfunction. The functional characteristics of each part in the system must be adequately described to allow the technician to infer the cause of the malfunction, or the environmental symptom-cause relationship must be specifically identified.

2. <u>Requirements of a Troubleshooting Aid</u>

In general, the troubleshooting aid must be capable of responding to the preceding considerations, which will largely be the result of how the person generating the aid interprets these considerations in relation to the system, or functional unit, for which he is responsible. More specifically, the troubleshooting aid should meet the following requirements:

a. Provide system definition by identifying the interface boundaries relative to associated systems, and by identifying the interrelationship of all parts within the system that are required to effect system performance.

b. State the preliminary condition of the system necessary to verify the symptom by identifying set-up requirements for the malfunctioning and associated systems.

c. State the relationship of symptom to all possible causes by identifying the functional interrelationships of parts involved in producing the indication of malfunction.

d. Identify the location of all parts in the system to facilitate isolation of suspect parts.

e. Provide a functional description of the system and each part in the system to identify the specific performance characteristics of each part.

Different configurations of the same system must meet the above requirements relative to the differences of interrelated parts and their specific performance characteristics.

3. Required Capabilities of Troubleshooting Aid Generator

The person assigned the responsibility for developing an adequate troubleshooting aid must be able to meet the requirements of the aid considering the characteristics of the troubleshooting activity previously identified. Most important is his ability to recognize and identify functional relationships of parts within systems, and systems within systems. Next in importance is his knowledge of the subject matter of the system for which he is responsible. He must be familiar with the structure, function, and schematic symbolizing of the parts, and be capable of performing signal flow or circuit analysis of the system in order to specify the functional relationships and effect on system output resulting from failure of the parts. Finally, he must be capable of documenting the results of his analysis so that it can serve as a troubleshooting aid.

The remainder of this section describes the procedure for the troubleshooting aid generator to follow in order to meet the aid requirements, and provides him with appropriate documentation criteria.

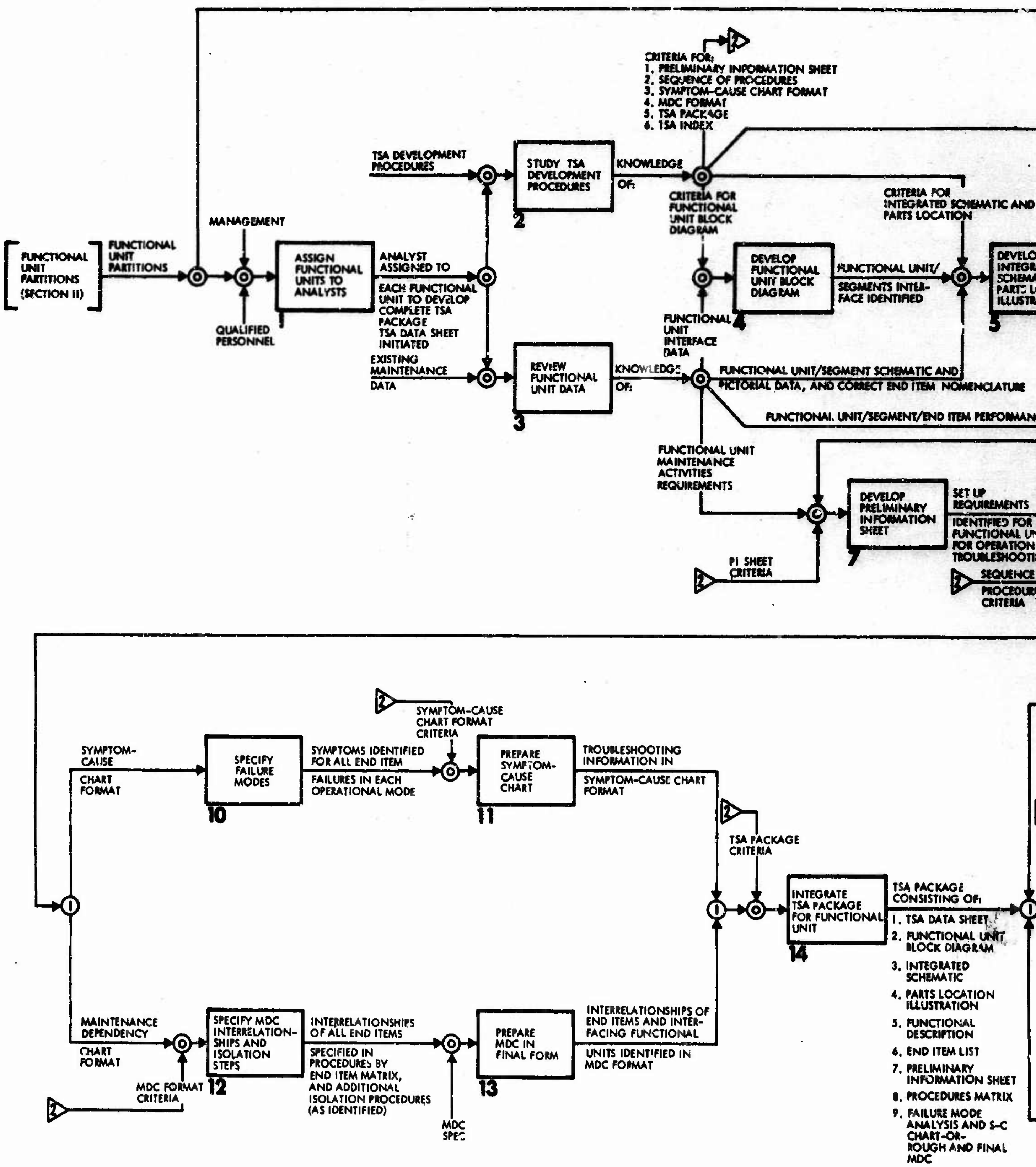
C. DEVELOPMENT OF TROUBLESHOOTING AIDS FOR AN EXTANT SYSTEM

The following discussion describes the use of source data and documentation criteria during development of the troubleshooting aid, and the role of management in controlling aid development. Steps in developing the aid are presented as numbered activities keyed to Figure 3-1, which describes the troubleshooting aid development approach. The sequence of performance is critical in that each activity utilizes information developed in a preceding activity. Other activities which are not part of troubleshooting aid development, but which are critical to updating and publishing are briefly discussed. It should also be noted that the outputs of Activities 6 and 8 are of value to the formatting of all maintenance activities in addition to troubleshooting.

1. Assign Functional Units to Analysts

The development of a troubleshooting aid begins with a recognized requirement to generate an aid for a functional unit identified as a result of the partitioning effort described in the preceding section of ~~this report~~. Management reviews the input and output boundaries and the performance descriptions of the functional unit in order to determine the requirements of the analyst to be assigned the responsibility for generating the troubleshooting aid. Management then selects the most qualified analyst available and provides him with the information of functional unit boundaries and performance description.

Management initiates the Troubleshooting Aid Data Sheet (Figure 3-2) by entering the System Name, Functional Unit Name and Number. The following entries are made on the Assignment line under Disposition: date of Assignment; name of the analyst, or aid generator, under "Remarks"; initials of the person making the assignment. The sheet is then presented to the



FUNCTIONAL UNIT PARTITIONS (SECTION II)
FUNCTIONAL UNIT PARTITIONS
MANAGEMENT
QUALIFIED PERSONNEL
ASSIGN FUNCTIONAL UNITS TO ANALYSTS
1
ANALYST ASSIGNED TO
EACH FUNCTIONAL UNIT TO DEVELOP COMPLETE TSA PACKAGE
TSA DATA SHEET INITIATED
TSA DEVELOPMENT PROCEDURES
STUDY TSA DEVELOPMENT PROCEDURES
2
EXISTING MAINTENANCE DATA
REVIEW FUNCTIONAL UNIT DATA
3
KNOWLEDGE OF:
CRITERIA FOR:
1. PRELIMINARY INFORMATION SHEET
2. SEQUENCE OF PROCEDURES
3. SYMPTOM-CAUSE CHART FORMAT
4. MDC FORMAT
5. TSA PACKAGE
6. TSA INDEX
CRITERIA FOR FUNCTIONAL UNIT BLOCK DIAGRAM
DEVELOP FUNCTIONAL UNIT BLOCK DIAGRAM
4
FUNCTIONAL UNIT INTERFACE DATA
FUNCTIONAL UNIT/
SEGMENTS INTER-FACE IDENTIFIED
CRITERIA FOR INTEGRATED SCHEMATIC AND PARTS LOCATION
5
FUNCTIONAL UNIT/SEGMENT SCHEMATIC AND PICTORIAL DATA, AND CORRECT END ITEM NOMENCLATURE
FUNCTIONAL UNIT/SEGMENT/END ITEM PERFORMANC
FUNCTIONAL UNIT MAINTENANCE ACTIVITIES REQUIREMENTS
DEVELOP PRELIMINARY INFORMATION SHEET
7
PI SHEET CRITERIA
SET UP REQUIREMENTS
IDENTIFIED FOR FUNCTIONAL UN
FOR OPERATION A
TROUBLESHOOTIN
SEQUENCE O
PROCEDURES
CRITERIA
SYMPTOM-CAUSE CHART FORMAT
SPECIFY FAILURE MODES
10
SYMPTOMS IDENTIFIED FOR ALL END ITEM
FAILURES IN EACH OPERATIONAL MODE
SYMPTOM-CAUSE CHART FORMAT CRITERIA
PREPARE SYMPTOM-CAUSE CHART
11
TROUBLESHOOTING INFORMATION IN
SYMPTOM-CAUSE CHART FORMAT
TSA PACKAGE CRITERIA
INTEGRATE TSA PACKAGE FOR FUNCTIONAL UNIT
14
TSA PACKAGE CONSISTING OF:
1. TSA DATA SHEET
2. FUNCTIONAL UNIT BLOCK DIAGRAM
3. INTEGRATED SCHEMATIC
4. PARTS LOCATION ILLUSTRATION
5. FUNCTIONAL DESCRIPTION
6. END ITEM LIST
7. PRELIMINARY INFORMATION SHEET
8. PROCEDURES MATRIX
9. FAILURE MODE ANALYSIS AND S-C CHART-OR-ROUGH AND FINAL MDC
MAINTENANCE DEPENDENCY CHART FORMAT
MDC FORMAT CRITERIA
SPECIFY MDC INTERRELATION-SHIPS AND ISOLATION STEPS
12
INTERRELATIONSHIPS OF ALL END ITEMS
SPECIFIED IN PROCEDURES BY END ITEM MATRIX, AND ADDITIONAL ISOLATION PROCEDURES (AS IDENTIFIED)
MDC SPEC
PREPARE MDC IN FINAL FORM
13
INTERRELATIONSHIPS OF END ITEMS AND INTER-FACING FUNCTIONAL
UNITS IDENTIFIED IN MDC FORMAT

A

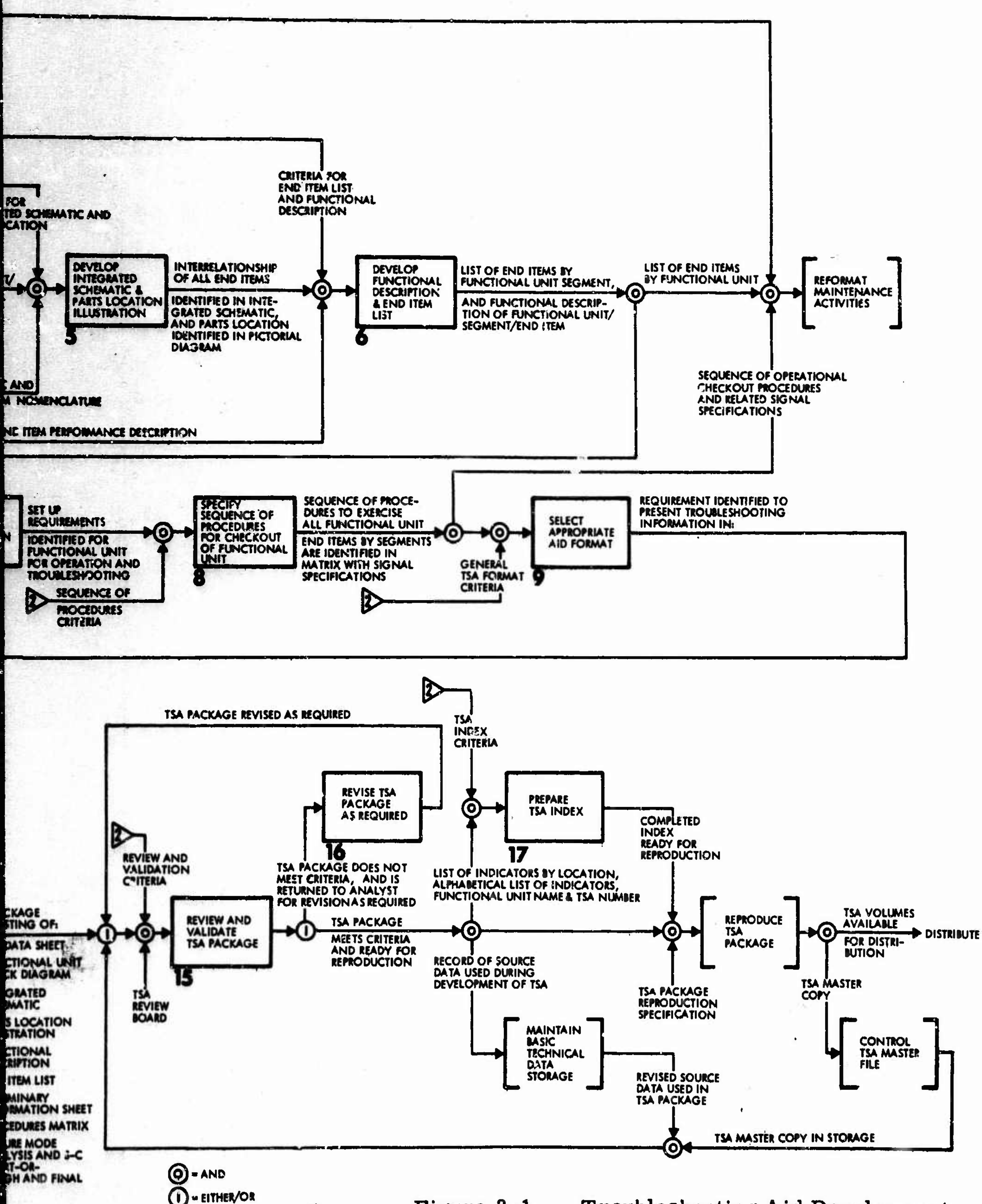


Figure 3-1. Troubleshooting Aid Development and Revision Approach

B

TROUBLESHOOTING AID DATA SHEET

SYSTEM NAME ____________________

FUNCTIONAL UNIT NAME ____________________

FUNCTIONAL UNIT NUMBER ____________________

ACTIVITY CODE ____________________

REVISION ____________________

SOURCE DATA

DOCUMENT	DATE	PAR.	FIG. NO.	REMARKS

NUMBER OF SHEETS

SEGMENT MATERIALS	DRAFT	FINAL
SCHEMATIC PARTS LOCATION FUNCTIONAL DESCRIPTION PRELIMINARY INFORMATION MDC/S-C CHART OTHER ________		

DISPOSITION

ACTIVITY	DATE		INITIAL	REMARKS
	IN	OUT		
ASSIGNMENT				
DEVELOPMENT				
SA REVIEW				
REVISION				
VALIDATION				
REVISION				
TYPING				
ART PREPARATION				
INDEXING				
COPY CHECK				
CAMERA				
PRINTING				
BINDING				
STORAGE				
DELIVERY				

PIMO 123

Figure 3-2. Troubleshooting Aid Data Sheet analyst, together with a copy of the Troubleshooting Aid Development Procedures and Criteria, and directions appropriate for obtaining source data for development of the functional unit troubleshooting aid. Source data should include all Technical Orders, Engineering Reports and Drawings, Failure Analysis Reports and any other information available that pertains to the functional unit.

2. Study Troubleshooting Aid Development Procedures

Personnel assigned the responsibility for a functional unit must read the Troubleshooting Aid Development Procedures to acquire the knowledge of the aid requirements and the techniques to meet these requirements. The troubleshooting aid development approach presented in Figure 3-1 should be used as a frame of reference to view the required sequence and relationship of all activities to be performed. The specific requirement of this activity is to acquire knowledge of the criteria governing development of:

- functional unit block diagram
- integrated schematic
- parts location illustration
- functional descriptions
- end item list
- preliminary information sheet
- sequence of procedures
- symptom-cause chart
- narrative procedures
- maintenance dependency chart
- integrated troubleshooting aid package

and consists of a study of the activities discussed in items 3 through 17 below and PIMO Troubleshooting Aid Specifications, Volume V.

3. Review Functional Unit Data

Personnel responsible for a functional unit should review all existing maintenance data appropriate to the functional unit. This data includes Technical Orders, Manuals, Engineering Drawings, Failure Analysis Reports, and any other information that is accessible. The specific requirement of this activity is to obtain knowledge of the functional unit:

- interface with other functional units
- lower level divisions, or segments
- schematic representation
- correct end item nomenclature
- performance descriptions
- maintenance activity preliminary requirements
- maintenance activity requirements.

This overview of all maintenance data for the functional unit should familiarize the personnel with information available for development of the troubleshooting aid package, and should identify certain characteristics of the functional unit that will later be used to assist them in selecting the appropriate aid fo- at (Activity 9).

4. Develop Functional Unit Block Diagram

This activity requires a detailed study of the functional unit composition and interface areas in order to develop a definitive block diagram of the subject. This diagram will define the functional unit when the following criteria are met for definition:

a. All interfaces in terms of energy or signal flow between the bounded functional unit and all interdependent functional units have been identified.

b. Specific test points and signal specifications between the functional unit of concern and all interfacing units have been identified.

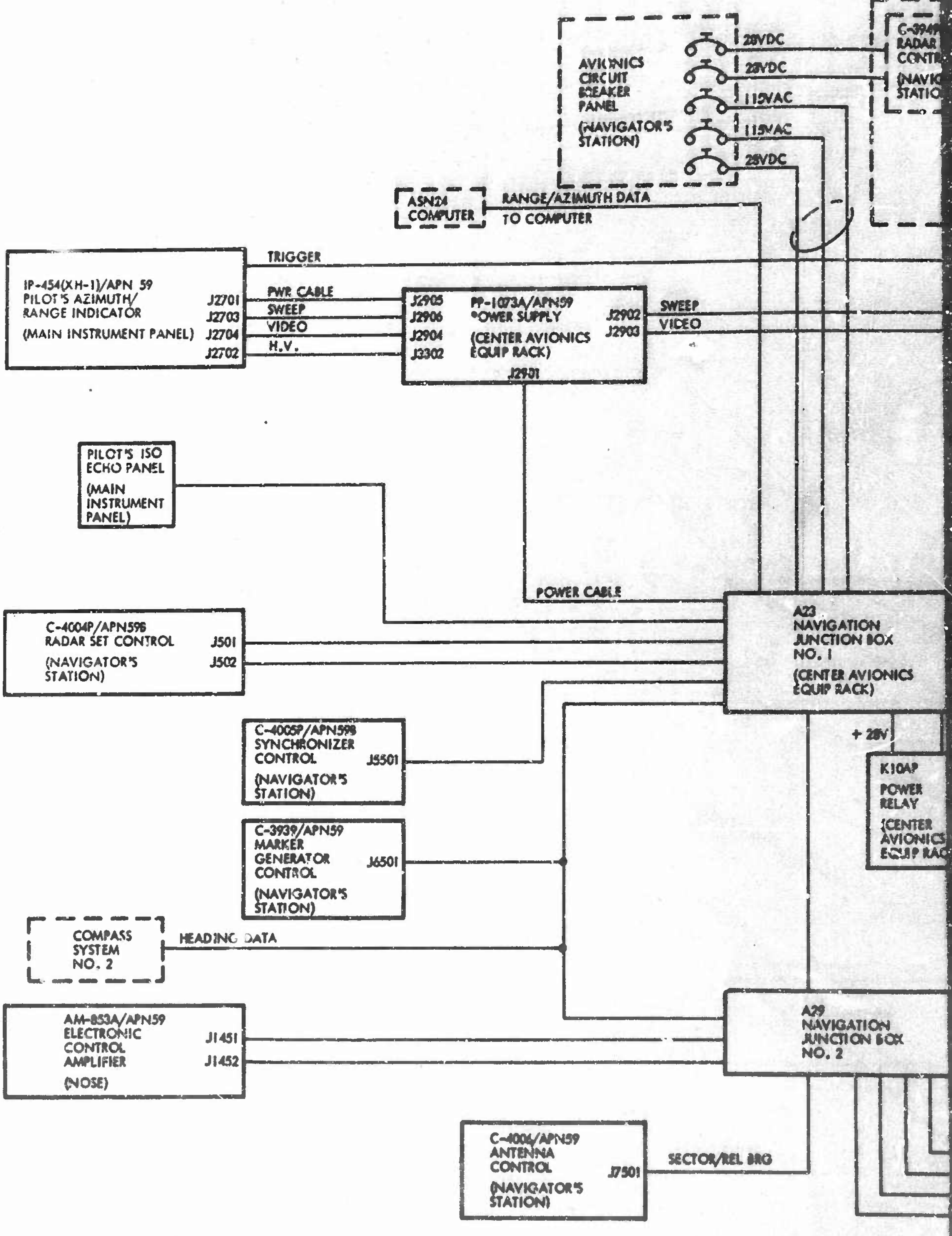
c. All included end items, or segments which contain identifiable end items, are specified.

Once the block diagram has been produced, it should be evaluated to determine whether the functional unit should be further segmented. In addition to the criteria governing the over-all aircraft partitioning, the analyst should consider each candidate segment as an ENTITY possessing a certain degree of independence. The objective is to identify manageable portions of the aircraft that can be treated by a troubleshooting aid. A valid SEGMENT must be bounded, all end items must be identified, and test points between segments must be specified. A segment is an entity at the next echelon in the functional hierarchy. For example, the system designated as Navigation has been segmented into functional units implemented by specific navigational equipment. One such functional unit, the AN/APN-59B Search Radar is illustrated in the block diagram of Figure 3-3. It is doubtful that further segmentation is required or desirable.

5. Develop Integrated Schematic and Parts Location Illustration

The requirements of this activity are the preparation of an integrated schematic that identifies all interrelationships involved in signal flow from functional unit or segment, input to output, and a pictorial diagram illustrating the location of the end items contained within the functional unit or segment. All source data used for this activity should be identified on the Troubleshooting Aid Data Sheet.

a. Integrated Schematic Intent Criteria. The basic intent of the schematic is to provide the troubleshooter with supplementary information not readily obtained from other troubleshooting aid materials. System



AVIONICS CIRCUIT BREAKER PANEL (NAVIGATOR'S STATION)
28VDC
28VDC
115VAC
115VAC
28VDC
RADAR CONTR (NAVIG STATIO
ASN24 COMPUTER
RANGE/AZIMUTH DATA TO COMPUTER
TRIGGER
IP-454(XH-1)/APN 59 PILOT'S AZIMUTH/ RANGE INDICATOR (MAIN INSTRUMENT PANEL)
J2701
J2703
J2704
J2702
PWR CABLE
SWEEP
VIDEO
H.V.
J2905
J2906
J2904
J3302
PP-1073A/APN59 POWER SUPPLY (CENTER AVIONICS EQUIP RACK)
J2902
J2903
SWEEP
VIDEO
J2901
PILOT'S ISO ECHO PANEL (MAIN INSTRUMENT PANEL)
POWER CABLE
C-4004P/APN59B RADAR SET CONTROL (NAVIGATOR'S STATION)
J501
J502
A23 NAVIGATION JUNCTION BOX NO. 1 (CENTER AVIONICS EQUIP RACK)
+ 28V
C-4005P/APN59B SYNCHRONIZER CONTROL (NAVIGATOR'S STATION)
J5501
K10AP POWER RELAY (CENTER AVIONICS EQUIP RAC
C-3939/APN59 MARKER GENERATOR CONTROL (NAVIGATOR'S STATION)
J6501
COMPASS SYSTEM NO. 2
HEADING DATA
AM-853A/APN59 ELECTRONIC CONTROL AMPLIFIER (NOSE)
J1451
J1452
A29 NAVIGATION JUNCTION BOX NO. 2
C-4006/APN59 ANTENNA CONTROL (NAVIGATOR'S STATION)
J7501
SECTOR/REL BRG

A

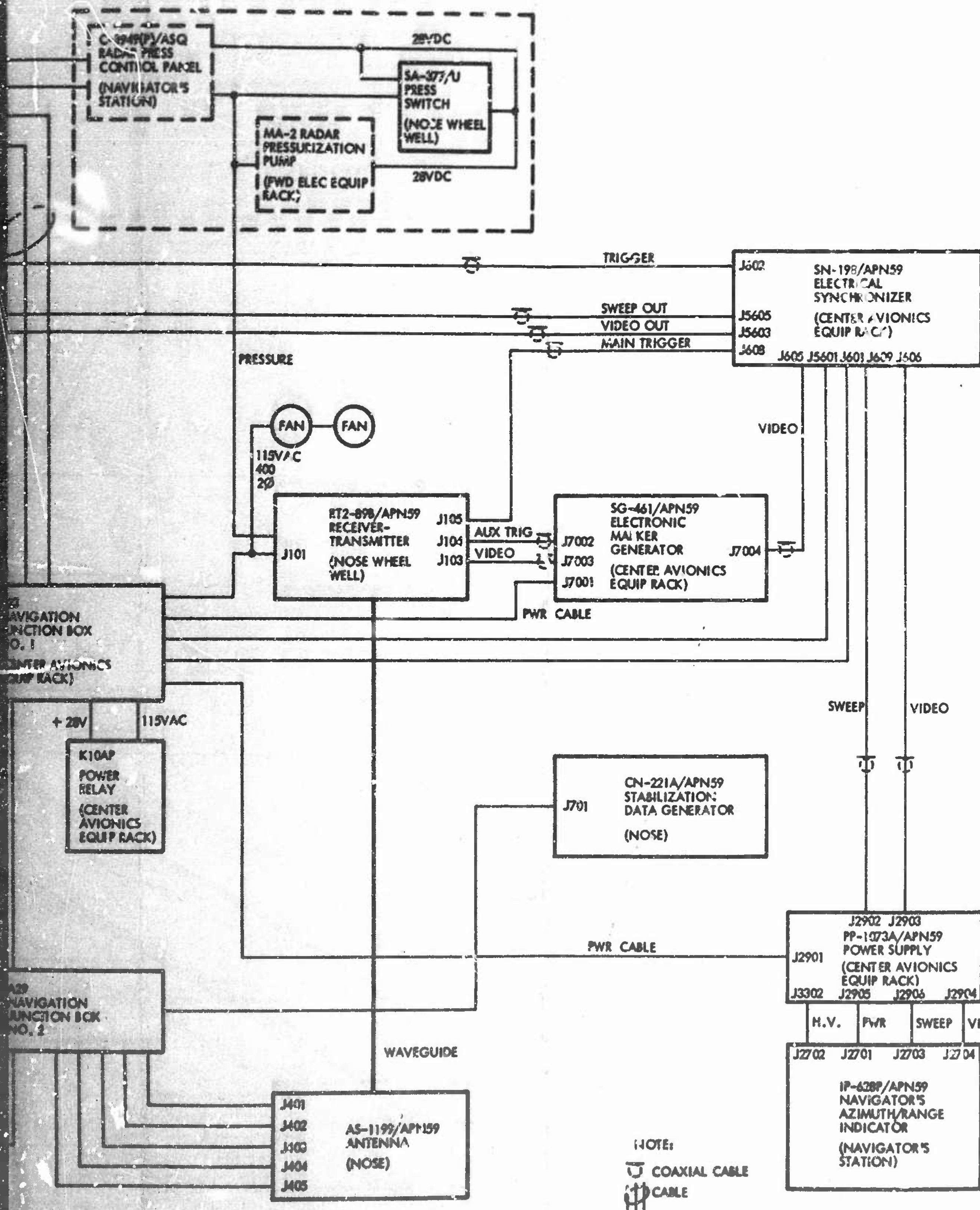


Figure 3-3 AN/APN-59B Search Radar Functional Unit Block Diagram

representation by means of schematics has been commonly designed to reveal the functional design and/or to serve as installation or manufacturing guides. Maintenance can be materially benefited by presenting this information in an integrated fashion. In addition, the development of such a schematic serves the purpose of specifically defining the functional unit, thereby assisting the personnel responsible for developing the troubleshooting aid in describing the total structure of the functional unit. In order to accomplish this intent, the following criteria must be met.

1) Isolate the functional unit, or segments of concern. This is accomplished by specifically identifying the interfaces between it and other functional units, or segments on the schematic. This effort is an outgrowth and amplification of the effort involved in developing the functional unit block diagram (Activity 4), and identifies the interface at specific end items within the functional unit.

2) Identify all end items schematically. A functional unit, or segment, should be represented by an integrated schematic; i.e., it is more effective to combine electrical, hydraulic, and mechanical entities into a single composite schematic instead of developing separate schematics for each of the different mechanization disciplines comprising the over-all functional unit. This convention is based upon the desire to present the over-all picture of the troubleshooting unit where troubleshooting unit is defined as a closed-loop system implementing a functional requirement. The items comprising this system may belong to various hardware classes.

3) Specify the functional interrelationship of all end items comprising the functional unit, or segment. Each end item must be connected to some other end item within the functional unit in order to properly mechanize the

function. If no interrelationship is found to exist, then the end item does not belong in the functional unit.

4) Trace the signal flows through the functional unit, or segment. Applying control loop analysis to verify continuous signal flow through all the end items under the various modes of operation will assist in describing the functional interrelationships. It also will identify the inclusion of end items that do not belong, or the exclusion of end items that do belong, in the functional unit.

Existing maintenance data for the functional unit should be searched for schematics, pictorial diagrams, illustrations, and descriptive text to assist in meeting the intent criteria.

b. Integrated Schematic Format Criteria. The following criteria are presented in order to standardize the presentation of integrated schematics, and to assist in meeting the intent criteria.

1) Use conventional engineering symbology in the schematic. This is particularly pertinent when developing detailed schematics. The conventions that are extant on schematics available from the Technical Manuals should be adhered to (if there is a conflict between standard engineering practices), because the technician may occasionally need to refer to the wiring diagrams furnished by the equipment vendor. Conflict in symbology between prime contractor-furnished schematics and vendor-furnished schematics should, therefore, be minimized. A list of symbols will be a necessary part of the troubleshooting aid volume: therefore, all peculiar conventions should be noted. In certain instances, pictorial representation of end items will help provide a more meaningful grasp of the system. In other cases

it may be desirable to present a schematic with some sections illustrated in greater detail than others.

2) The arrangement of the elements on the schematic should be such as to best facilitate its use. First, it is recommended that an attempt be made to maintain a left-to-right flow of signals through the schematic. Feedback signal flow will generally be from right to left. However, this convention should not be allowed to constrain the analyst to the point where components must be repeated or excessive line crossings are needed. Secondly, it is recommended that the schematic group functional elements be placed so that their actual physical location can be readily ascertained. These recommendations should not be construed as constraints to the implementation of the intent criteria; instead, they should be considered as techniques to accomplish the objectives of the schematics.

3) Identification of system elements on the schematic should include removable end items by:

   (a) Name

   (b) Part number

   (c) Location

   These should also be enclosed in a box where it lends clarity to the schematic.

4) Interconnecting circuitry should include:

   (a) Electrical wiring; hydraulic plumbing, pneumatic ducting and mechanical linkage identification numbers.

   (b) Connector identifying numbers enclosed in a rounded rectangle and placed on each side of the connector.

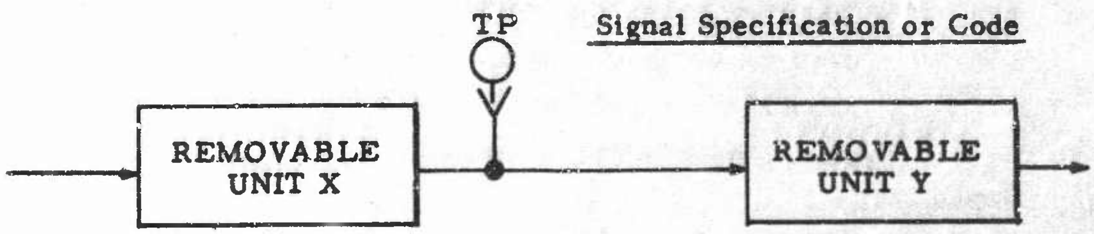
(c) Test points to assist in the isolation of faulty end items, when determined necessary by the analyst. If the schematic supports an MDC, the signal specification availability is adequate for this identification. Test points are usually indicated by a standard symbol. It is recommended that the test points be numbered and coded. The following test point symbols are to be used. (See Figure 3-4). Numbering permits use of a signal specifications table to identify the normal reading and tolerances at the test point when space to write signal specifications is at a premium.

(d) Terminal boards where signal flow converges or diverges, or where needed to trace signal flow continuity.

5) The schematic should include:

A title in bold type centered at the bottom of the sheet. This title will consist of the name of the system or segment, and its corresponding numerical designator. If multiple sheets are required for a schematic, enter under the title the term "sheet 1 of n," where 1 refers to the specific sheet number and n the total number of sheets.

The change series of the total system for which the schematic is applicable. This note should be placed in the lower left-hand side of the sheet and headed by the term "effectivity" in reversed block letters. Different system design configurations should be



	BACKGROUND	WHEN USED
TP	Black	Test points designed into the equipment which are directly accessible, such as jacks, exposed terminals, and events (actions) which may be recognized from outside the equipment. (These events may or may not require the use of test equipment for their recognition.)
TP	Grey (with black lettering)	Secondary test points or events (actions) which may be determined or observed only after the equipment enclosure has been opened, and which are readily accessible. (These events usually require the use of test equipment for their recognition.)
TP	White	Test points or events (actions) which are difficult to access and which always require the use of test equipment.

Figure 3-4 Test Points

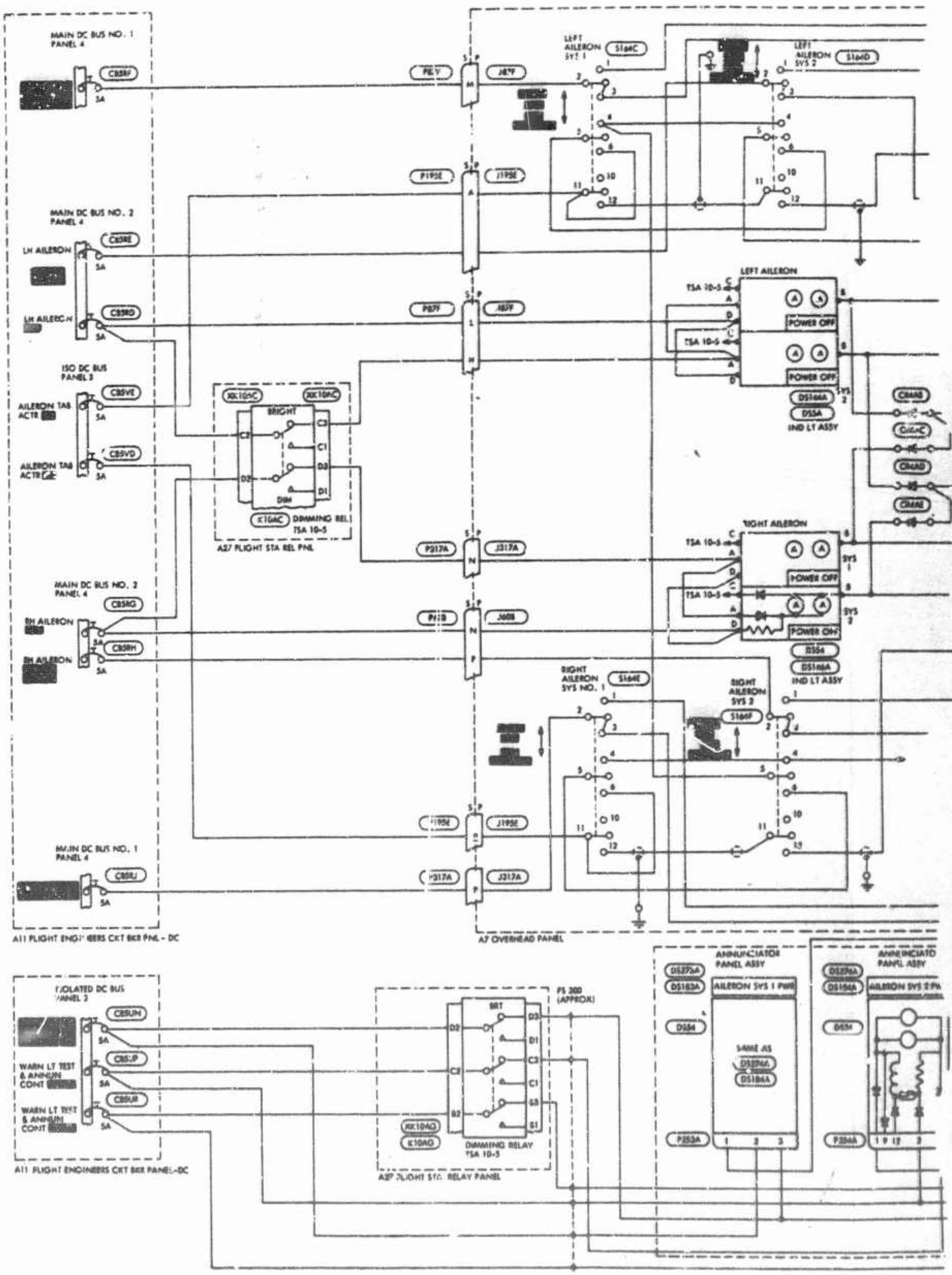
identified by a number enclosed in a triangle, ⚠ . If only a minor portion of the schematic differs between two series of the system, the difference in circuitry should be presented in a block with identification of alternate mechanization for the appropriate series. If there are major differences in the functional unit configurations of two or more series, individual schematics should be prepared for each series, and the series effectivity noted for each schematic.

When notes are required, use standard engineering practice. The location of the note will usually depend upon the available space; however, when space permits, it should be located in the lower right area of the schematic. If notes appear on source schematics that are pertinent to installation only and are not needed for troubleshooting, they may be deleted. The word "Note" should be in reversed block letters.

Each schematic, and other troubleshooting aids as well, will receive a data which will be located in the extreme lower right. This date shall be the date of development completion on the part of the analyst. The date, the title, and the effectivity note should appear in line in the margin across the bottom of the sheet.

6) For field use, the final size of the schematic should be limited to 11 x 17-inch sheets. If it appears that more space will be required, the analyst should prepare the rough schematics on separate sheets, or clearly indicate where the artist should break it into multiple sheets.

Figure 3-5 is an example of a portion of a typical schematic diagram showing electrical elements of a functional unit. Note that the end items are indicated by dashed boxes as well as identifying numbers. This particular


MAIN DC BUS NO. 1
PANEL 4
CB5RF
5A
MAIN DC BUS NO. 2
PANEL 4
LH AILERON
CB5RE
LH AILERON
CB5RD
ISO DC BUS
PANEL 3
AILERON TAB ACTR
CB5VE
AILERON TAB ACTR
CB5VD
MAIN DC BUS NO. 2
PANEL 4
RH AILERON
CB5RG
RH AILERON
CB5RH
MAIN DC BUS NO. 1
PANEL 4
CB5RJ
A11 FLIGHT ENGINEERS CKT BKR PNL - DC
BRIGHT
DIM
K10AC
DIMMING REL
TSA 10-5
A27 FLIGHT STA REL PNL
LEFT AILERON SYS 1
S164C
LEFT AILERON SYS 2
S164D
P195E
J195E
P87F
J87F
P217A
J217A
LEFT AILERON
TSA 10-5
POWER OFF
DS144A
DS5A
IND LT ASSY
RIGHT AILERON
POWER OFF
POWER ON
DS146A
IND LT ASSY
RIGHT AILERON SYS NO. 1
S164E
RIGHT AILERON SYS 2
S164F
SYS 1
SYS 2
A7 OVERHEAD PANEL
ISOLATED DC BUS
PANEL 3
CB5UN
WARN LT TEST & ANNUN CONT
CB5UP
WARN LT TEST & ANNUN CONT
CB5UR
A11 FLIGHT ENGINEERS CKT BKR PANEL-DC
BRT
XK104G
K10AG
DIMMING RELAY
TSA 10-5
A27 FLIGHT STA RELAY PANEL
FS 300 (APPROX)
ANNUNCIATOR PANEL ASSY
AILERON SYS 1 PWR
SAME AS
DS54
P253A
P254A
AILERON SYS 2 PWR

A

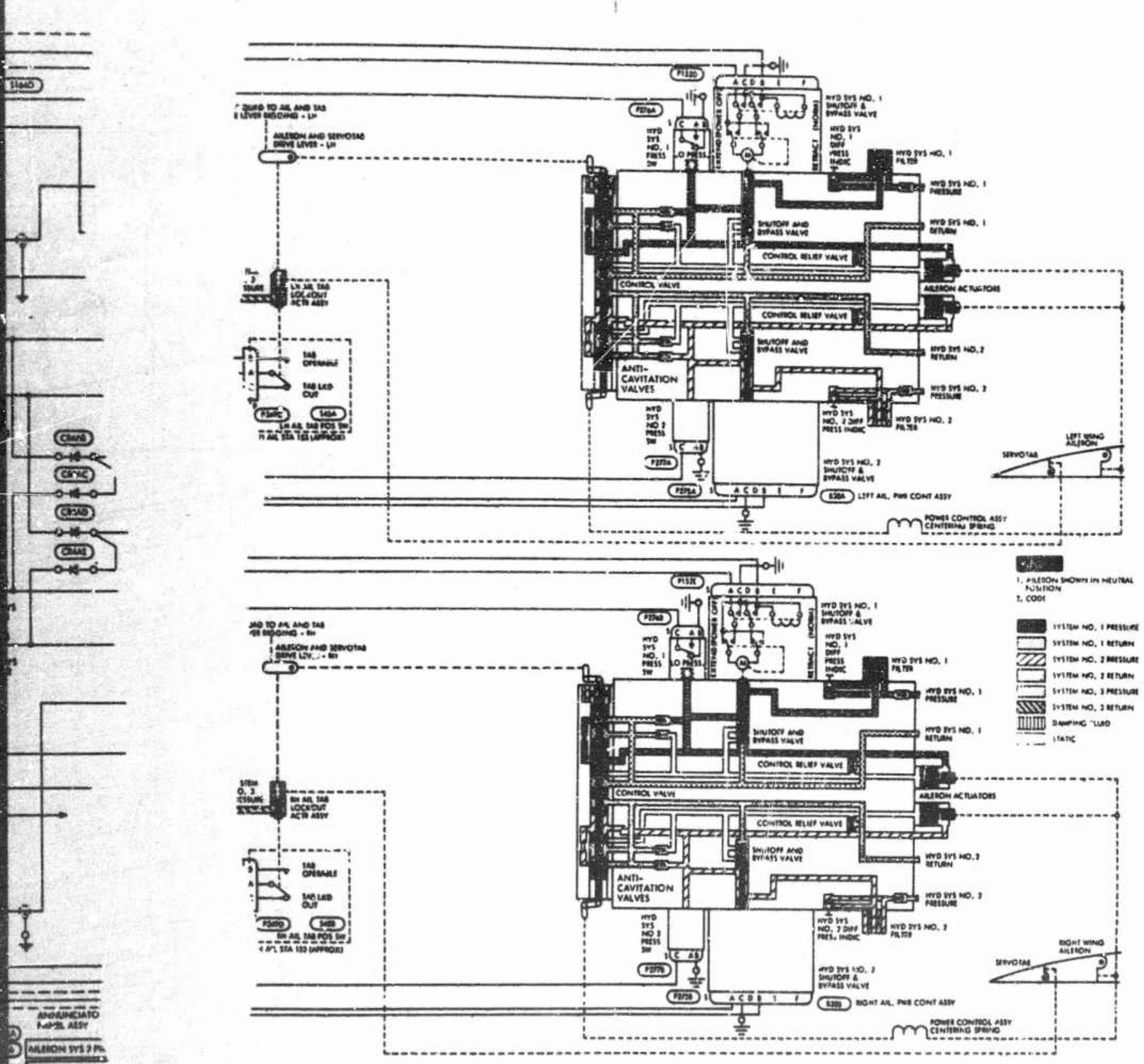


Figure 3-5 Aileron Control and Trim System Schematic Diagram

B

diagram is intended as a typical approach only and does not represent the only way to render a functional unit. Representation of functional elements facilitates the maintenance technician's ability to troubleshoot. This schematic is a composite showing both electrical and hydraulic functional elements. Mechanical linkage is represented by dashed lines, and is further developed on the parts location illustration.

c. Parts Location Illustration Intent Criteria. The basic intent of this illustration is to identify the location of the end items to minimize the time required to gain access to a specific end item during fault isolation. In addition, its development will further assist in defining the functional unit by identifying end item particulars that may not have been included in the schematic representation,such as idler pulleys, cable turnbuckles, and travel stops. The following criteria must be met to accomplish this intent.

1) Identify the physical characteristics of each end item in the functional unit. The physical characteristics should include sufficient detail to permit the troubleshooter to recognize the real end item from its pictorial representation.

2) Identify the interconnection or physical interrelationship of end items in the functional unit. This illustration of interrelationships should supplement the integrated schematic by providing more detail than is appropriate for a schematic, and is particularly important to the troubleshooter in tracing mechanical linkage or hydraulic plumbing during fault isolation.

3) Identify the location of end items in the functional unit relative to some over-all aircraft system reference. This is partially accomplished by identifying the interrelationship of end items; however, the illustration represents specific details abstracted from the total

system, and the location of the details should be keyed to some general location on a gross level representation of the total system.

d. <u>Parts Location Illustration Format Criteria.</u> The following criteria are presented in order to standardize the presentation of parts location illustrations, and to assist in meeting the intent criteria.

1) Develop sufficient general detail line drawings to provide reference for the location of functional unit end items within the total aircraft system. Where specific end items are isolated in their locations, use letter designators to refer to specific lower level details. The letter designators should follow alphabetical progression, starting with "A", for details at the functional unit input, and progress following signal flow. The letter designator should be a white block letter on a black rectangular field.

2) Present the end item detail drawings in a consistent plane of view with sufficient detail to identify each end item. Where letter designators have been used to identify the location of details, repeat the same letter designator near the detail and either group the detail drawing in a box, or use an arrow to point from the letter designator to the detail.

3) Identify each end item in the detail drawing with an Arabic number designator, progressing from "1" at the functional unit input, in the direction of signal flow, to the functional unit output. Each number should be located adjacent to the end item it represents, with an arrow pointing from the number to the specific end item.

4) Prepare an illustration key consisting of the number

designators and their corresponding correct nomenclature, to be included in or adjacent to the illustration. Preferably, when keys are used outside the art, these shall be located below the illustration and precede the figure title.

5) Page size, type size, and figure identification criteria are the same as the criteria for integrated schematics. Figure 3-6 is an example of a parts location illustration that meets the above criteria.

6. Develop End Item List and Functional Description

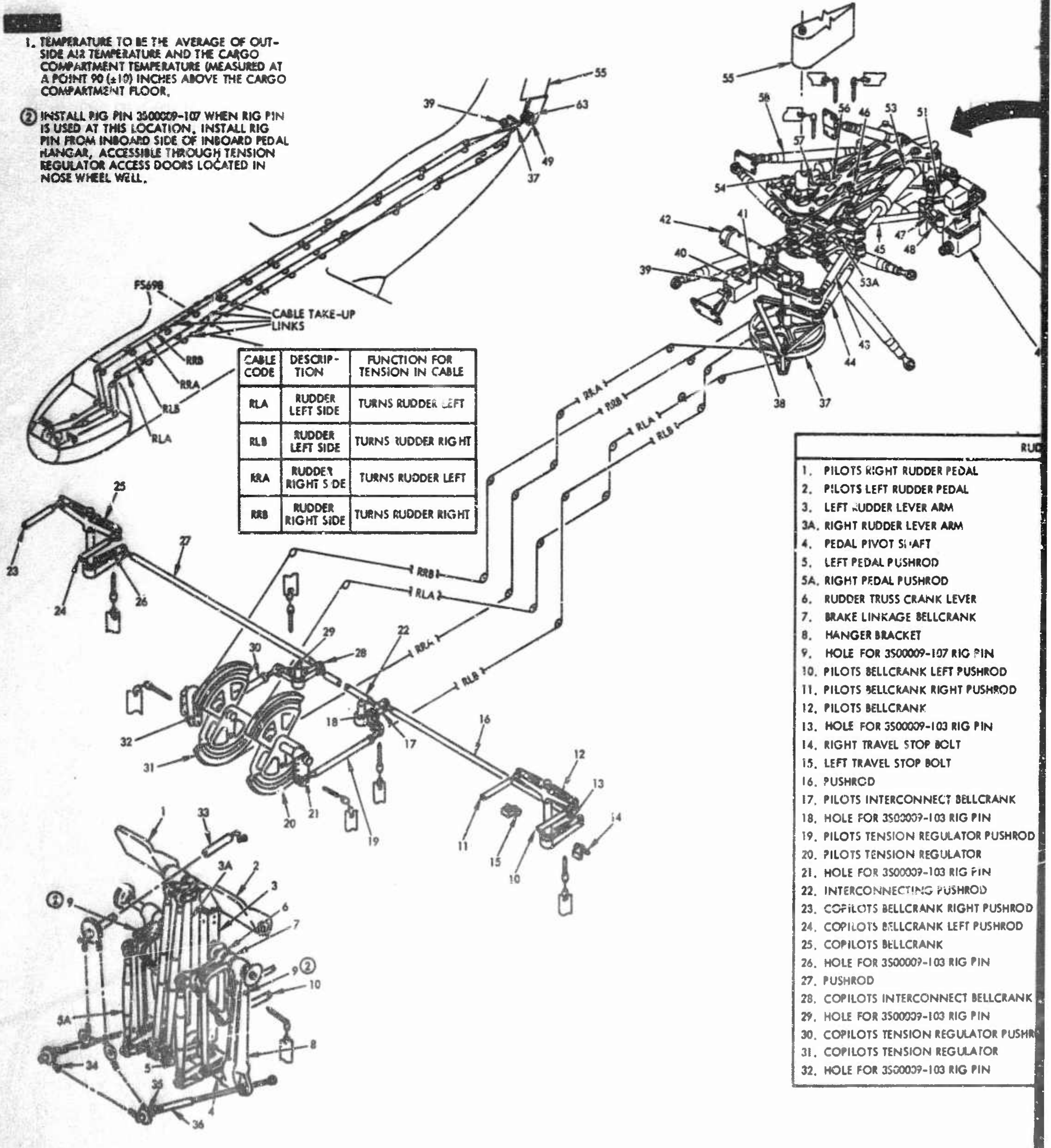
The requirements of this activity are the preparation of a list of all end items contained in the functional unit, and a functional description of the functional unit, segments, and end items. The integrated schematic and parts location illustration should be used as a basis for identifying the end items, and existing descriptive data should be searched for appropriate information for the functional description. All source data used for this activity should be identified on the Troubleshooting Aid Data Sheet.

a. End Item List Requirements. The purpose of the end item list is to provide a standard terminology by identifying the correct nomenclature for all end items which comprise the functional unit. Front panel identifying nomenclature for switches, controls, indicators, circuit breakers, etc., should be in upper case letters. Each end item should be identified by a sequential Arabic number, such that the number of the last end item on the list represents the total number of end items in the functional unit.

Figure 3-7 is a suggested form to assist in the development of this end item list. The functional unit name and number are entered at the top of each sheet in the list. The sequence and total number of the sheets in a list are also entered on this line. The first column of the list provides for identification of lower level segments, when these segments have been

1. TEMPERATURE TO BE THE AVERAGE OF OUTSIDE AIR TEMPERATURE AND THE CARGO COMPARTMENT TEMPERATURE (MEASURED AT A POINT 90 (±10) INCHES ABOVE THE CARGO COMPARTMENT FLOOR.

② INSTALL RIG PIN 3500009-107 WHEN RIG PIN IS USED AT THIS LOCATION. INSTALL RIG PIN FROM INBOARD SIDE OF INBOARD PEDAL HANGAR, ACCESSIBLE THROUGH TENSION REGULATOR ACCESS DOORS LOCATED IN NOSE WHEEL WELL.



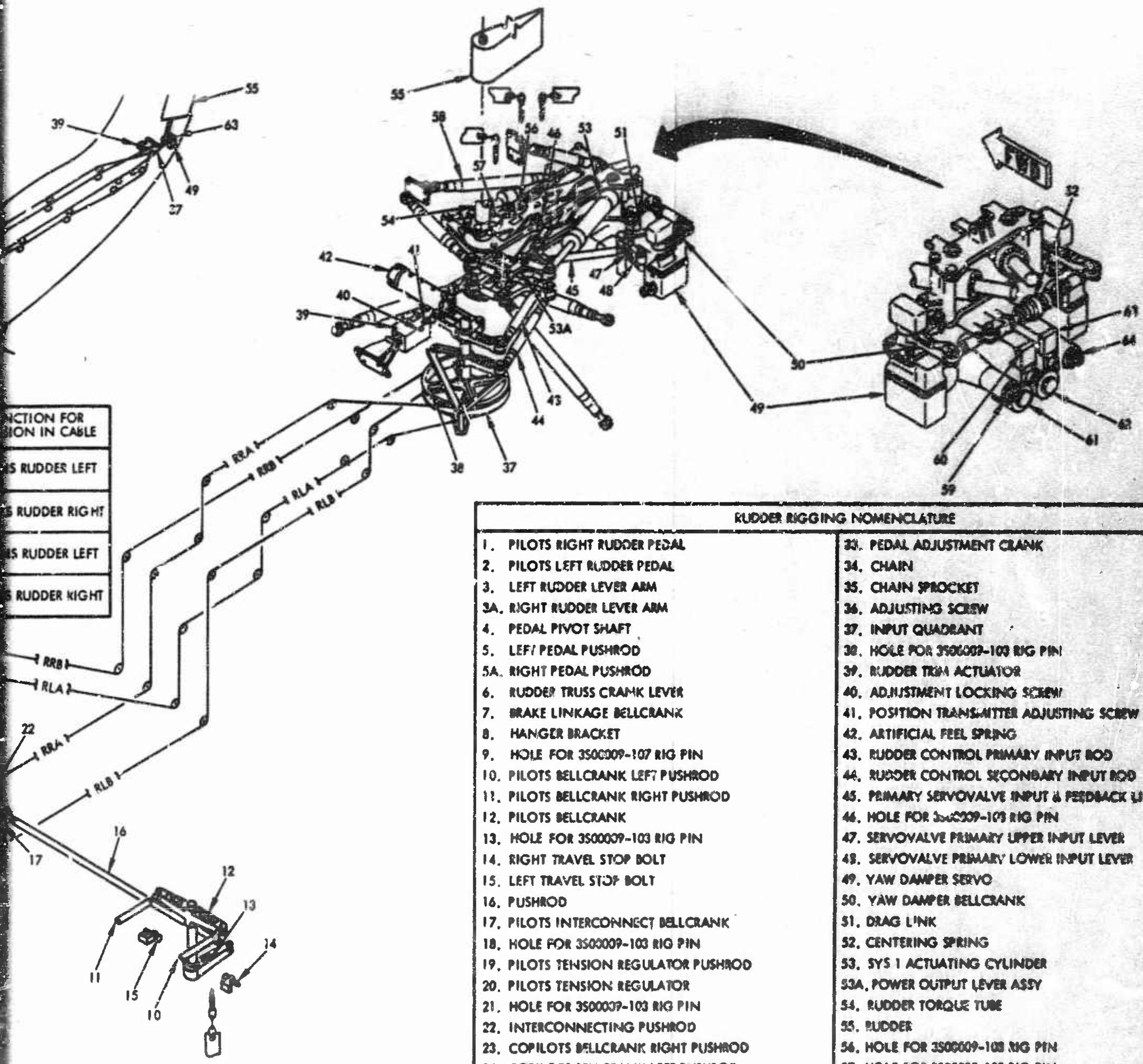
CABLE CODE	DESCRIPTION	FUNCTION FOR TENSION IN CABLE
RLA	RUDDER LEFT SIDE	TURNS RUDDER LEFT
RLB	RUDDER LEFT SIDE	TURNS RUDDER RIGHT
RRA	RUDDER RIGHT SIDE	TURNS RUDDER LEFT
RRB	RUDDER RIGHT SIDE	TURNS RUDDER RIGHT

RUD

1. PILOTS RIGHT RUDDER PEDAL
2. PILOTS LEFT RUDDER PEDAL
3. LEFT RUDDER LEVER ARM
3A. RIGHT RUDDER LEVER ARM
4. PEDAL PIVOT SHAFT
5. LEFT PEDAL PUSHROD
5A. RIGHT PEDAL PUSHROD
6. RUDDER TRUSS CRANK LEVER
7. BRAKE LINKAGE BELLCRANK
8. HANGER BRACKET
9. HOLE FOR 3500009-107 RIG PIN
10. PILOTS BELLCRANK LEFT PUSHROD
11. PILOTS BELLCRANK RIGHT PUSHROD
12. PILOTS BELLCRANK
13. HOLE FOR 3500009-103 RIG PIN
14. RIGHT TRAVEL STOP BOLT
15. LEFT TRAVEL STOP BOLT
16. PUSHROD
17. PILOTS INTERCONNECT BELLCRANK
18. HOLE FOR 3500009-103 RIG PIN
19. PILOTS TENSION REGULATOR PUSHROD
20. PILOTS TENSION REGULATOR
21. HOLE FOR 3500009-103 RIG PIN
22. INTERCONNECTING PUSHROD
23. COPILOTS BELLCRANK RIGHT PUSHROD
24. COPILOTS BELLCRANK LEFT PUSHROD
25. COPILOTS BELLCRANK
26. HOLE FOR 3500009-103 RIG PIN
27. PUSHROD
28. COPILOTS INTERCONNECT BELLCRANK
29. HOLE FOR 3500009-103 RIG PIN
30. COPILOTS TENSION REGULATOR PUSHR
31. COPILOTS TENSION REGULATOR
32. HOLE FOR 3500009-103 RIG PIN

Figure 3-6 R
P

A



RUDDER RIGGING NOMENCLATURE	
1. PILOTS RIGHT RUDDER PEDAL	33. PEDAL ADJUSTMENT CRANK
2. PILOTS LEFT RUDDER PEDAL	34. CHAIN
3. LEFT RUDDER LEVER ARM	35. CHAIN SPROCKET
3A. RIGHT RUDDER LEVER ARM	36. ADJUSTING SCREW
4. PEDAL PIVOT SHAFT	37. INPUT QUADRANT
5. LEFT PEDAL PUSHROD	38. HOLE FOR 3S00009-103 RIG PIN
5A. RIGHT PEDAL PUSHROD	39. RUDDER TRIM ACTUATOR
6. RUDDER TRUSS CRANK LEVER	40. ADJUSTMENT LOCKING SCREW
7. BRAKE LINKAGE BELLCRANK	41. POSITION TRANSMITTER ADJUSTING SCREW
8. HANGER BRACKET	42. ARTIFICIAL FEEL SPRING
9. HOLE FOR 3S00009-107 RIG PIN	43. RUDDER CONTROL PRIMARY INPUT ROD
10. PILOTS BELLCRANK LEFT PUSHROD	44. RUDDER CONTROL SECONDARY INPUT ROD
11. PILOTS BELLCRANK RIGHT PUSHROD	45. PRIMARY SERVOVALVE INPUT & FEEDBACK LINKAGE
12. PILOTS BELLCRANK	46. HOLE FOR 3S00009-103 RIG PIN
13. HOLE FOR 3S00009-103 RIG PIN	47. SERVOVALVE PRIMARY UPPER INPUT LEVER
14. RIGHT TRAVEL STOP BOLT	48. SERVOVALVE PRIMARY LOWER INPUT LEVER
15. LEFT TRAVEL STOP BOLT	49. YAW DAMPER SERVO
16. PUSHROD	50. YAW DAMPER BELLCRANK
17. PILOTS INTERCONNECT BELLCRANK	51. DRAG LINK
18. HOLE FOR 3S00009-103 RIG PIN	52. CENTERING SPRING
19. PILOTS TENSION REGULATOR PUSHROD	53. SYS 1 ACTUATING CYLINDER
20. PILOTS TENSION REGULATOR	53A. POWER OUTPUT LEVER ASSY
21. HOLE FOR 3S00009-103 RIG PIN	54. RUDDER TORQUE TUBE
22. INTERCONNECTING PUSHROD	55. RUDDER
23. COPILOTS BELLCRANK RIGHT PUSHROD	56. HOLE FOR 3S00009-103 RIG PIN
24. COPILOTS BELLCRANK LEFT PUSHROD	57. HOLE FOR 3S00009-103 RIG PIN
25. COPILOTS BELLCRANK	58. SUPPORT BAR
26. HOLE FOR 3S00009-103 RIG PIN	59. SYS 1 LOAD LIMIT PILOT VALVE SOLENOID
27. PUSHROD	60. SYS 1 SHUTOFF AND BYPASS VALVE
28. COPILOTS INTERCONNECT BELLCRANK	61. SYS 1 FILTER
29. HOLE FOR 3S00009-103 RIG PIN	62. SYS 2 FILTER
30. COPILOTS TENSION REGULATOR PUSHROD	63. SYS 2 SHUTOFF & BYPASS VALVE
31. COPILOTS TENSION REGULATOR	64. SYS 2 LOAD LIMIT PILOT VALVE SOLENOID
32. HOLE FOR 3S00009-103 RIG PIN	65. RUDDER POWER CONTROL ASSY.

Figure 3-6 Rudder Control and Trim System Parts Location Diagram

B

FUNCTIONAL UNIT NAME Aileron Control and Trim NUMBER 4-1 SHEET 1 OF 12

SEGMENT NAME	ITEM NO.	END ITEM NAME	REF. DESIG.	LOCATION	REMARKS
Aileron Trim	1	AILERON TRIM CONT ckt bkr	CB5AT	No. 2 C.B. Pnl	Interface with Essen AC Bus No. 1
	2	AILERON TRIM POS IND ckt bkr	CB12F	No. 4 C.B. Pnl	Interface with Main DC Bus No. 1
	3	Pedestal disconnect connector	J100G	Pilots Cont. Ped.	Shared with other functional units.
	4	Pedestal disconnect connector	P100G	Pilots Cont. Ped.	Same as J100G
	5	Trim Control Switch	S132A	Pilots Cont. Ped.	
	6	Trim Control Switch	S132B	Pilots Cont. Ped.	
	7	Aileron Trim Actuator Assembly -motor -position transmitter	B208	FS959, LBL10 (Approx)	Interface with aileron rigging segment by providing variable base for artificial feel spring (Item 37).
	8	Ail. Trim Actr. Assy. Connector	P15GE	On B208	
	9	AILERON TRIM indicator	DS214A	Pilots Center Inst. Pnl	
	10	Ail. Trim indicator connector	PIK	On DS 214A	
	11	Interconnect wiring	See Int. Schematic	See Integrated Schematic	Provides electrical interconnection for all aileron trim end items.
Aileron Control Rigging		FORWARD RIGGING			
	12	Pilots Control Wheel		Plts Cont Column	
	13	Pilots Control Column Cables -turnbuckles		Plts Cont Column	
	14	Pilots rower Cont. Col Cable Pulleys		Plts Cont Column	
	15	Plts Cont Col. Cable alignment pulleys		Plts Tens. Reg.	
	16	Pilots Tension Regulator		Under Flt Deck	
	17	Pilots Tens. Reg. Stop Bolt Assy		Plts Tens. Reg.	
	18	Interconnecting Pushrod		Plts. Tens. Reg.	Interconnects Items 16 and 30
	19	Left Aileron Control Cable -Turnbuckle	ALA	Fuselage	

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Figure 3-7 List of End Items by Functional Unit/Segment defined by the functional unit block diagram. End items contained in each segment should then be sequentially numbered (second column), and listed in order of signal or energy flow from input to output (third column). The reference designator of the end item is entered in the fourth column. The location of the end item within the total system is entered in the fifth column. Information concerning end item interface with other functional units or segments within this functional unit should be entered in the "Remarks" column.

b. Functional Description Intent Criteria. The intent of the functional description is to provide information to the troubleshooter concerning the performance of the functional unit in supporting total system performance; functional unit segments in supporting functional unit performance; and specific characteristics of the end items involved in mechanizing the functional unit/segments performance.

The following criteria must be met to accomplish this intent.

1) Describe the functional unit performance. This should provide a general description of the complete functional unit performance, identifying lower level segments as required, in the following terms:

   (a) commonalities to other similar functional unit performance.

   (b) special characteristics unique to this particular functional unit design.

   (c) interrelationship of the functional unit of concern with other functional units from which it obtains energy, or to which it provides energy or signals.

2) Describe functional unit segment performances. This should provide a more specific description of the functional unit at the next lower level, if lower level segments

have been defined. Consideration of descriptive terms is the same as for the functional unit.

3) Describe the end items. Description of the end items should be concerned with the following:

   (a) unique physical characteristics not obvious in the parts location illustration.

   (b) unique performance characteristics that separate the specific end item from other similar end items.

   (c) interrelationships of end items to mechanize the functional unit/segment performance.

c. Functional Description Format Criteria. The following criteria are presented in order to standardize the presentation of functional descriptions, and to assist in meeting the intent criteria.

1) Wording of Text. The text shall be factual, specific, concise, and clearly worded so as to be readily understandable to relatively inexperienced personnel performing the work on the equipment, yet provide technicians with sufficient information to insure peak performance of the equipment. The sentence form shall be simple and direct, avoiding the obvious and the elementary, and omitting discussions of theory except where essential for practical understanding and application, or as required by the applicable detail specification. Engineering knowledge reflected in the manual shall first be converted into the most easily understood wording possible. Technical phraseology requiring a specialized knowledge shall be avoided, except where no other wording will convey the intended meaning.

2) Grammatical Person and Mode. The third person indicative shall be used for description and discussion, for example: "The torsion link assembly transmits torsional loads from the axle to the shock strut".

3) Paragraphing. The first paragraph in the functional description shall be titled "General", and contain a general description of the functional unit. The lower level segments, or principal end items, should be identified in this paragraph. The second paragraph should describe the normal operation of the functional unit, from the input source, through the end items to the output. The remaining paragraphs, in order of presentation, should be concerned with alternate operational mode descriptions, segment descriptions, and end item descriptions. Each paragraph should be titled with the name of the operational mode, segment, or end item with which the description is concerned. The complete title should appear in upper case letters, with the descriptive paragraph starting on the same line. No paragraph numbering is required. Where appropriate, the figure number of artwork that supports the discussion should be referenced in parenthesis immediately after the paragraph name.

4) Use of Supportive Art. The text should be supported by illustrations to the extent necessary. Illustrations shall also be used when required by the applicable detail specification, to furnish pictorial identification of parts and tools. The minimum number of illustrations essential for such purposes should be used. Illustrations serving no specific instructional function should not be used. Illustrations that are duplicates in appearance and content of an illustration appearing in the same manual should not be used; nor should an illustration be used which is

altered in appearance by rearrangement but contains no different information. Titling duplicate illustrations differently does not justify the use of the same illustration more than once in the same manual. Use of illustrations in the functional description should be limited to providing additional detail not appropriate to parts location or schematic illustrations. Figures appearing in the functional description should be identified by the functional description TSA number, followed by a dash and the Arabic numerals progressing from "1", and should be located as close as possible to the paragraph they support.

5) Columnar Arrangement. The text of the functional description should be arranged in columns such that two columns would appear on a page 8-1/2 inches wide. A page, 17 inches wide would permit four columns, and a page, 35 inches wide would permit six columns.

6) Page Size, Type Size, and Title Criteria. These are the same as the criteria for integrated schematics.

7. Develop Preliminary Information Sheet

The requirement for this activity is to provide the necessary information to allow the technician to prepare both himself and the functional unit for troubleshooting. To meet this requirement, personnel responsible for aid development should review all maintenance activities appropriate for the functional unit. This is necessary to determine test equipment and personnel requirements, and preliminary conditioning of the entire system necessary for the technician to start troubleshooting the functional unit. All source data used for this activity should be identified on the Troubleshooting Aid Data Sheet.

a. Preliminary Information Sheet Intent Criteria. It is the intent of this information sheet to provide troubleshooting personnel with a summary of the prerequisites for starting troubleshooting. In order to do this, the following intent criteria must be met.

1) Provide a table of required test equipment. This table should indicate the name, stock identification number and use or application of all test equipment involved in the troubleshooting activity. This table should exclude tools considered as part of the technician's standard tool kit.

2) Provide fabrication instructions for special test fixtures that are not considered standard test equipment.

3) Identify the personnel requirements for troubleshooting. This information should identify the maximum number of personnel required, and describe their general work station and interaction during troubleshooting.

4) Identify the system configuration necessary to initiate troubleshooting of the functional unit. The sequence of steps (including appropriate notes, cautions, and warnings) necessary to activate other functional units that interface with the unit of concern should be described. The initial setting of circuit breakers, switches, and controls necessary for functional unit operation should be identified.

5) Prepare a key of effectivity. Where different configurations or model series of the same system type exist, it is necessary to provide information of mechanization differences between the series for troubleshooting purposes. Each model series and differences of functional unit equipment configuration should be identified separately and assigned a numerical key that will identify differences in information to be presented in the trouble shooting aid.

b. <u>Preliminary Information Sheet Format Criteria.</u> Refer to Figure 3-8 for an example of the format in which the preliminary information should be presented. The following specific criteria apply to format preparation:

1) Specific front panel nomenclature for circuit breakers, switches and controls will be lettered exactly as it appears on the panel markings, and presented as white letters on a black background.

2) Circuit breakers, switches and controls without specific nomenclature will be identified by their common names with black upper case lettering.

3) Sufficient piece-part identification should be provided for fabrication of special test fixtures (when appropriate) to allow the technician to order the required items.

4) Group circuit breakers, switches and controls by location in the table to reduce the movement required of the technician in verifying or positioning these items.

8. <u>Specify Sequence of Procedures for Checkout of Functional Unit</u>

The requirement of this activity is to identify the sequence of procedures necessary to exercise all end items contained in the functional unit. The effort involved in meeting this requirement is principally an operational mode analysis of the functional unit which results in segmentation of the total procedure into discrete groups of steps, and insures proper sequencing of segments and steps by following the signal flow through the interrelated end items appropriate to each mode of operation. This effort also involves a review of all maintenance activities appropriate for the end items to suggest the impact of servicing, alignment, and calibration requirements on the total functional unit performance. The source data for the operational checkout procedures should be identified on the Trouble-

Figure 1. Test Equipment

NAME	AN, PART, OR STOCK NO.	USE AND APPLICATION
CONTROLS SYSTEM RIGGING KIT	3500009 (LOCKHEED NO.)	KIT INCLUDES AN INCLINOMETER FOR MEASURING ANGLES.
GAUGE, PUSH-PULL DIAL	DPP-50 (CHATILLON NO.) OR 6635-578-5286 TORQUE WRENCH (50 to 400 INCH POUND RANGE)	TO MEASURE FORCES REQUIRED TO ROTATE THE CONTROL WHEEL.
GENERATOR SET	6115-553-8957, 6115-663-5595, OR 6125-669-6754	TO ENERGIZE ELECTRICAL CONTROL CIRCUITS.
HYDRAULIC TEST STAND	4920-670-9415 OR 4920-615-4248	TO PRESSURIZE NO. 1 AND NO. 2 HYDRAULIC SYSTEMS.
TESTER, SPRING RESILIENCY, PORTABLE (MODEL L-10)	6635-550-6496	TO MEASURE BREAKAWAY AND FRICTION FORCES AT THE CONTROL WHEEL.
TESTER, COMPRESSION AND TENSION (MODEL L30-M)	6635-578-5286	TO MEASURE CONTROL WHEEL OPERATING FORCES OF 10 TO 30 POUNDS.
TENSIOMETER	6635-530-1128	MEASURING TENSION IN CONTROL CABLES.
MULTIMETER	AN/PSM-6	MEASURING VOLTAGES AND CONTINUITY.

PERSONNEL REQUIRED

TWO MEN WITH INTERCOMMUNICATION SETS ARE REQUIRED TO TROUBLESHOOT AILERON CONTROL AND TRIM SYSTEM. STATION MAN A AT FLIGHT STATION TO OPERATE CONTROLS. STATION MAN B AS REQUIRED TO OBSERVE MOVEMENT OF AILERON CONTROL SURFACES AND LINKAGES, AND TO MAKE NECESSARY RIGGING CHECKS AND CONTROL SURFACE MEASUREMENTS.

EQUIPMENT CONDITION

1. AIRCRAFT MUST NOT BE ON JACKS AND FUEL TANKS SHOULD BE LESS THAN HALF FULL.
2. RESERVOIRS FOR NO. 1 AND NO. 2 HYDRAULIC SYSTEMS MUST BE PROPERLY SERVICED.

[redacted]

IF NO. 1 AND NO. 2 HYDRAULIC SYSTEMS HAVE HAD RECENT CORRECTIVE MAINTENANCE, THEY MUST BE BLED AND CHECK OPERATED ACCORDING TO THE CORRESPONDING CHECKOUT PROCEDURE.

[redacted]

IF AILERON POWER CONTROL ASSEMBLIES HAVE BEEN INSTALLED RECENTLY OR HAVE BEEN INOPERATIVE FOR A LONG TIME, BLEED THE VALVE DAMPER ASSEMBLIES ACCORDING TO SERVICING INSTRUCTIONS FOR POWER CONTROL ASSEMBLY SERVOVALVE DAMPER.

3. ROTATE PILOT'S CONTROL WHEEL TO NE CATED BY INDEX MARKS ON WHEEL HUBS ON TOP OF CONTROL COLUMNS.

[redacted]

ENGAGING OR DISENGAGING THREE PH WITH THE ELECTRICAL SYSTEM ENERGIZED DAMAGE TO MOTORS BY OVERLOADING PHASES. ALWAYS VERIFY THAT ELECTRIC FORE ENGAGING OR DISENGAGING CIR APPLY UNSWITCHED POWER DIRECTLY TO

4. ASSURE THAT CIRCUIT BREAKERS LISTED IN
5. ASSURE THAT SWITCHES ARE POSITIONED

Figure 2. Functional Ci

CIRCUIT BREAKER NAME
[redacted] PHASE A
HYD SYS NO. 3 PUMP NO. 1 PWR PHASE B
HYD SYS NO. 3 PUMP NO. 1 PWR PHASE C
[redacted] PHASE A
HYD SYS NO. 3 PUMP NO. 2 PWR PHASE B
HYD SYS NO. 3 PUMP NO. 2 PWR PHASE C
[redacted] PHASE A
AILERON TAB ACTR [redacted]
AILERON TAB ACTR [redacted]
[redacted]
WARN LT TEST & ANNUN CONT [redacted]
WARN LT TEST & ANNUN CONT [redacted]
[redacted]
LH AILERON [redacted]
[redacted]
RH AILERON [redacted]
LH AILERON [redacted]
RH AILERON [redacted]
[redacted]
HYDRAULIC SYSTEM NO. 3- [redacted]
HYDRAULIC SYSTEM [redacted] -

A

...L WHEEL TO NEUTRAL POSITION AS INDI-
...ON WHEEL HUBS ALIGNED WITH SCRIBE MARKS
...OLUMNS.

[redacted]

...GING THREE PHASE CIRCUIT BREAKERS
...TEM ENERGIZED COULD RESULT IN
... OVERLOADING ONE OF THE MOTOR
... THAT ELECTRICAL POWER IS OFF BE-
...ENGAGING CIRCUIT BREAKERS THAT
...ER DIRECTLY TO THREE PHASE MOTORS.

...AKERS LISTED IN TABLE 4-1B ARE CLOSED.

...E POSITIONED ACCORDING TO TABLE 4-1C.

...ctional Circuit Breakers

...E	BUS	FLT. ENGR. CKT. BKR. PNL.
...PHASE A	MAIN AC NO. 1	NO. 1
...R PHASE B	MAIN AC NO. 1	NO. 1
...R PHASE C	MAIN AC NO. 1	NO. 1
...PHASE A	MAIN AC NO. 3	NO. 1
...R PHASE B	MAIN AC NO. 3	NO. 1
...R PHASE C	MAIN AC NO. 3	NO. 1
	ESSEN AC NO. 1	NO. 2
	ISOLATED DC	NO. 3
	ISO[illegible]ED DC	NO. 3
[redacted]	ISOLATED DC	NO. 3
[redacted]	ISOLATED DC	NO. 3
[redacted]	ISOLATED DC	NO. 3
	MAIN DC NO. 1	NO. 4
	MAIN DC NO. 2	NO. 4
	MAIN DC NO. 1	NO. 4
	MAIN DC NO. 2	NO. 4
	MAIN DC NO. 2	NO. 4
	MAIN DC NO. 2	NO. 4
	MAIN DC NO. 1	NO. 4
	MAIN DC NO. 1	NO. 4
	MAIN DC NO. 2	NO. 4

Figure 3. Preliminary Control Settings

CONTROL NAME	SETTING	LOCATION
RIGHT AILERON SYS 1	[redacted]	PILOT'S FORWARD OVERHEAD PANEL
RIGHT AILERON SYS 2	[redacted]	PILOT'S FORWARD OVERHEAD PANEL
LEFT AILERON SYS 1	[redacted]	PILOT'S FORWARD OVERHEAD PANEL
LEFT AILERON SYS 2	[redacted]	PILOT'S FORWARD OVERHEAD PANEL

[redacted]

1. AF63-8075 THROUGH 63-8077 IF NOT MODIFIED BY ECP LH-C141-100-181K AND AF63-8078 THROUGH 63-8037 IF NOT MODIFIED BY T.O. 1C-141A-616.
2. AF61-2775 THROUGH 61-2779, AF63-8075 THROUGH 63-8077 IF MODIFIED BY ECP LH-C141-100-181K, AF63-8078 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-616, AND AF63-8088 AND UP.
3. AF61-2775 THROUGH 61-2779 IF NOT MODIFIED BY T.O. 1C-141A-788
   AF63-8075 THROUGH 63-8077 IF NOT MODIFIED BY T.O. 1C-141A-788 & ECP LH-C141-100-181K
   AF63-8078 THROUGH 63-8079 IF NOT MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8081 THROUGH 63-8078 IF NOT MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8080 THROUGH 63-8078 IF NOT MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8082 THROUGH 63-8087 IF NOT MODIFIED BY T.O. 1C-141A-[illegible] & T.O. 1C-141A-616
4. AF61-2775 THROUGH 61-2779 IF MODIFIED BY T.O. 1C-141A-788
   AF63-8075 THROUGH 63-8077 IF MODIFIED BY T.O. 1C-141A-788 & ECP LH-C141-100-181K
   AF63-8078 THROUGH 63-8079 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8081 THROUGH 63-8079 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8080 THROUGH 63-8079 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8082 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF 63-8088 AND UP
5. TERMINAL STRIPS INSTALLED IN AF 63-8075 AND UP. LEADS ARE WIRED STRAIGHT THROUGH IN AF61-2775 THROUGH 61-2779.
6. AF 63-8075 THROUGH 63-8077 IF NOT MODIFIED BY ECP LH-C141-100-181K
   AF 63-8078 THROUGH 63-8087 IF NOT MODIFIED BY T.O. 1C-141A-616
7. AF 61-2775 THROUGH 61-2779 IF MODIFIED BY ECP LH-C141-100-181K
   AF63-8075 THROUGH 63-8077 IF MODIFIED BY ECP LH-C141-100-181K
   AF63-8078 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-616
   AF63-8088 AND UP
8. AF61-2775 THROUGH 61-2779, AF63-8075 THROUGH 63-8077 IF MODIFIED BY ECP LH-C141-100-181K, AF63-8078 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-616, AND AF63-8088 AND UP

Figure 3-8 Preliminary Information Sheet

B

shooting Aid Data Sheet.

The sequence of procedures will be adequately specified when the following criteria have been met:

a. All positions of all switches and each operating control must be exercised by the procedure.

b. The procedure must be developed in terms of gross level segments. Identification of these segments may be based on, but not necessarily restricted to, the segments defined on the functional unit block diagram (Activity 4).

c. Sequence of segments must be specified in order to mechanize the functional unit for operation. A suggested list of segments is:

1) Apply energy source.

2) Establish zero reference (if appropriate for functional unit).

3) Checkout control input (if appropriate for functional unit). An example is checkout of mechanical rigging.

4) Operate total functional unit (if appropriate for functional unit, to null input and output, and to "bleed" hydraulic components and/or free mechanical friction resulting from functional unit inactivity).

5) Operate in primary mode.

6) Operate in secondary mode (if appropriate).

7) Operate in all additional modes (when appropriate). Each mode should be treated as a separate segment.

8) Perform special tests (if appropriate). Such tests are:

(a) Simulated environment

(b) Self test

8) Shut down and remove energy source.

d. Segments which must be performed for the energizing of the equipment into full operational status shall be numbered sequentially and placed flush left. Procedures which can be exercised as options after an energizing procedural step and before the next energizing procedural step, i.e., mode changes, range changes, and checkout procedures, shall be lettered sequentially within the numbered step and indented.

e. Specify sequence of steps within segments to develop signal flow from input to output.

f. Identify as steps all personnel performances that produce observable results, and specify the results in terms of expected nominal values and acceptable tolerances.

g. If sequencing of either segments or steps is not dependent upon progressive functional unit mechanization, specify the sequence to minimize movement of the technician in meeting performance requirements.

h. Develop a procedures-by-end-item matrix. List the sequence of procedures down the left hand column, and enter the principal end items from the end item list (Activity 6) across the top. Using the integrated schematic and parts location illustration, trace the signal flow for each procedural step. Enter an "X" in the column for each end item involved in the performance of each step, in the row corresponding to each specific step. This will verify that all end items contained within the functional unit have been exercised by the procedure. If any end item columns do not have at least one entry, either the procedure is not adequate, or the end item has been mistakenly included in the functional unit.

8. <u>Select Appropriate Troubleshooting Aid Format</u>

The requirement of this activity is selection of either a Symptom-Cause Chart or a Maintenance Dependency Chart format as the best means for presenting specific functional unit troubleshooting information to the technician. The format selected should be simple in terms of interpretation and should provide sufficient information to permit the technician to accurately isolate the malfunction with a minimum of time and effort.

Since a malfunction symptom is the result of an interrupted or distorted controlled signal flow, the troubleshooting aid must be capable of identifying every possible source of interruption or distortion. In very simple systems with few components and a singular signal flow, Symptom-Cause Charts may be adequate.

The utility of a Maintenance Dependency Chart is most fully developed when the signal flow diverges as a result either of switching actions or proper end item function; when signal flow occurs through separate but dependent paths; when signals converge from either separate sources or through separate paths, and when the troubleshooting procedure is so complex that an extreme amount of verbal redundancy would be necessary to present all necessary information concerning the dependency of signal flow to describe the required operations.

The above ground rules represent the preliminary screening technique. Based on the knowledge of the functional unit acquired during development of the integrated schematic and sequence of procedures, personnel responsible for developing the aid must now consult the criteria for either type of aid to determine which format to use. The criteria for Symptom-Cause Chart format are discussed in Activities 10 and 11, and the criteria for Maintenance Dependency Charts are discussed in Activities 12 and 13.

10. Specify Failure Modes

The requirement of this activity is to identify all symptoms resulting from the failure of each individual end item and interfacing functional units during normal system operation. In order to assure identification of all symptom-cause relationships for a functional unit, a failure mode analysis should be conducted which will specify the malfunction indication resulting from the failure of each end item involved in each operational mode.

Figure 3-9 represents a suggested work sheet for this analysis. The functional unit name and number are entered at the top of each sheet in the list. The sequence and total number of the sheets in the analysis are also entered on this line. The operational procedure (from Activity 8) should be entered in the first column of the form. End items associated with each operational step should be entered in the second column, as well as interfacing functional units that could be the cause of symptoms relative to this functional unit. The potential failure mode of each second column entry should be identified in the third column. Such entries might include: "broken", "shorted", "open", "fails high", "fails low", or short descriptors of other failure modes appropriate to the end item. The malfunction indication, or symptom, resulting from each end item failure mode should be entered in the fourth column, in terms of deviation from the expected result of the operational step. The fifth column should identify the location or test point for observing the symptom. Any additional qualifying information, such as test equipment requirements or references to adjustment procedures, should be entered in the "Remarks" column.

11. Prepare Symptom-Cause Chart

The requirement of this activity is to present the troubleshooting information in a Symptom-Cause Chart format. Figure 3-10 is an example of this Symptom-Cause Chart format. Completion of the failure mode analysis (Activity 10) will provide the basis for meeting the following criteria for Symptom-Cause Chart presentation.

a. All symptoms of functional unit end malfunctions must be specified.

b. A one-to-one relationship must exist between symptom and cause.

FAILURE MODE ANALYSIS OF ______________________ FUNCTIONAL UNIT, NO. __________ SHEET ____ OF ____

OPERATIONAL PROCEDURE	INTERFACE FUNC UNIT/ END ITEM	FAILURE MODE	SYMPTOM	TEST POINT	REMARKS

Figure 3-9 Failure Mode Analysis Worksheet

MALFUNCTION IN STARTING MODE (CONTINUED)

SYMPTOM	PROBABLE CAUSE	ISOLATION PROCEDURE	REMEDY
ENGINE ACCELERATES WITH STARTER BUT FAILS TO "LIGHT OFF". (CONTINUED)	Defective exciter unit.	Substitute unit known to be good. **WARNING** Lethal voltage may remain in capacitor of exciter unit after system is turned OFF. Be sure to discharge capacitor by grounding connector spring of igniter plug lead. To discharge capacitor when lead is removed from engine, ground center electrode with insulated screw driver. Be sure screw driver is touching electrode.	Replace exciter unit.
	Fuel control malfunction.		If all the above items have checked satisfactorily, replace the fuel control.
ENGINE "LIGHTS OFF" BUT FAILS TO ACCELERATE TO IDLE SPEED (HUNG OR SLOW START)	Starter speed too low due to inadequate air supply to starter.	Check starter control valve for proper operation.	Replace the valve.
		Check air supply.	Turn off all pneumatically operated equipment and attempt to start the engine. If engine speed is still too low, troubleshoot the APU or replace the external air supply, whichever is applicable.
	Starter cut-out relay operating too soon.	Check maximum speed that starter (alone) will rotate engine.	Replace starter.
	Internal interference between rotating parts.	Discontinue start and listen for rubbing or scraping sounds during coast down.	Replace the engine.
	Air trapped in fuel system.		Bleed control by exercising power lever. If results are unsatisfactory, bleed control.
	Constant speed drive not disconnected.		Disconnect CSD.
	P_b sensing line leaking.	Check tube for leaks and cracks.	Overcome leak or replace tube.
	Fuel control malfunctioned.	Check engine trim.	If retrimming the engine does not remedy the trouble, replace the fuel control.
	Fuel control linkage improperly rigged.	Check angle of pointer at fuel control at fuel control when throttle lever is in [redacted]	Correct rigging of linkage.
	Burner pressure signal line restricted.	Disconnect signal line and check for restriction.	Remove restriction.
	Leaks or restrictions in fuel system. Suspect ice during conditions conducive to icing.	Check systems for leaks or restrictions. Check for dirty or clogged fuel pump or fuel control filters.	Clean filters. Repair or replace components as necessary.
	Defective fuel control.	Check fuel flow gage for fuel control output. Will normally indicate minimum flow. Burner pressure sensing mechanism not sufficiently sensitive at transition point to permit further acceleration.	Replace fuel control

MA

SYMPTOM	P
ENGINE "LIGHTS-OFF" BUT FAILS TO ACCELERATE TO IDLE SPEED (HUNG OR SLOW START) (CONTINUED)	P_b fue (C
	Def
	Pre val air
	Def sur
	Def or v
HIGH FUEL FLOW, HIGH EGT, WITH OR WITHOUT TORCHING DURING START.	Ice con bel
	Fue dur ing shu
	Fue trim
	Fue func
EXHAUST GAS TEMPERATURE EXCEEDS LIMITS DURING START. (SEE MAINTENANCE ACTION REQUIRED FOR ENGINE OVERTEMPERATURE CONDITION.)	Def cat
	Def syst
	Sta eng
	Fuel dum ing shu
	Fue trim
	Def
ENGINE ROTATES WITH STARTER AND "LIGHTS OFF" BUT ACCELERATION BECOMES SLOW AT TRANSITION POINT (MINIMUM FUEL FLOW).	Def

F

A

	REMEDY
... of ... Be ... g ... To ... ved ... with ... river	Replace exciter unit.
	If all the above items have checked satisfactorily, replace the fuel control.
	Replace the valve.
	Turn off all pneumatically operated equipment and attempt to start the engine. If engine speed is still too low, troubleshoot the APU or replace the external air supply, whichever is applicable.
	Replace starter.
g	Replace the engine.
	Bleed control by exercising power lever. If results are unsatisfactory, bleed control.
	Disconnect CSD.
	Overcome leak or replace tube.
	If retrimming the engine does not remedy the trouble, replace the fuel control.
n	Correct rigging of linkage.
	Remove restriction.
.	Clean filters. Repair or replace components as necessary.
	Replace fuel control

MALFUNCTION IN STARTING MODE (CONTINUED)

SYMPTOM	PROBABLE CAUSE	ISOLATION PROCEDURE	REMEDY
ENGINE "LIGHTS-OFF" BUT FAILS TO ACCELERATE TO IDLE SPEED (HUNG OR SLOW START) (CONTINUED)	P_b signal leakage past fuel control P_b limiter (CPRL).	Perform CPRL leakage check.	Replace fuel control.
	Defective fuel pump.	Check fuel pump outlet pressure.	Replace fuel pump.
	Pressurizing and dump valve mounting seal air leak.		Replace seal.
	Defective bleed pressure ration system.	Check that valve opening and closing points are within limits.	Replace pressure ratio system or defective unit.
	Defective bleed valve or valve actuator.	Check operation of valve. Check for leaks or restrictions in system.	Repair or replace defective components.
HIGH FUEL FLOW, HIGH EGT, WITH OR WITHOUT TORCHING DURING START.	Ice or water in fuel control pressure (P_b) bellows.		Drain bellows chamber and purge P_b sensing line.
	Fuel pressurizing and dump valve not draining fuel from engine at shutdown.	Check that the pump valve is open when the engine is not operating.	Replace the valve.
	Fuel control over-trimmed.	Check engine trim and throttle rigging.	Trim the fuel control or adjust the throttle rigging.
	Fuel control malfunction.		If the fuel control cannot be trimmed, replace it.
EXHAUST GAS TEMPERATURE EXCEEDS LIMITS DURING START. (SEE MAINTENANCE ACTION REQUIRED FOR ENGINE OVER-TEMPERATURE CONDITION.)	Defective EGT indicating system.	Check fuel flow reading at high EGT indication.	Replace faulty equipment.
	Defective starter system.	Check maximum speed at which starter rotates engine.	Replace starter or air valve
	Starter accelerating engine too slowly.	Check the air supply to the starter.	If the air pressure is too low, check the APU or external power cart.
		Check that the compressor unloading valve is open.	If the valve is stuck closed, replace the valve.
		Check that the starter control valve is fully open when the starter switch is actuated.	Replace the starter control valve.
	Fuel pressurizing and dump valve not draining fuel from engine at shutdown.	Check that the pump valve is open when the engine is not operating.	Replace the valve.
	Fuel control over-trimmed.	Check engine trim and throttle rigging.	Trim the fuel control or adjust the throttle rigging.
	Defective fuel system.	Fuel flow must not exceed 1200 pph during start.	If the fuel control cannot be trimmed, replace it.
ENGINE ROTATES WITH STARTER AND "LIGHTS OFF" BUT ACCELERATION BECOMES SLOW AT TRANSITION POINT (MINIMUM FUEL FLOW).	Defective fuel control.	Check fuel flow gage during slow acceleration. Will normally indicate minimum flow. Burner pressure sensing mechanism not sufficiently sensitive at transition point to permit faster acceleration. Becomes worse with lower temperatures.	Replace fuel control if condition becomes intolerable.

Figure 3-10 Example of a Symptom-Cause Chart

B

c. The operational mode in which the symptom occurs must be identified.

1) Include the operational mode in the symptom description.

2) If there are several operational modes, prepare a separate chart for each operational mode and title each chart with the name of the operational mode.

d. The Symptom-Cause Chart must be a four-column format. The four columns are titled: Symptom, Probable Cause, Isolation Procedure, and Remedy.

1) Group all similar symptoms and make a single symptom description entry in the Symptom column. Separate all different symptom descriptions with a horizontal line across all four columns.

2) List each possible cause of the symptom in the Probable Cause column, with the most probable cause appearing first and the least probable cause appearing last. Separate all probable causes with a horizontal line across columns two, three and four.

3) Specify the procedure to follow in isolating each probable cause in the Isolation Procedure column, directly adjacent to the probable cause for which it will isolate.

4) Specify the action to be taken to correct the malfunction in the Remedy column, directly adjacent to the isolations procedure that identifies the cause.

12. Specify Maintenance Dependency Chart Interrelationships and Fault Isolation Steps

The requirement of this activity is to specify the interrelationships of all end items by the operational procedural steps, identifying additional steps when appropriate to isolate the malfunctioning end item, and describing the characteristics of signal flow at available checkpoints identified by the specification of end item relationships. This requirement can be met by converting the procedures-by-end-item matrix (developed in Activity 8) into a rough Maintenance Dependency Chart, and adding test routines as substeps under the procedural steps on the matrix.

a. Characteristics of a Maintenance Dependency Chart. A Maintenance Dependency Chart is a chart which illustrates the dependency and interrelation of all elements and functional entities within the equipment or system by use of symbols. The dependency charts shall provide data necessary to diagnose the equipment. These charts shall conform to the following:

1) By graphic means, show all of the circuit interdependencies in such a manner as to facilitate troubleshooting.

2) Identify all significant checkpoints and indications necessary to troubleshoot the equipment. These must be arranged in a manner which minimizes the number of checks that a technician must make to isolate a malfunction.

3) Present all signal data (waveforms, angular motions, timing, voltage, pressures, etc.) in a manner to facilitate its use in troubleshooting.

4) Relate key troubleshooting to procedural data (turn-on, adjust, calibrate, operation, alignment, and performance check).

b. Criteria for Development of a Maintenance Dependency Chart. The chart shall be laid out in quadrille fashion and shall consist of the following four basic parts: headings, notes, procedure, and body. Column headings list the name and hardware location of functional entities, circuit elements, and event indicators. An event is defined as an action, or the presence of a voltage, signal or other data at a defined point, that results from a turn-on, operational, or checkout procedure, or the presence of initiation data. Notes shall provide specifications and, as necessary, descriptions of the events that occur in the column below. The procedure column shall contain steps, as necessary, which specify the operational or checkout procedure required to obtain all of signal availabilities developed as a result of the step. By the use of symbols the body of the chart shall present the relationship between functional entities and events. In preparing this type of chart, all circuits of the equipment must be exercised in a manner which permits logical diagnosis.

An example of Maintenance Dependency Chart l ut is presented in Figure 3-11. The following criteria apply to development of the chart:

1) <u>Headings</u>: Column headings shall list the name and location of the action indicators, event or availability points (including availabilities from other functional units) and end items (also referred to as functional entities or circuit elements). With the exception of availabilities existing at schematic test points, this information should appear across the top of the procedures matrix (Activity 8) and in the end item list (Activity 6).

   (a) End item or Functional Entity Entries --end items, circuit elements, or circuit element groupings (functional entities) include:

      (1) Part of a circuit element

      (2) A circuit element

      (3) A stage or group of circuit elements

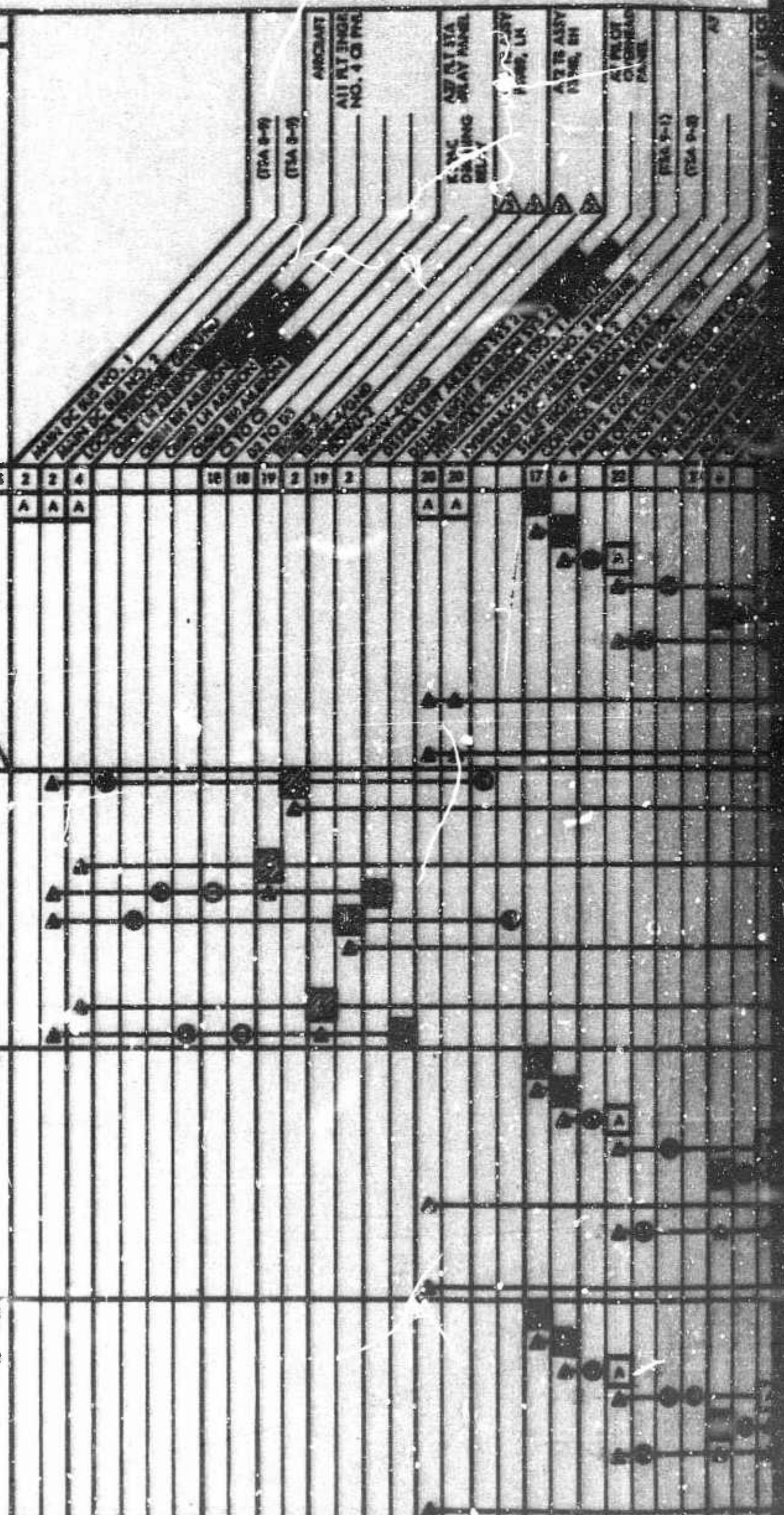
      (4) A group of stages

      (5) A replaceable module or group of modules.

As shown in Figure 3-12, the extreme top of the MDC

TURN ON PROCEDURE

SIGNAL SPECIFICATIONS



6. ROTATE PILOT'S CONTROL WHEEL TO CYCLE AILERONS THROUGH SIX COMPLETE CYCLES TO BLEED SYSTEMS, AND RETURN TO NEUTRAL POSITION.

[illegible]

IF THE AILERON SYSTEM CHATTERS OR SHOWS SIGNS OF INSTABILITY DURING OPERATION, BLEED THE POWER CONTROL ASSEMBLY VALVE DAMPERS.

7. CHECK OPERATION WITH HYDRAULIC SYSTEM 1.

A. SET LEFT AILERON SYS 2 AND RIGHT AILERON SYS 2 SWITCHES TO [illegible]

B. MEASURE FORCE REQUIRED TO ROTATE PILOT'S CONTROL WHEEL CLOCKWISE FROM NEUTRAL POSITION UNTIL LEFT AILERON STARTS TO MOVE FROM FAIRED POSITION.

C. MEASURE FORCE REQUIRED TO ROTATE PILOT'S CONTROL WHEEL CLOCKWISE UNTIL LEFT AILERON REACHES A POSITION 15 (±1) DEGREES OR 13-1/32 (±26/32) INCHES DOWN FROM FAIRED NEUTRAL POSITION.

(CONTINUED)

A

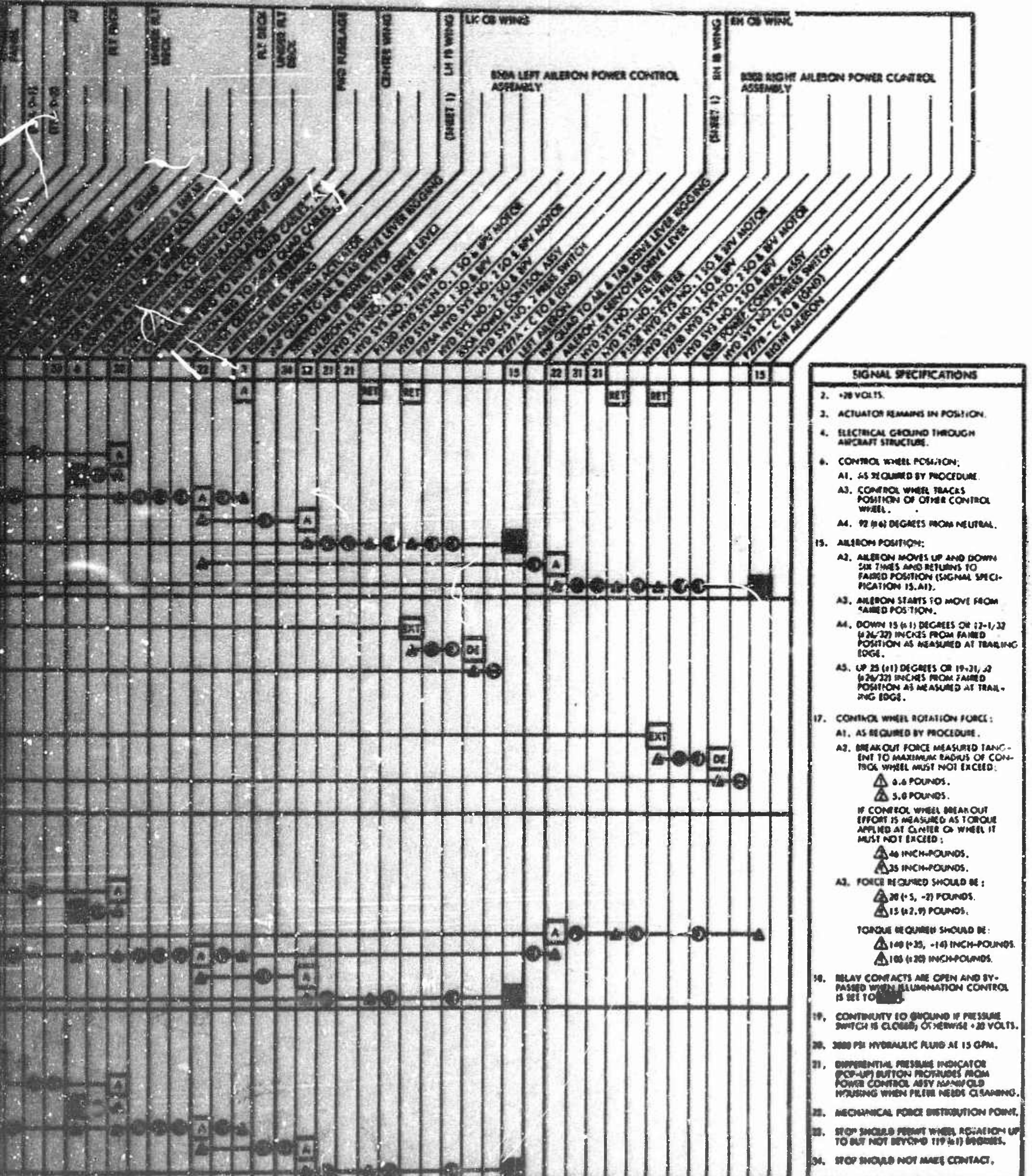


Figure 3-11 Typical Maintenance Dependency Chart

B

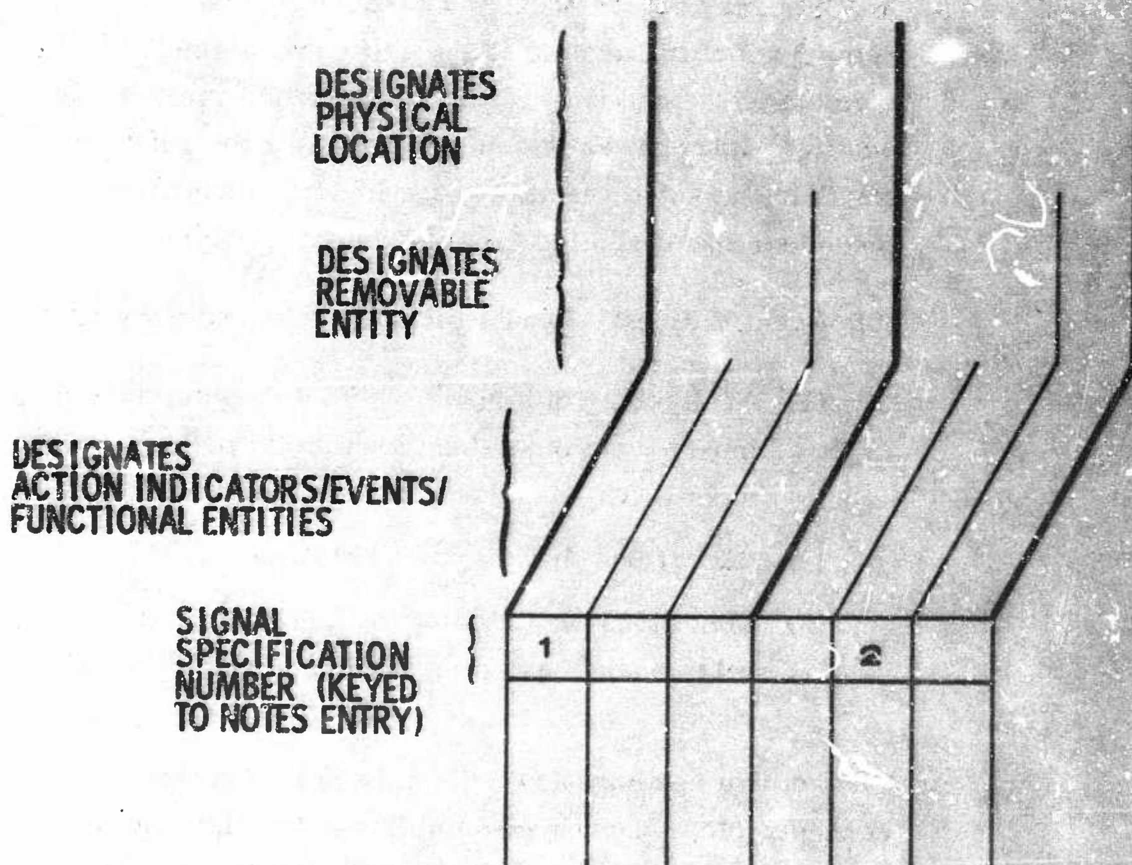


Figure 3-12 Maintenance Dependency Chart Heading Section

Heading section (the area above the slanted circuit element entry column) is reserved for end item identification and physical location information. All functional entity nomenclature shall be consistent with that appearing on the end item list (Activity 6). Assembly numbers, colloquial names, or abbreviations may be used as a reference key. Once the location information has been spelled out on the MDC, it may be abbreviated where appropriate on the remainder of the sheet. In the event that a single circuit element is the end item, it is not identified again in the end item entry area. When adjacent columns refer to items in the same assembly, the location identifier is placed so that it applies to more than one column.

(b) Event Entries. Events include such conditions as:

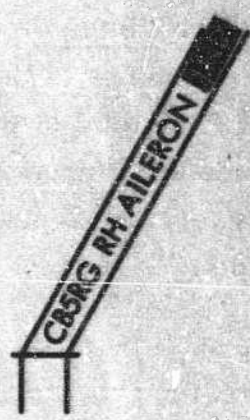
(1) Availability of signals or power inputs, including inputs from other functional units or test equipment (when required).

(2) Indications that may be observed.

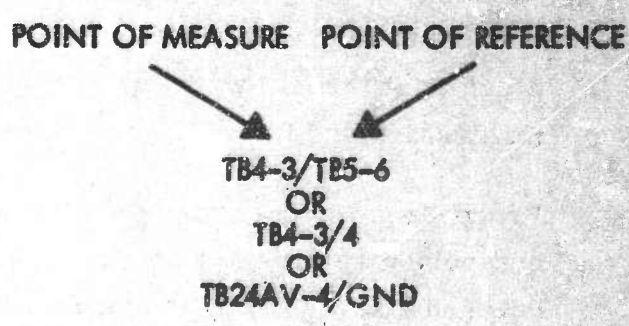
(3) Conditions or states of the equipment, i.e., relay energizes, temperature normal, motor runs.

The column headings for indicators of action that are recognizable without disassembling the equipment, e.g., front-panel indicators or front-panel test points, are solid black with white lettering. All other column headings have a white background with black lettering.

For events which are to be observed, the point of observation is entered as a column heading. When the indication is observable from the outside of the equipment, the panel nomenclature for the indication or a descriptive action identifier is illustrated by white lettering on a black background. During development, this is illustrated by placing a box around the letters to appear on the block, and blocking in the upper left-hand corner of the box as follows. See Figure 3-10 for its appearance in the MDC heading.



For events which are to be measured, the points of measure are listed as follows. See Figure 3-10 for its appearance in the MDC heading.



Signal Specifications -- Specifications or description for the event or action to be observed or measured shall be referenced by a number located in a box at the base of the column heading. The specification numbers at the base of the column heading shall refer to signal specification notes in the right-hand margin of the chart. The numbers should be independent and sequential throughout all specifications. Specification numbers for each functional unit shall begin with the number one, and refer to identical specifications, i.e., 115V, always carries the same specification number.

2) Procedure Column. Procedural steps shall be provided as line headings in the left hand column of the dependency chart. The total of the procedural steps shall completely exercise each functional entity. The procedural steps shall exercise all positions of all switches and operating controls.

There shall be a one-to-one correlation between the steps in the MDC procedure column and the operational check-out steps (Activity 8) to provide for direct access to the dependency chart step from the operational checkout step. However, dependency chart steps may have additional substeps which are performed to break into the circuit or to inject known signals for fault isolation. These substeps will cover portions of the equipment for which no external symptoms are developed incident to malfunction and for which no self-test facility exists.

Procedures for operating the external test equipment will not include set up information if this information is covered elsewhere. For standard test equipment, the operational step shall be worded as: "Adjust Hydraulic Test Stand for 3000 ($\pm$ 150) PSI". For special purpose test equipment, the step shall be worded as: "Set Test Set [redacted] switch to [redacted] ".

Each procedural step shall be enclosed between bold lines across the body of the chart to indicate events or availabilities which are associated with the procedural step.

3) <u>Body.</u> The body of the chart shall consist of a series of horizontal lines on which are represented the dependency of circuit action from the performance of a procedural step. Each line will represent a short series path from a signal availability point (test point or other) to an indication, or to a branch point (availability point) directly or through circuit elements, or through functional entities. The lines shall be arranged from top to bottom in order of increasing dependency.

Each branch point, whether a divergent or convergent branch, shall be identified as a test location (availability point) whether or not a test jack has been provided. Each branch point shall have an availability for the voltage or signal at that branch point.

(a) Basic Symbols. Only three basic symbols are to be used to represent the functional entities or circuit elements in the short series paths on the body of the chart:

Event Box:	□	To represent an action or availability of one or more events resulting from the proper operation of the functional entities associated with the event.
Functional Entity Dot:	●	To represent a functional entity or a group of functional entities.
Dependency Marker:	▲	To indicate dependency upon another event.

Special configurations of the basic symbols are sometimes used to advantage. Most of the frequently used variations of the three basic symbols are presented in Figure 3-13.

(1) Event Box -- Nomenclature in the event box specifies the type of action or availability of the event. The definition of symbols table lists the various nomenclatures that can appear in the box and their meaning. To assist in determining the accessibility of the events indicated on the Maintenance Dependency Charts, three distinguishable kinds of backgrounds are used within the event boxes. These backgrounds and their uses are:

BLACK (with white lettering) — Events which may be recognized from outside the equipment. Examples are: Front panel meters, front panel lamps, PPI display, motor running, etc. Notice that this recognition includes events other than those which may be observed by sight.

Note: When developing the MDC, use black letters in the box and blacken in the upper left hand corner as shown: $\boxed{A}$

CROSS HATCH (with black lettering) — Events which may be determined or observed only after the equipment enclosure has been opened, and which are readily accessible, (These events may or may not require the use of test equipment for their recognition.)

WHITE $\boxed{A}$ — Events which are too difficult to gain access and which require the use of test equipment for observation.

(2) Functional Entity Dot --The purpose of the circuit element entry is to identify the end items involved in energy flow or energy

CATEGORY	SYMBOL	MEANING
EVENT		Event symbol background indicates ease of access.
		Black: Front Panel, recognized from outside the equipment.
		Cross Hatch: Easy Access, requires opening of equipment enclosure (may or may not require test equipment).
		White: Difficult Access, requires test equipment.
	NA	Signal not available.
	A	Signal available and within specification.
	A1 A2 etc.	Signal available and within specification, but under different procedural condition, or circuit path.
	REM A	Remains available, and within specification, but under different procedural conditions, or circuit path.
	LIT	Front panel indicator lit; filament lit.
		Indicator flashing.
		Motor runs within specification.
	EN	Relay or special purpose switch energized.
	DE	Relay or special purpose switch de-energized.
		Motor stops running.
	etc.	Indicator reads within specification, but under different procedural condition or circuit path.
		Previously lit indicator goes out.
	CLO	Functional entity closed.
	OPN	Functional entity open.
	EXT	Functional entity extended.
	RET	Functional entity retracted.
DEPENDENCY MARKER		Event on same line is dependent upon event or condition in column above proof marker.
		Event is dependent upon a redundant event or condition in column above proof marker.
SPECIAL NOTE MARKER	1	Special note pertaining to further identification of functional entity.
		Special note pertaining to aircraft effectivity.
FUNCTIONAL ENTITY		Circuit or circuit element that must function properly for event on same line to occur.
		Indicates functional entity requires more than one event to prove proper operation.
		No continuity through binary element.
		Continuity through binary element.
		Redundant circuit elements; either will produce event.

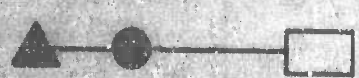
Figure 3-13 Definition of Symbols

transformation; therefore, the appropriate symbol to use to identify function flow is the functional entity dot. In some cases it is appropriate to show an availability at a circuit element terminal, but it is still necessary to enter the total entity as a circuit element and identify its function relative to energy flow with the appropriate symbol.

There are several variations of the functional entity dot. One such variation is the partial dot (◐) that indicates the functional entity which it represents is only partially involved in producing the corresponding event. Other variations of the functional entity dot are described in Figure 3-13.

(3) Dependency Marker -- A solid triangle is used to illustrate the dependency of a following event upon the availability or existence of a previous event. When any of multiple events may satisfy the subsequent dependency requirement, an open triangle with the letter R shall be used.

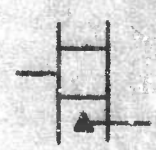
(b) Basic Dependency Structure. A dependency line consists of dependency markers, functional entities, and event boxes connected together. A dependency structure consists of a series of such dependency lines. Each dependency line is constructed using the three basic symbols. The simplest dependency line would appear as follows:



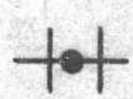
By itself, this dependency line has very little meaning except to indicate that the event ( ) is dependent upon the proper operation of the functional entity ( ) and the availability of some previous event ( ).

In order to provide meaning to this dependency line, the symbols are ordered into one of two types of columns: the event/dependency column and the functional entity column.

The event/dependency column consists of event boxes and dependency markers. The simplest event/dependency column would appear as follows:

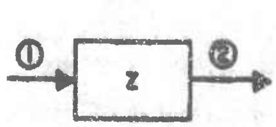


The functional entity column consists of only functional entities, even though these entities may be depicted more than once. The simplest form of a functional entity column would appear as follows:

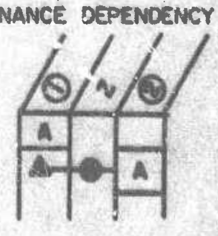


(1) Simple Dependency Line -- A functional entity with one input and a single output results in a simple dependency line as follows:

BLOCK DIAGRAM



MAINTENANCE DEPENDENCY CHART

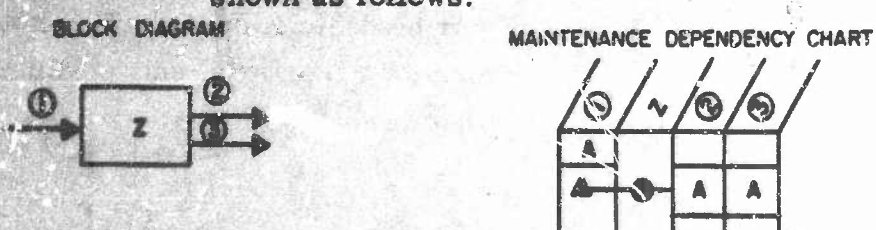


The MDC shows that the output event at (2) is dependent upon functional entity Z and the input event at (1).

(2) Multiple Input Dependency Line -- A functional entity with more than one input and a single output as a multiple input dependency line is shown as follows:

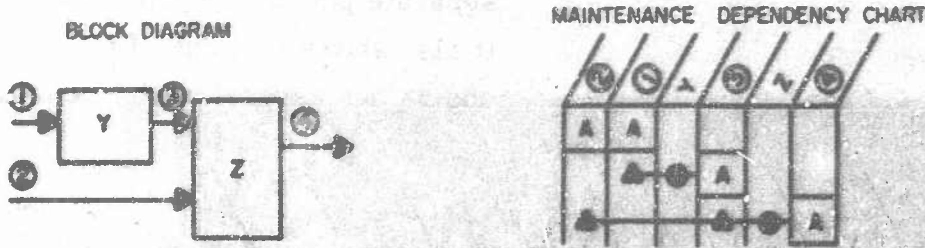
The MDC shows that the output event at (3) is dependent upon functional entity Z and the input events at (1) and (2).

(3) Multiple Output Dependency Line -- A functional entity having one input and multiple outputs is a multiple output dependency line shown as follows:



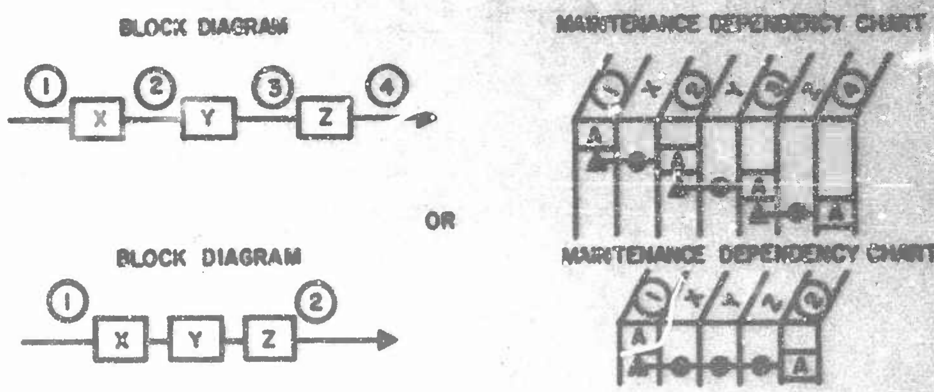
The MDC shows that both outputs at (2) and (3) are dependent upon functional entity Z and the input event at (1).

(4) Dependency Chain -- A dependency chain consists of a series of interrelated dependency lines. The following example shows a dependency chain consisting of two dependency lines.

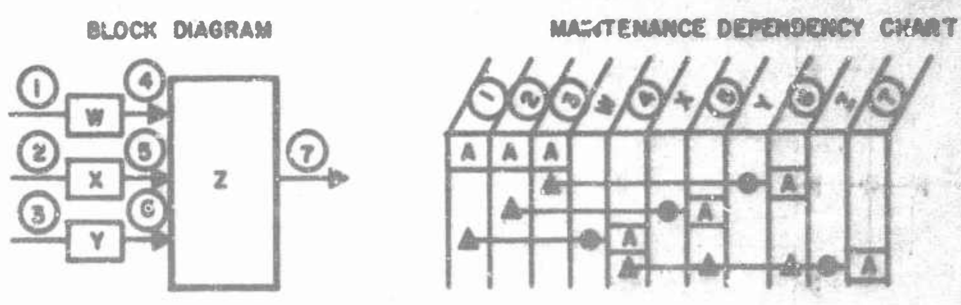


The last dependency line in this example shows that the output event at (4) is dependent upon functional entity Z and the event at (3) and (2)

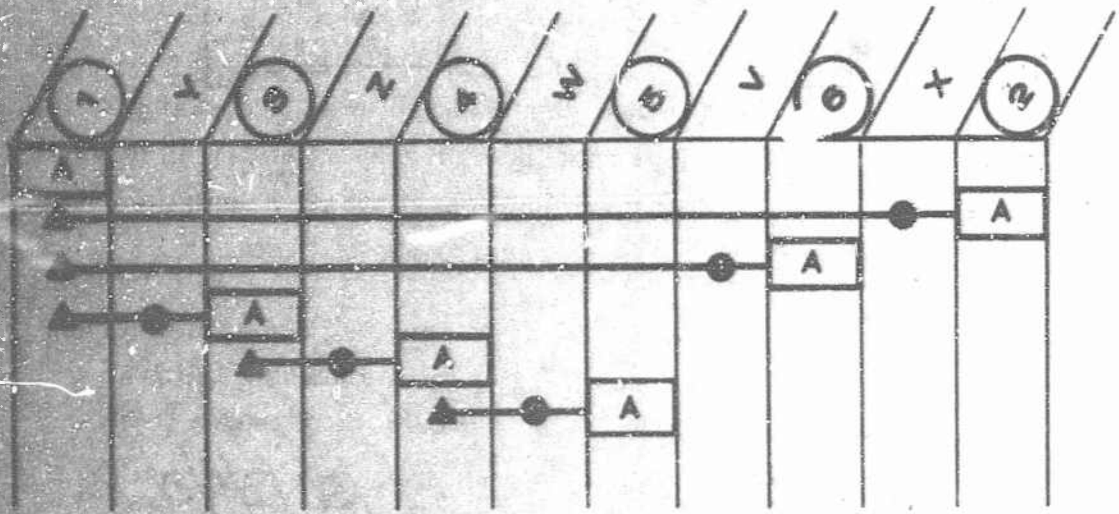
(a). Serial Relationships. As a rule serial relationships are shown as follows:



(b) Parallel Relationship. As a rule parallel relationships are shown as follows:

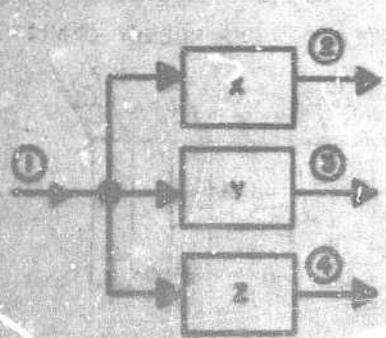


(c) Serial-Parallel Relationships. The following example shows clearly by its structural layout that there are three separate parallel dependency chains. It also shows that one of the dependency chains has several serial relationships.

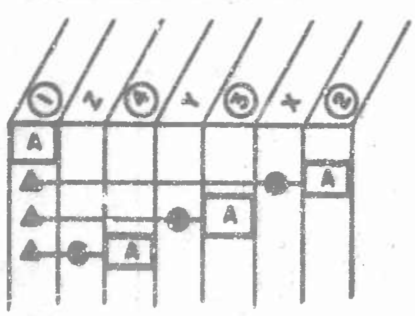


(d) Parallel Divergent Branches. When a path diverges into a number of paths, it is depicted by an event/dependency column using a single event and the appropriate number of dependency markers. This situation is shown as follows:

BLOCK DIAGRAM

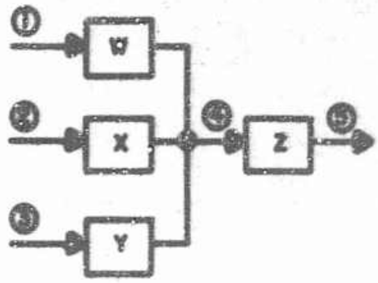


MAINTENANCE DEPENDENCY CHART

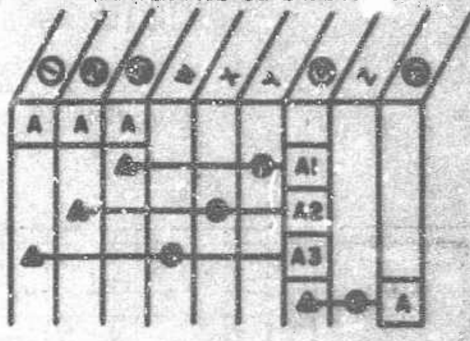


(e) Parallel-Convergent Branches. When paths converge into a single path, they are depicted by an event/dependency column using a composite event and a single dependency marker. This situation is shown thus:

BLOCK DIAGRAM

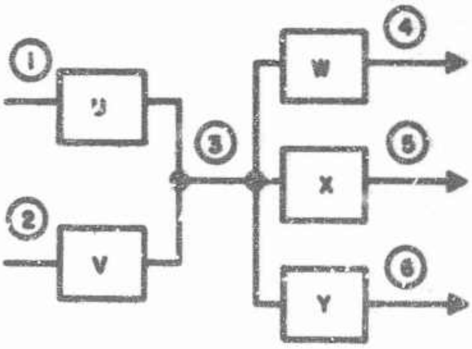


MAINTENANCE DEPENDENCY CHART

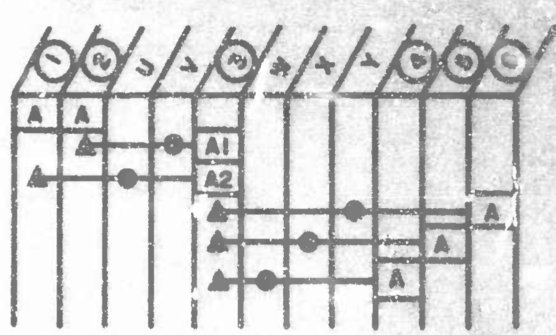


(f) Convergent-Divergent Branches. The following example illustrates a situation in which both divergent and convergent branches exist.

BLOCK DIAGRAM



MAINTENANCE DEPENDENCY CHART



(5) Time Delays -- Protective time delays, which occur after a procedural step is initiated, are illustrated by placing a band of screen shading horizontally across the page immediately after the entry of the time delay device. Time is assumed to begin with the setting of the switch that initiates the step in which the time delay occurs. The length of the time delay is indicated within the shaded band. When the time

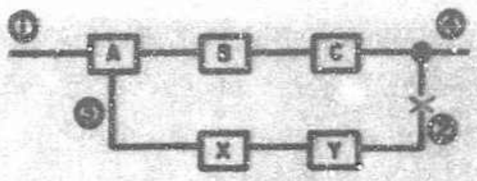
delay is not directly related to the step, special notations may be added within the time delay band, e.g., "2 seconds after motor exceeds 3000 rpm."

The time delay band shown in the following illustration indicates that event [redacted] is expected 11.0 (±1.5) seconds after the procedural step was accomplished.

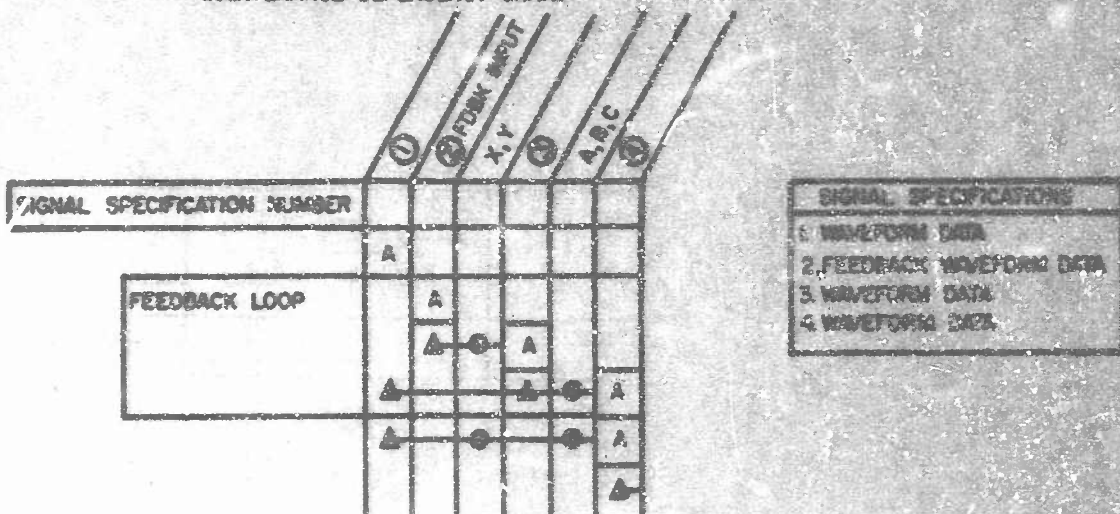
(6) Feedback Loop -- When the output of a circuit is sent back to appear as part of the input to the circuit, a feedback loop exists. To disclose the functional dependency of such a loop requires that the loop be broken. Under these conditions, the normal (main) input into the loop, plus a proper stimulus inserted at the break, will result in a known output. Breaking the loop allows functional dependency to appear as a simple serial dependency chain.

Feedback loops are identified in the procedure column and enclosed in a manner similar to checkout steps (refer to example Feedback Block Diagram and Maintenance Dependency Chart below).

FEEDBACK BLOCK DIAGRAM

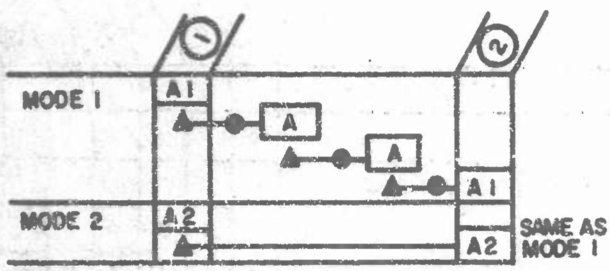


MAINTENANCE DEPENDENCY CHART



The complete dependency structure of the broken loop is then shown within the enclosed area. Directly below the enclosed area, the dependency structure of the loop is again shown but with the loop connected as normal. This structure appears as a horizontal line consisting of a dependency marker, a series of dots, and an output. In other words, the line shows that if the input to the loop is available and all functional entities within the loop are good, then the output of the loop is available. Using this technique, the detailed dependency structure of a feedback loop is disclosed while also showing how the loop as a whole fits into the general dependency scheme of the MDC when normally connected.

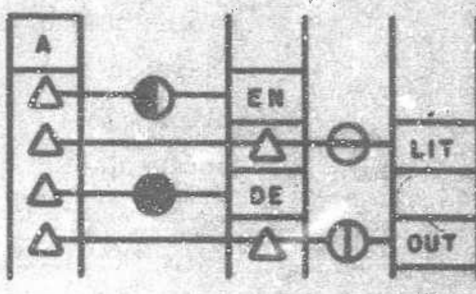
(7) Redundant Dependency Chains. When a complex dependency chain produces an end availability which proves a group of functional entities good under one mode of operation, it may be proven good under another mode as follows:



The two end availabilities above (furthest to the right) are measured at the same physical test point. The last line is interpreted thus: if A2 at 1 is now available, and if A1 at 2 was available during mode 1, then A2 at 2 is available for mode 2. This implies that all functional entities required for mode 1 are also necessary for mode 2. The words "same as mode 1" eliminate the need for redeveloping the entire dependency chain of mode 1 again for mode 2.

(8) Binary State Symbol --A variation of the circuit dot is the open circle containing a line in it. This symbol represents a circuit element which assumes one of two states. Examples of such elements are relay contacts, hydraulic valves, and thermal

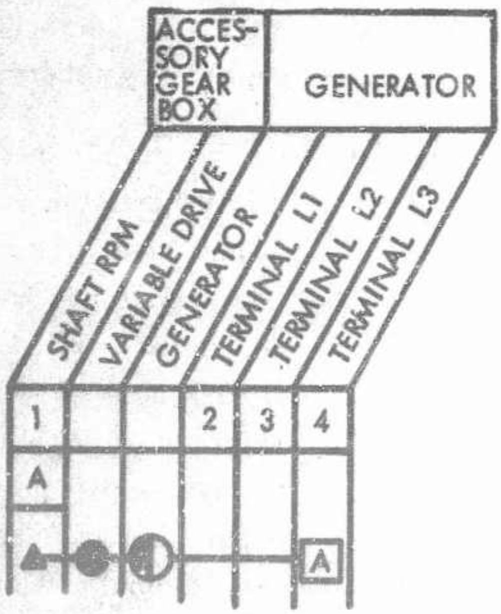
switches. The symbol (⊖) indicates continuity; whereas, (⦶) indicates discontinuity. Examples of their use are as follows:



(c) Dependency Chain Arrangement -- All initial input conditions are entered on the first line of the chart. Inputs are generally grouped at the left side of the chart. Outputs are generally grouped at the right side of the chart. Initial conditions, such as "Equipment Temperature Normal", are included as appropriate in the dependency scheme.

(d) Distribution Points --Other dependency charts may require the availability of a signal that is generated on this sheet. For easy access to this availability from the other dependency charts (or from another sheet of the same chart), it shall be located at the right of the MDC and is referred to as an End Distribution Point. Enter the availability point where it would normally occur (only if a dependency marker appears in that column) and repeat the event nomenclature entry and availability symbol as far to the right as possible to provide each access from other parts of the dependency chart.

(e) Identification of Circuit Elements Within a Higher Order Assembly -- When a higher order system (black box) is required to function in the circuit to produce the availability of an end item comprising that system, the black box should be entered as an entity. An example is illustrated below where operation of the generator is required to produce a signal at winding terminal L3. In this example, the generator is the circuit element required to convert the energy from the dependency (shaft rpm) to the availability (115 vac) at an accessible test point (terminal L3). The partial symbol indicates that this path does not completely validate generator operation.



(f) Mechanical Relationships -- Mechanical systems such as gear trains, follow energy relationship laws as do electrical or hydraulic energy flow systems. Such mechanical systems shall be depicted and charted in the same manner as electrical or hydraulic systems.

4) Signal Specification Notes. A dependency notes table shall list the description in terms of normal reading and tolerance data of voltage, revolutions per minute, pressure, etc., or black on white photographs of waveform and tolerance that are associated with each of the indications called for in the box at the base of the column heading (see Figure 3-11). Waveforms shall be retouched only as required to ensure that the pertinent technical information is visible, i.e., rise time, pulse width. The indication for an event shall be identified by a number identical to the number listed in the box. Only those signal specifications needed for a particular MDC sheet are included on it.

When different design series of the system require normal readings and tolerances, that information may be flagged by a triangle with the series designated by a number inside the symbol. This number will agree with the effectivity key appearing in a table on the preliminary information sheet (Activity 7).

13. Prepare Maintenance Dependency Chart in Final Form

The requirement of this activity is to identify the interrelationship of the functional unit end items and interfacing functional units in the formal MDC format. This is accomplished by rearranging the rough MDC developed in Activity 12 to meet the formal MDC format criteria identified in the following discussion and in the specifications governing MDC presentation.

a. Size of MDC Sheet. The size of a single MDC sheet in final form is 11 inches high by 17 inches wide.

b. Size of Body. The maximum space allocated for the body of the MDC is 6-3/4 inches high (including signal specification number entry box of the heading) by 11-1/4 inches wide.

1) The maximum number of entries on the finished form is 63 end items (horizontal arrangement) and 37 events (vertical arrangement).

2) If a single sheet requires more end item entries, a double width sheet is acceptable, where it begins at the left side of the left-hand sheet and extends across the binding to the right-hand page. This will permit a maximum of 143 end item entries and 37 events. Figure 3-14 below illustrates the doublesheet MDC layout when this approach is adopted. Note that the paths that cross the binding must be identified by a serial numeric system.

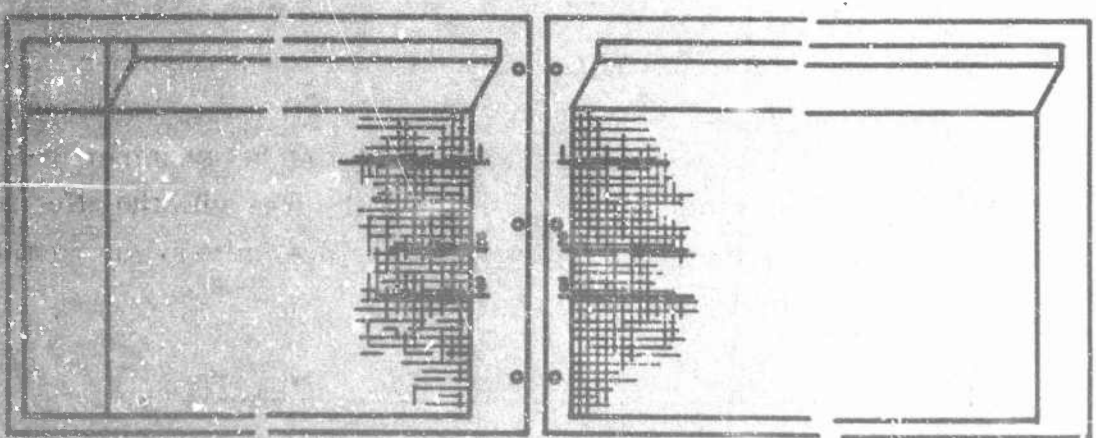


Figure 3-14 MDC Layout Across Binding

c. <u>Size of Heading.</u> The maximum space allocated for the heading of the MDC is 1-7/8 inches high (excluding signal specification number entry box) by 12-5/8 inches wide. See Figures 3-11 and 3-12 for examples of the following space allocations:

1) Space allocated for designators of action indicators/events/functional entities shall be arranged in a parallelogram, the bottom of which is horizontal, and with sides and entry separation lines slanting from lower left to upper right at

45 degrees. The length of the bottom corresponds to the width of the body, and the length of the side is 2-3/16 inches.

2) Space allocated for removable entity entries is 11/16 inches high, and width corresponds to the body.

3) Space allocated for location entries is 5/8 inches high and width corresponds to the body.

d. Size of Procedures. The maximum space allocated for procedures is 2-1/8 inches wide by 6-1/2 inches high.

e. Size of Signal Specifications Notes. The maximum space allocated for notes entries is 1-5/8 inches wide by 6-3/4 inches high, including signal specifications title block.

f. Deviations from Maximum Size. Deviations from total page size are not permitted. Deviations from maximum size of body, procedure heading, or note entries will use space otherwise allocated; therefore, these sizes may be exceeded only when it is possible to sacrifice space otherwise allocated.

g. Adherence to MDC Preparation Instructions. Adherence to the MDC preparation instructions with regard to non-repetition of end items and unnecessary duplication of identical paths resulting in multiple indications will help to reduce the size of the MDC. Attention to end-item placement on the sheet so that procedures and events flow along a right-down diagonal will also help in subdivision as well as use of the MDC.

h. Identification of MDC Sheets. The upper outer corner of each sheet shall identify the function unit number and name with the Maintenance Dependency Chart below it, both flush to margin. The figure number and title of the MDC, and in parenthesis the number of total sheets, shall appear at the bottom center of each chart.

The lower outer corner shall identify the page number. The lower inner corner shall identify the effectivity and date of origin or change.

14. Integrate Troubleshooting Aid Package for Functional Unit

The requirement of this activity is to assemble into one package all worksheets, forms, and drawings generated during the development of the troubleshooting aid. This package is to be presented for review and validation; consequently, the material shall be arranged in the following order:

a. Troubleshooting Aid Data Sheet. This is the first sheet in the package. In addition to the information assigned in Activity 1, new entries shall include:

1) Source data for the schematic, parts location illustration, functional description, preliminary information sheet, and procedures.

2) The number of sheets in the draft.

3) The dates that development was begun and ended, and the initials of the person responsible for aid development.

b. Sequence of Remaining Material. The remaining material shall be in the following sequence:

1) Functional Unit Block Diagram

2) Integrated Schematic

3) Parts Location Illustration

4) Functional Description

5) End-Item List

6) Preliminary Information Sheet

7) Checkout Procedures by End-Item Matrix

8) Failure Mode Analysis or MDC Rough Draft

9) Symptom-Cause Chart or MDC Final Draft

15. Review and Validate Troubleshooting Aid Package

The requirement of this activity is to verify that the information contained in the final version of the troubleshooting aid is sufficiently adequate and accurate for troubleshooting purposes. Sufficient adequacy is dependent upon how the personnel responsible for aid development have met the criteria for each activity. Accuracy is also dependent upon this same condition; however, it may be necessary to verify the procedures on the equipment if there is a question that cannot be resolved otherwise. The following steps shall meet the requirement of this activity:

a. Review the development of the package for completeness and to determine that the criteria for each activity performed have been met. Correct identification of interface areas is especially important.

b. Validate the information in terms of the development criteria, and if necessary, designate procedures for validation with the equipment.

c. Review changes in source data to determine the effect of the change on material that was developed using old source data.

d. If the total package does not meet the criteria for completeness and validity, note the discrepancies and return the total package to the responsible personnel for completion, validation, or revision.

e. If the total package does meet the criteria, dispose of it in the following manner:

1) Prepare a copy of the Troubleshooting Aid Data Sheet and forward it to the Basic Technical Data Storage function as a copy of the source data used in the development of the aid.

2) Forward the End Item List to personnel responsible for preparing Troubleshooting Aid Index (Activity 17).

3) File the Functional Unit Block Diagram, Procedures Matrix, Failure Mode Analysis or Rough MDC under function number and name for future reference, if required by changes to source data.

4) Prepare the final version of the integrated troubleshooting aid by assembling in the following order:

   (a) Preliminary Information Sheet

   (b) Maintenance Dependency Chart or Symptom-Cause Chart

   (c) Integrated Schematic

   (d) Parts Location Illustration

   (e) Functional Description

   Number all pages for left or right presentation, and verify that all figures are numbered sequentially as they appear. Verify that references to figures are accurate. Change as necessary.

5) Enter date and initials in "Review" row of Troubleshooting Aid Data Sheet, and attach it to top of final version.

6) Forward final version of the integrated troubleshooting aid to Reproduction Department for typing, illustration, and printing.

18. Revise Troubleshooting Aid Package

The requirement of this activity is to correct inadequacies in the total troubleshooting aid package due to failure to meet development criteria, or changes of source data after the development effort was completed. Because of the sequential dependency of developing activity products, personnel responsible for revision shall repeat those portions of Activities 3 through 14, as required to determine that voids and discontinuities do not exist.

Upon completion of the package revision, the person performing this activity will enter the data and his initials in the "Revision" row of the Troubleshooting Aid Data Sheet and return it for review and validation (Activity 15).

17. Prepare Troubleshooting Aid Index and Troubleshooting Aid Volume Front Matter

The requirement for this activity is the preparation of a complete index for all troubleshooting aids, and the front matter for the volumes containing the troubleshooting aids. This requirement cannot be met until troubleshooting aids for all functional units have been completed; however, it should be started and added to in the following manner as soon as individual functional unit end item lists are received from Activity 15.

a. Preparation of TSA Index. Preparation of the TSA index should be started first to provide data for the TSA volume front matter.

1) Prepare parts location illustrations as necessary to permit location and identification of each indicator. Assign a figure number to each illustration. Designate each indicator with an Arabic number in a sequentially progressive manner.

2) Prepare a three-column list of all indicators by location. The first column shall contain the parts location illustration key number of the indicator. The second column shall contain the correct nomenclature of the indicator. The third column shall contain the number(s) of the troubleshooting aid(s) in which the indicator is identified as an end item.

3) Prepare a two-column alphabetical list of all indicators. The first column shall contain the correct nomenclature of the indicator. The second column shall contain the number(s) of the troubleshooting aid(s) in which the indicator is identified as an end item.

4) Prepare a three-column alphabetical list of all troubleshooting aids based on the first initial of the proper name, common name, and generic name. The first column shall contain the name; the second column shall contain the troubleshooting aid number; and the third column shall contain the number of the volume containing the troubleshooting aid (to be assigned later).

5) Prepare a title page, list of effective pages, and table of contents for the index. The title page and list of effective pages shall meet the criteria for this material as identified in MIL-M-4410. The table of contents shall identify the section of the TSA index which contains the following:

   (a) Location of Indicators -- Each general location grouping shall be placed in a separate section. The general level parts location illustrations shall determine the number of sections to be assigned.

   (b) Alphabetical Listing of Indicators.

   (c) Alphabetical Listing of Troubleshooting Aids.

6) The final page size of the TSA index shall be 4-3/4 inches wide by 6-1/2 inches high.

b. Preparation of TSA Volume Front Matter. TSA volume front matter shall normally be included in the following sequence:

1) Title Page and Cover -- The title page shall be arranged

in accordance with MIL-M-4410. The cover shall contain the same information without a date.

2) List of Effective Pages -- The list of effective pages shall be arranged in accordance with MIL-M-4410.

3) Table of Contents --A table of contents shall be prepared to list the types of data and the page number for each specific type of information for each system partition included in the manual.

4) Index to Manual Set -- When multiple manuals are necessary for equipment or system fault isolation information presentation, an index to the total set of manuals shall be included. This index shall be arranged alphabetically by equipment or system partition name with a reference to the appropriate manual.

5) Manual Use Sheet -- One page of instructions in the use of the manual contents shall be prepared to expedite proper utilization of the materials. These instructions shall be self-explanatory to the manual user and shall include a clear and concise description of new or unique conventions, terminology, and symbology.

D. OTHER FUNCTIONS RELATED TO TROUBLESHOOTING AID DEVELOPMENT

In addition to the partitioning of the total system into functional units, there are four other major functions which interface with the development of troubleshooting aids. These are the formatting of other maintenance activities, the reproduction of the troubleshooting aid material, the maintenance of a basic technical data storage, and the control of troubleshooting aid master copies.

1. Re. rmat Maintenance Activities

It is important that there be a one-to-one correlation between troubleshooting information and all other maintenance information in terms of functional unit partitions, end item nomenclature, and checkout procedures. As this information becomes available during development of the troubleshooting aids, it should be provided to the personnel responsible for other maintenance activities, either as definitive inputs for their use, or as comparative inputs to determine that there is agreement between these two efforts.

2. Reproduce Troubleshooting Aids

After the final version of each aid is delivered to the reproduction facility, there will continue to be interaction between aid development and reproduction personnel concerning such things as layout, proofing, and page numbering.

3. Maintain Basic Technical Data Storage

Records of all source data used in development of each troubleshooting aid shall be filed such that future changes to existing hardware and/or procedures for any portion of the total system shall identify the specific aids affected. The revised source data and aid identification shall be forwarded to the development effort (Activity 15) for determination of the extent of change required for existing troubleshooting aid material.

4. Control Troubleshooting Aid Master File

A master file of all aids completing reproduction shall be maintained for reference and control purposes. This file shall contain the most current released version of each aid, and shall serve as the effective data for determining the impact of more recent data changes.

E. DEVELOPMENT OF TROUBLESHOOTING AIDS FOR A NEW SYSTEM

The same criteria and sequence of activities apply to troubleshooting aid development, whether it be for a new system under development or for an existing system. The principal differences in the characteristics of the effort are based on the characteristics of the source data and personnel assigned the responsibility for development activities.

1. <u>Source Data</u>

Data available for a new system under development may be in the form of contract specifications, engineering notes, and such basic data as final versions of pre-release drawings, parts lists, and procedures.

2. <u>Personnel Assignments</u>

Each contractor may have different definitions of personnel classification; therefore, no specific rule for personnel assignment shall be presented. However, the following assignments of responsibility for specific activities are suggested, and are to be interpreted in terms of constraints imposed by the characteristics of available source data and contractor personnel classifications.

a. <u>System Level Engineer.</u> A person concerned with total system and functional unit interface should have responsibility for Activities 1 and 15.

b. <u>Design Level Engineer.</u> A person concerned with functional unit interface, mechanization, and operation should have lead responsibility for Activities 2 through 10, and 12.

c. <u>Technical Writers.</u> A person concerned with sentence structure and final presentation format should have lead responsibility for Activities 11, 13, 14, 16 and 17. He must be able to interpret the results of all preceding activities to determine that the material is properly integrated.

d. <u>Interaction of Design Engineering and Technical Writer.</u> The design engineer may require the assistance of the writer in the wording of procedures (Activity 3), and the writer may require the assistance of the engineer in clarifying certain characteristics of any activity product. Revision of the aid (as required by Activity 16) may be a joint effort.

e. <u>Interaction During Review and Validation.</u> For the sake of expediency, it may be desirable to have the technical writer and design engineer join the system engineer for Activity 15. This may result in immediate resolution of minor problem areas, and may better define major problem areas that require further analysis. However their participation in this activity does not change the requirement to identify specifically the criterion violation or other reasons for revising the material.

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13. ABSTRACT

This report describes the latest phase in the program to develop and evaluate PIMO (Presentation of Information for Maintenance and Operation); a job guide concept applied to maintenance. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Three immediate behavioral effects were expected: 1) reduction in maintenance time, 2) reduction in maintenance errors, and 3) allow usage of inexperienced technicians with no significant penalty. Experienced and inexperienced Air Force technicians performed maintenance on C-141A aircraft using PIMO Job Guides presented in audio-visual and booklet modes. Performance was measured in terms of time to perform and procedural errors. The performance was compared with the performance on the same jobs by a control group, i.e., experienced technicians performing in the normal manner. The following conclusions were drawn from the test results: 1) after initial learning trials, both experienced and inexperienced technicians using PIMO can perform error-free maintenance within the same time as experienced technicians performing in the normal manner, 2) inexperienced technicians perform as well as experienced technicians when both use PIMO, 3) there is no significant difference between audio-visual and booklet modes, 4) the users revealed an overwhelmingly positive reaction to PIMO, and 5) the performance improvements provide the capabilities to significantly improve system performance defined in terms of departure reliability, time-in-maintenance, and operational readiness. This report also presents a description of the recommended operational system, specifications and guidelines for PIMO format development, including troubleshooting.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Maintenance Aids, Improved						
Job-oriented Guides						
Aircraft Maintenance						
Troubleshooting Aids						
Field Test of Maintenance Aids						
Audio-visual Presentation, Maintenance Data						
Maintenance Dependency Charts, Preparation of						
PIMO, Programmed Information for Maintenance						
Technical Data, Reformatting of						
Technical Data, Specifications for						
Technical Orders Comparison of (with PIMO)						
PIMO, Project Final Report						

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