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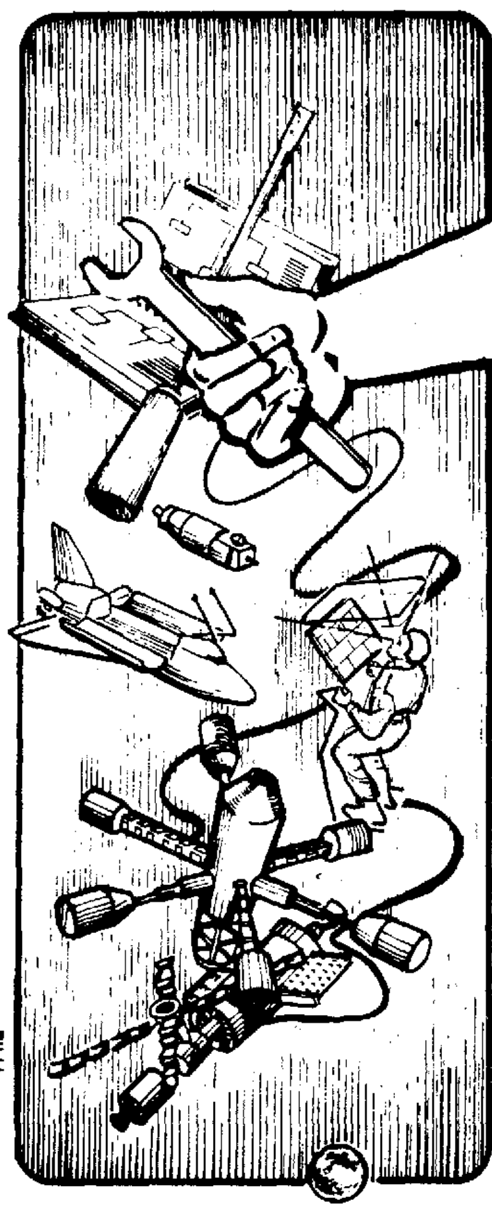

PHASE IIIB

CREW INTERFACE SPECIFICATIONS DEVELOPMENT FOR INFLIGHT MAINTENANCE AND STOWAGE FUNCTIONS

PREPARED BY

GENERAL ELECTRIC

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FINAL REPORT

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Submitted in Accordance with Data Requirements List
(DRL Line Item #2) of Contract NAS 9-13375

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PHASE IIIB

ABSTRACT

This report presents the findings and data products developed during the Phase IIIB Crew Interface Specification Study for Inflight Maintenance and Stowage functions performed by General Electric - Houston Operations for the NASA, Lyndon B. Johnson Space Center, under Contract NAS 9-13774. Technical Monitors for this study were Messrs. G. C. Franklin and C. D. Perner of the Spacecraft Design Division. Documentation from this study can be used by NASA as definitive guidelines for development of a family of standardized Job Performance data aids, containing integrated graphics, that will support performance by the crew of inflight maintenance tasks.

During the Phase IIIB contract period, the following data products were developed:

- General Specification, Crew Inflight Corrective Maintenance Job Performance Aids Requirements
- General Specification, Crew Inflight Troubleshooting Job Performance Aids Requirements

The above Crew Inflight Maintenance and Support data specification products were developed after review of the Apollo and Skylab Program mission results, crew technical debriefings, and crew inflight data concepts. Space Shuttle Program mission and spacecraft design concepts were also surveyed as was Naval and Air Force Department of Defense maintenance aid concepts. From this information base, a family of data concepts to support crew inflight troubleshooting and corrective maintenance activities was developed and specified. Recommendations are made for the improvement of inflight maintenance planning, preparations and operations in future spaceflight programs through the establishment of an inflight maintenance organization and specific suggestions for techniques to improve the management of the inflight maintenance function.

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1.0 INTRODUCTION

This report presents the findings of and the data products developed during the Phase IIIB Crew Interface Specification Development Study for Inflight Maintenance (IFM) and Stowage functions in future manned space flights. The study was performed by General Electric, Space Division, Technical and Support Services Department - Houston Operations under contract to the NASA-Lyndon B. Johnson Space Center. The purpose of this study was to continue the process, demonstrated in earlier phases of this study, of developing specification documentation that can be used by the NASA as definitive guidelines for improving the definition, control, and management of crew interfaces involved in the new requirement areas of inflight maintenance and stowage. The study was performed for the Engineering and Development Directorate, Spacecraft Design Division of NASA-JSC under contract NAS 9-13774. The Technical Monitors for the study were Mr. George Franklin (Asst. Chief for Crew Station Design) and Mr. Chris Perner (Chief, Crew Station Integration Section).

This Phase IIIB Study is one of a series of studies performed by GE - Houston Operations under a Crew Interface Specification Development Program for Inflight Maintenance, Assembly, Servicing and Stowage functions. The various study phases and the specifications delivered are delineated below:

PHASE I STUDY	-	CONTRACT NAS 9-11336
PHASE II STUDY	-	CONTRACT NAS 9-12249
PHASE IIIA STUDY	-	CONTRACT NAS 9-13375
PHASE IIIB STUDY	-	CONTRACT NAS 9-13774

Specification Products delivered:

SC-C-0009	General Specification, Operations Location Coding System for Crew Interfaces
SC-S-0011	General Specification, Loose Equipment and Stowage Management Requirements
SC-S-0012	General Specification, Loose Equipment and Stowage Data Base Information Requirements
SC-S-0013	General Specification, Spacecraft Loose Equipment Stowage Drawing Requirements
SC-S-0014	General Specification, Inflight Stowage Management Data Requirements
SC-M-0016	General Specification, Inflight Maintenance Management Requirements
SC-M-0017	General Specification, Inflight Maintenance Task and Support Requirements Analysis
SE-P-0089	General Specification, Crew Inflight Corrective Maintenance Job Performance Aids Requirements
SE-T-0090	General Specification, Crew Inflight Toubleshooting Job Performance Aids Requirements

A major concept in the near future spaceflight mission planning efforts is the emphasis on the need for more autonomous flight crew control of space missions. This in turn increases the dependency of the flight crew on on-board procedural and technical reference data. The Crew Interface Study of Inflight Maintenance and Stowage functions has been directed toward development of new crew data concepts to assist in performing inflight maintenance tasks and stowage management with less dependency on real-time ground control functions. This has involved detailed examination of methods, techniques, and data used on the Apollo and Skylab missions and assessment of where new data concepts would be appropriate in view of the requirements of the Shuttle Program missions and systems design concepts.

A basic guideline for all phases of the Crew Interface Study effort has been to maintain a measure of continuity and consonance with presently implemented NASA and contractor engineering practices while evolving new concepts for crew support data for the expanded inflight maintenance and stowage management functions that will exist in future manned spaceflight missions. The specification documents developed for the Phase IIIB study are the result of a thorough assessment of past space program methods and, where possible, are extensions or modifications of present NASA data concepts to meet the new demands of the Shuttle Program.

The Skylab Program missions dramatically demonstrated the mission and economic values that can accrue from inclusion of an on-board IFM capability for performing a wide variety of corrective maintenance tasks on both spacecraft systems and experiment hardware. The Skylab program also demonstrated that, with proper restraints, man can perform almost any maintenance task in the zero-g environment of space that he can perform on the ground provided sufficient on-board data, tools, spare parts and test equipment are provided. This emphasizes the need for in-depth planning for inflight maintenance as an integral part of future space program activities. Skylab mission experience also identified a need for graphical and pictorial type data as well as the textual type checklist procedures for some kinds of inflight maintenance tasks. Much time was lost in establishing the identity of parts and in determining the meaning of the procedural text data. Pictorial and graphics additions could have reduced errors and the time required to perform these tasks.

The Phase IIIB study has been concerned with the development of specifications that provide format and content guidelines for standard systematic methods of including graphics and logic type information as integral parts of the crew inflight maintenance support data.

2.0 SUMMARY OF RESULTS

The results and specification data products of the General Electric - Houston Operations Phase IIIB Crew Interface Specification Development Study for Inflight Maintenance and Stowage functions are summarized and identified in the following paragraphs of this section and in subsequent sections of this report.

The major purposes of the Phase IIIB study were to establish a firm technical basis, from past mission experience and current Shuttle Program directions, for new crew data concepts for inflight maintenance on future manned spaceflight programs and to specify and document these concepts for ready application by NASA-JSC to future space programs as is appropriate.

The following data products and/or drafts of NASA specifications were developed and delivered to NASA during the Phase IIIB study contract.

- SE-P-0089 General Specification
  Crew Inflight Corrective Maintenance
  Job Performance Aids Requirements

- SE-T-0090 General Specification
  Crew Inflight Troubleshooting
  Job Performance Aids Requirements

The basic study approach utilized for the Phase IIIB program is shown graphically in Figure 1. The initial series of tasks (1.1, 1.2, and 1.3) in the study were directed toward providing a Reference Inflight Maintenance Concept that would reflect the Space Shuttle Program operational plans and mission concepts. Related IFM definitions were also established to serve as the basis for subsequent establishment of information requirements for IFM Troubleshooting and Corrective Maintenance Job Performance Aids. A detailed discussion of the initial series of tasks are presented in the following Section 3.0 of this report.

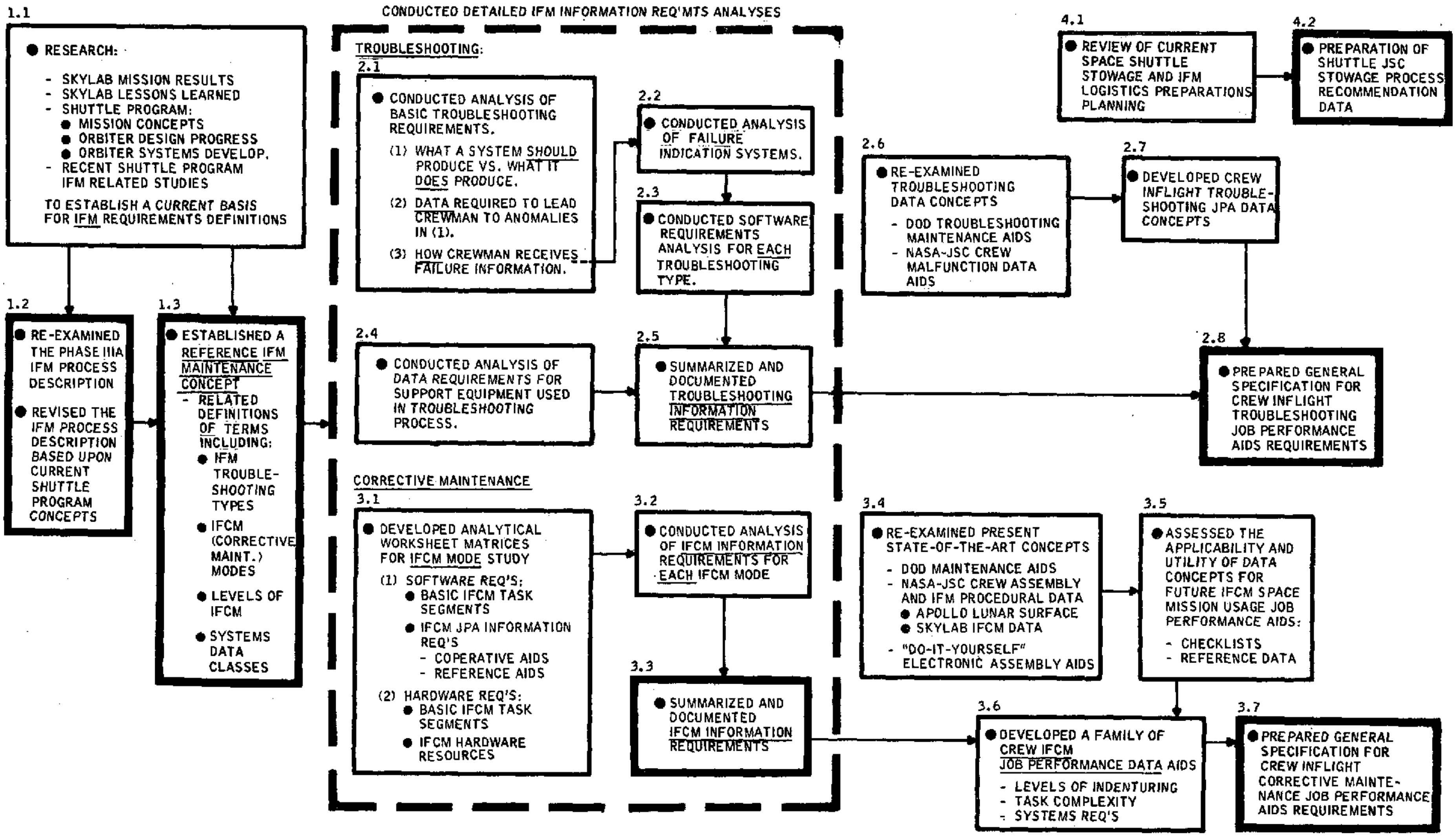
The second series of study tasks (2.1-2.8) addressed the establishment of information requirements for the various types of IFM on-board Troubleshooting activities, the definition of data concepts for each type of Troubleshooting and the preparation of the general specification for Crew IFM Troubleshooting Job Performance Aids requirements. These tasks are discussed in detail in Sections 4.0 and 5.0 of this Final Report.

The third series of study tasks (3.1-3.7) involved establishing the information requirements for Crew Inflight Corrective Maintenance (IFCM) support, reviewing present state-of-the-art job performance aids, developing IFCM Job Performance Aid Data concepts and preparing the General Specification for IFCM Job Performance Aids requirements. Discussions of this third series of tasks are included in Sections 6.0 and 7.0 of this report.

The last series of study tasks (4.1, 4.2) were concerned with the examination of future mission IFM support equipment provisioning concepts and related data requirements. Major revision in these processes are in progress such that a specification in this area now appears inappropriate. However, study data and observations of requirements in this area are provided.

Conclusions and Recommendations for the Crew IFM Interface Specification Development Program have been included in Section 9.0 of this Final Report.

FIGURE 1
PHASE IIIB
STUDY DESCRIPTION



3.0 REFERENCE OPERATIONAL INFLIGHT MAINTENANCE CONCEPT DEVELOPMENT

Major guidelines for all phases of the Crew Interface Specification Development Study have been to develop data product concepts and their specifications that:

- are relevant to current program needs
- have generic applicability to future manned spaceflight programs
- are evolutionary in nature, i.e., new data concepts should evolve from the data products of previous programs so that continuity with previously used data products can be maintained. (The purpose of this guideline was to ensure utilization of proven concepts of past missions while evolving new concepts to meet future mission requirements.)

With these guidelines in mind, the establishment of new support data requirements for inflight maintenance required the research of past space program crew operations conventions and data. In particular, the Skylab inflight maintenance supportive data products were examined in detail along with the crew debriefing and film data on these crew inflight maintenance tasks. Areas where additional support data and support hardware would have been helpful were identified.

In order that current program requirements were considered, the Phase IIIB Study effort included a detailed survey of the Shuttle Program mission concepts, systems design concepts for both the orbiter vehicle and major payloads, and crew station configurations and operational concepts. This research established basic candidate requirements that will exist for inflight maintenance activities in manned spaceflight programs of the near future.

In addition to the research of background Space program inflight maintenance related data, a re-examination of Department of Defense and airline maintainability program requirements and maintenance support data concepts was conducted to obtain a thorough technical basis for the Phase IIIB effort. One consistent major factor observed in these DOD and airline maintainability programs was the initial establishment of a Maintenance Concept or Policy. The Maintenance Concept defines criteria covering repair philosophies, maintenance support levels, personnel factors, maintenance time constraints, etc. The Maintenance Concept serves the purpose of providing a basis for the establishment of maintainability requirements in the system/equipment design and for the establishment of total maintenance support requirements. It leads to the identification of support requirements to include maintenance tasks, task frequencies and times, personnel quantities and skill levels, spare/repair parts, support equipment and tools, facilities and data resources required.

During the previous Phase IIIA Crew Interface Specification Development Study, a major effort was directed toward the definition of an Inflight Maintenance Program and supportive analytical methods for identifying the specific requirements for inflight maintenance support. A major element in this program was the early identification of the Inflight Maintenance Concept.

The Phase IIIB research program has noted that the Shuttle Program has established a basic maintenance concept for ground operations but as yet no formally defined Inflight Maintenance Concept has been established for the operational Shuttle Program. This fact is a function of the basic research and development nature of the early Shuttle vehicles and also of the budgetary constraints that have forced some planning efforts to be rescheduled to a later time in the development cycle.

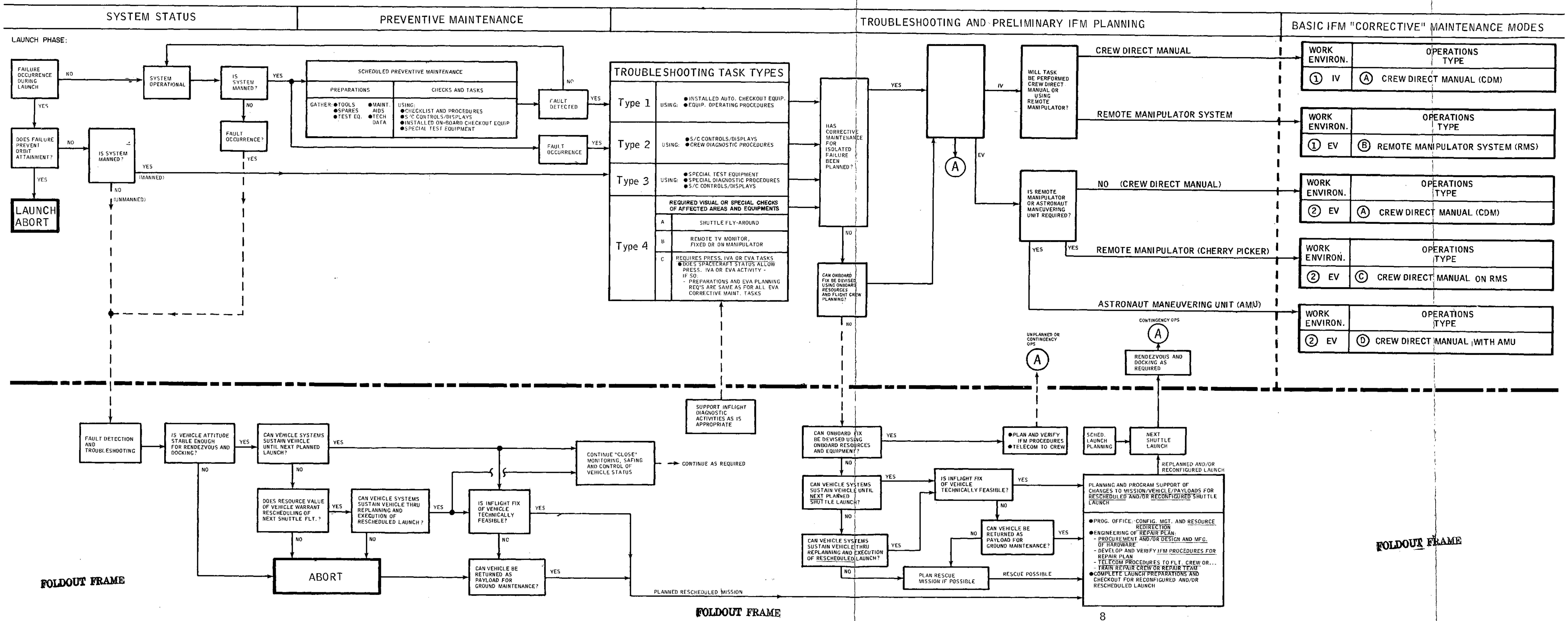
As a result of the above noted limitations, it was necessary that the Phase IIIB study effort establish an assumed or reference Inflight Maintenance Concept that would be descriptive of what the anticipated operational environment of the Space Shuttle vehicles and payloads would be. However, prior to the establishment of the Inflight Maintenance Concept it was necessary to re-examine the Phase IIIA Inflight Maintenance Functions Analysis that provided a description of the anticipated functions that would be required for inflight maintenance.

3.1 INFLIGHT MAINTENANCE (IFM) PROCESS DESCRIPTION

The Phase IIIA Inflight Maintenance Operational Functions Analysis was reviewed and updated to reflect the latest Shuttle Program concepts. This updated analysis is presented in Figure 2 and contains a description of the basic crew Inflight Maintenance functions that are anticipated on future operational Shuttle orbiter missions. It is assumed that IFM will be performed on the basic orbiter vehicles, their payloads and on retrieveable and revisited vehicles or satellites. It can be noted that there are four types of Troubleshooting crew functions identified. These types are classified with respect to the type of equipment or resource utilized in performing the troubleshooting task. In addition, five basic Inflight Corrective Maintenance functional modes are identified. These mode classifications have been made on the basis of the work environment of the IFM task and upon the type of operations involved.

The Updated Operational IFM Functions Analysis served as the basis for the development of the Reference Inflight Maintenance Concept.

FIGURE 2 INFLIGHT MAINTENANCE (IFM) OPERATIONAL FUNCTIONS ANALYSIS CHART



3.2 INFLIGHT MAINTENANCE CONCEPT

Utilizing the updated IFM Operational Functions Analysis data and the other research, previously described, of the Skylab and Shuttle programs, an assumed or Reference Inflight Maintenance Concept was developed. This concept is presented in Figure 3. Amplifying definitions of this concept are included as Appendix D to this Report. The purpose of the development of this Inflight Maintenance Concept was to structure the basic operational inflight maintenance functions such that detailed requirements for supportive data could be more effectively identified. The classification of Inflight Maintenance activities into Troubleshooting Types and Corrective Maintenance Modes has been done to isolate the supporting data subject matter in the manner that crew usage of the data will normally occur in real-time mission usage. The subsequent discussion of the data concepts and specification development in these two areas (Troubleshooting and Corrective Maintenance) is not intended to indicate a separation of these functions in real-time mission usage but does reflect the basic difference of data requirements necessary for these inflight maintenance activities.

The development of troubleshooting support data development is discussed in the following Paragraphs 4.0 and 5.0 of this report. Inflight Corrective Maintenance data concepts development and specification preparations are discussed in Paragraphs 6.0 and 7.0.

FIGURE 3
REFERENCE
OPERATIONAL INFLIGHT MAINTENANCE CONCEPT*
(FOR THE CREW INTERFACE SPEC. DEVELOPMENT STUDY)

- ON-ORBIT INFLIGHT MAINTENANCE (IFM) WILL BE PERFORMED ON BOTH MANNED VEHICLES, PAYLOADS, RETRIEVED, AND REVISITED VEHICLES.

- PREPLANNED IFM TASKS WILL BE MINIMIZED BUT WILL BE PERFORMED AND WILL INCLUDE:
  - SCHEDULED (IFM) - TO REPLACE LIFE LIMITED COMPONENTS, TO SERVICE AND REPLENISH EXPENDABLES, TO ADJUST OR CALIBRATE SYSTEMS
  - UNSCHEDULED (IFM) - TO RESTORE SYSTEM AND EQUIPMENT OPERATIONS

- CONTINGENCY IFM TASKS WILL BE PERFORMED WHENEVER UNANTICIPATED FAILURE OR DAMAGE OCCURS WHICH COULD JEOPARDIZE THE MISSION SUCCESS OR SAFETY OF THE CREW. THESE TASKS WILL BE PLANNED IN REAL-TIME.

- RESCUE AND RESUPPLY CAPABILITY WILL EXIST FOR OPERATIONAL FLIGHT SUCH THAT IFM SPARES AND DATA CAN BE RESUPPLIED BY ANOTHER VEHICLE. THIS CAPABILITY SHOULD NOT BE UTILIZED IN PLANNING FOR IFM BUT IT WILL EXIST FOR CONTINGENCY SITUATIONS.

- BOTH IVA AND EVA INFLIGHT MAINTENANCE TASKS WILL BE PERFORMED.

- PROVISIONS FOR IFM WILL BE INCLUDED AS LOOSE EQUIPMENT STORAGE ON THE ORBITER VEHICLE AS WELL AS ON PAYLOADS VEHICLES.

- BASIC GENERAL IFM PROVISIONS CAPABILITY SHALL BE PROVIDED ON ORBITER VEHICLE. THIS SHALL INCLUDE:
  - WORK STATION
  - IFM BASIC TOOL SET AND SPECIAL PROCESS TOOLS ETC.
  - SPARES AND MATERIALS
  - SPECIAL TEST EQUIPMENT

- IFM SHALL INCLUDE BUT NOT BE LIMITED TO:
  - FOUR TYPES OF INFLIGHT TROUBLESHOOTING ACTIVITIES

    (1) - USING INSTALLED AUTOMATIC TROUBLESHOOTING EQUIPMENT (PERFORMANCE MONITOR SYSTEM)
    (2) - USING SPACECRAFT CONTROLS/DISPLAYS WITH CREW DIAGNOSTIC PROCEDURES
    (3) - USING SPECIAL TEST EQUIPMENT
    (4) - VISUAL INSPECTION OF FAILURE SITE

  - FIVE MODES OF INFLIGHT CORRECTIVE MAINTENANCE TASKS

    (1A.) INTRAVEHICULAR - CREW DIRECT MANUAL MODE
    (1B.) INTRAVEHICULAR - REMOTE MANIPULATOR OPS. MODE
    (2A.) EXTRAVEHICULAR - CREW DIRECT MANUAL MODE
    (2C.) EXTRAVEHICULAR - CREW DIRECT MANUAL FROM REMOTE MANIPULATOR MODE (CHERRY PICKER)
    (2D.) EXTRAVEHICULAR - CREW DIRECT MANUAL FROM ASTRONAUT MANEUVERING UNIT MODE

- THERE SHALL BE THREE LEVELS OF INFLIGHT CORRECTIVE MAINTENANCE

    (1) SUBASSEMBLY LEVEL
    (2) ASSEMBLY LEVEL
    (3) SYSTEMS LEVEL

- THERE SHALL BE THREE TYPES OF SYSTEMS SUPPORT DATA

    (1) ELECTRICAL/ELECTRONIC
    (2) MECHANICAL/ELECTRO-MECHANICAL
    (3) FLUID/FLUID-ELECTRO-MECHANICAL

- THERE SHALL BE TWO TYPES OF JOB PERFORMANCE AIDS

    (1) COOPERATIVE (ACTIVE) - I.E., CHECKLISTS
    (2) REFERENCE (PASSIVE) - I.E., SYSTEMS DATA

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*DEFINITIONS ASSOCIATED WITH THIS INFLIGHT MAINTENANCE CONCEPT ARE PRESENTED IN APPENDIX "C" OF THIS REPORT

4.0 IFM TROUBLESHOOTING INFORMATION REQUIREMENTS ANALYSIS

The Skylab missions and crew debriefings reflected certain inadequacies in support data thru examples where textual only procedural data was misinterpreted and also where excessive time was required in interpreting audio-textual maintenance procedures that were uplinked to the crew. In view of these comments, and due to additional Shuttle equipment provisions, such as the Performance Monitor System, it was felt necessary to establish "what did the crew really need to know in order to perform Inflight Maintenance (Troubleshooting and Corrective Maintenance) tasks?" The study effort to identify Inflight Troubleshooting Information requirements involved development and usage of analytical matrices that could be used to examine each Troubleshooting Type (as per Figure 2) with respect to information requirements for each Type. The summary of the results of this analysis are presented in Figure 4.

FIGURE 4 SUMMARY OF INFLIGHT TROUBLESHOOTING INFORMATION REQUIREMENTS ANALYSIS

IFM TROUBLESHOOTING TYPES / CATEGORICAL IFM TROUBLESHOOTING SUPPORT REQUIREMENTS		I	II	III	IV
		LOOP INTEGRITY CHECKS		SUBASSY. LVL. CHECKS	CONTINGENCY VISUAL CHECKS
		WITH PERFORMANCE MONITORING EQUIP	WITH SPACECRAFT OR PAYLOADS CONTROLS/DISPLAYS	WITH SPECIAL TEST EQUIP	
SOFTWARE	● SYSTEMS DATA	0	3	3	2
	● ACCESS LOC. & AREA DATA	0	0	3	3
	● PARTS IDENT. & LOC. DATA	0	0	3	2
	● TOOLS IDENT. & LOC. DATA	0	0	2	2
	● PROCEDURES (SEQ. TYPE)	2	1	3	3
	● PROCEDURES (DECISION TYPE)	3	3	3	3
	● SPECIAL TEST EQUIP. DATA	1	1	3	1

LEGEND

3 = REQUIRED

2 = PROBABLY REQUIRED

1 = PROBABLY NOT REQUIRED

0 = NOT REQUIRED

5.0 INFLIGHT TROUBLESHOOTING JOB PERFORMANCE AIDS SPECIFICATION DEVELOPMENT

The identified troubleshooting information requirements and the data types to support these requirements served as a basic design reference for the development of specification data describing these data types. In addition to this basic reference, state-of-the art data concepts being used by Department of Defense, airlines and other users of aerospace and similar complex systems, were examined to determine optimum data configurations for the various troubleshooting types.

Five distinct types of Job Performance Aid data concepts were developed. These data types were primarily dictated by (1) Troubleshooting types and (2) the capability of the specific troubleshooting type to identify the failure level. After development of the various data concepts for inflight troubleshooting Job Performance Aids, a specification was developed to satisfy the requirements of Paragraph 3.3 of the Statement of Work and line item 4 of the Data Requirements List (DRL). The resulting General Specification, SE-T-0090, for Inflight Troubleshooting Job Performance Aids Requirements is included as Appendix A of this Final Report.

6.0 INFLIGHT CORRECTIVE MAINTENANCE (IFCM) INFORMATION REQUIREMENTS ANALYSIS

The study effort to identify Inflight Corrective Maintenance Information requirements involved the development of analytical matrices that could be used to examine each IFCM mode with respect to software or information requirements necessary for job performance aids on each task segment of an inflight corrective maintenance task. An analysis was conducted for all IFCM modes and a summary of the results is presented in Figure 5.

The major Phase IIIB Study purpose was to develop IFM Job Performance Aid data concepts. However, in order to appreciate the crew task implications of IFCM, it was felt a preliminary investigation of supportive hardware for IFCM tasks should be made. This was done in order to have an appreciation for the scope and basic categories of this equipment that would be involved in IFCM. An analytical matrix was developed to define IFCM hardware support requirements. This matrix is presented in Figure 6 for reference only since the analysis and documentation of the requirements for each mode of IFCM was not a study requirement. However, an examination of the matrix and the categories of supportive hardware required emphasizes the magnitude of the provisioning consideration that must be made to support an effective inflight maintenance program for the Shuttle and subsequent spaceflight programs.

FIGURE 5 INFLIGHT CORRECTIVE MAINTENANCE INFORMATION REQUIREMENTS ANALYSIS

INFLIGHT MAINTENANCE CORRECTIVE MAINTENANCE MODE: Summary of 5 C. M. Modes (3EVA, 2IVA)

ENTRY LEGEND: # = NO. OF MODES REQUIRING DATA; - = NO REQUIREMENT; R = REQUIRED; P = POSSIBLY REQUIRED

	IFCM TASK	IFM PREPARATIONS AND POST IFM OPS			TRANSLATION	PREPARATIONS WORKSITE	RESTORING ACTIONS					
									REPAIR OR REPLACE ACTIONS		SUBASSY LEVEL	
	IFCM INFORMATION REQUIREMENTS	IFM PREP.	ORB. & P/L'S SYSTEMS OPS (IFM PREP. & POST)	AIRLOCK OPS. (PREP. & POST)	TO AND FROM	PREP - WORKSITE STAB. - EV SYSTEMS DEPREP	SITE ASSESS. AND/OR "OPEN UP" "CLOSE OUT"	SERVICING AND PREVENT. MAINT. ACTIONS	SYSTEMS LVL.	ASSY LVL.	CORRECT. MAINT.	TROUBLE SHOOTING
COOPERATIVE JPA REQ'S	DATA TO AID:											
	▲ SEARCH FOR CORRECT SET OF IFM TASK PROCEDURES	5R	-	-	-	-	-	-	-	-	-	-
	▲ SELECTION OF CORRECT ENTRY POINT IN PROCEDURES	-	5P	-	-	-	5P	5P	5P	4R,1P	4R	4R
	▲ - IDENTIFYING REQ'D SUPPORT ITEMS FOR TASK SEQ (TOOLS, ETC.)	5R	-	-	4P	4R	4R	4R	4R	4R	4R	4R
	- FINDING OF SUPPORT ITEMS (STOWAGE LOCATION)	5R	-	-	-	-	-	-	-	-	-	-
	▲ - IDENTIFYING REQUIRED SYS. CONTROLS CONFIGURATION FOR TASK	-	5R	-	-	5P	5P	-	-	-	-	-
	● - TASK PERFORMANCE (TASK INSTRUCTION - ACTION VERB)	-	5P	3R	3R	4R,1P	5R	5R	5R	4R,1P	4R	4R
	- TASK COMPREHENSION THROUGH AMPLIFYING COMMENTS	-	3P	3P	3P	5P	4R,1P	5R	5R	4R,1P	4R	4R
	- CORRECT PERFORMANCE TASK SEQUENCE	5R	5R	3R	3R	4R,1P	5R	5R	5R	5R	4R	4R
	- TASK SEQUENCE BRANCHING	-	-	-	-	-	5P	-	-	5R,1P	3R,1P	4R
	- FINDING LOCATION OF TASK	5R	-	-	3R,2P	-	4R,1P	3R,1P	4R	3R	3R	3R
	- FINDING "OBJECTS" OF TASK ACTION (PART NAMES)	-	-	3P	3P	4P	3R,2P	3R,2P	5R	5R	4R	3R,1P
	- CORRECT SELECTION OF TOOL TO PERFORM TASK	5R	4P	3P	-	3P	3R,1P	5R	4R,1P	4R,1P	3R,1P	3R,1P
	- KNOWLEDGE OF EQUIPMENT LOCATION IN TASK AREA	1P	-	3P	-	-	3R,2P	4R,1P	4R,1P	4R,1P	3R,1P	3R,1P
	- KNOWLEDGE OF PARTS											
	- PART NAME	-	-	-	-	-	-	5P	5P	5P	4P	4R
	- PART SHAPE AND SIZE	-	-	-	-	-	5P	5P	5P	5P	4P	3P
	- PART INSTALLATION ORIENTATION	-	-	-	-	-	5P	5P	5P	5P	4P	3P
	- PART #	-	-	-	-	-	-	-	4P	4P	4P	
	- PART CODE FOR CROSS INDEXING TO SCHEMATIC OR PROC. DATA	-	-	-	-	-	-	-	5P	5P	3P,1R	3P,1R
	- LOCATING PART INSTALLED IN ASSY.	-	-	-	-	-	-	-	-	5R	4R	4R
	- LOCATING PART WITHIN FUNCTION DESCRIPTION OF SYS.	-	-	-	-	-	-	-	3P,2R	5R	4R	4P
	- LOCATING OF TEST POINTS WITHIN ASSY.	-	-	-	-	-	-	-	-	-	-	4R
	● SPECIAL PROCESS TASK PERFORMANCE	5P	5P	3P	3P	3R,2P	5P	3R,2P	4R,1P	4R,1P	4R	-
REFERENCE JPA REQ'S	▲ UNDERSTANDING OF SYSTEMS CONFIGURATION											
	- POWER, DATA & SIGNAL SOURCES AND DISTRIBUTION	-	5P	-	-	-	-	5R	5R	5R	4R	4R
	- LINE CONNECTION AND POWER FLOW	-	-	-	-	-	-	5R	5R	5R	4R	4R
	- SYSTEM PERFORMANCE CHARACTERISTICS (NORMAL RANGES, LIMIT VALVES, C/W TRIGGER VALUES)	-	-	-	-	-	5P	5P	5P	5P	4P	4R
	- SYSTEMS LOGIC	-	5P	-	-	5P	5P	5P	5R	5R	3P	4R
	- COMPONENT FUNCTIONS	-	5P	-	-	-	5P	5P	5P	5P	4P	4R
	- COMPONENT IDENT. & LOCATION	-	-	-	-	4R		5R	5R	5R	4R	4R
	- PLUMBING CONNECTIONS, DISTRIBUTION AND FLOW	-	-	-	-	4P		4R,1P	5R	5R	4R	4R
	- SENSOR LOCATIONS, TYPES AND SIGNAL DISTRIBUTION	-	-	-	-	-	-	-	-	-	-	4R
	- MEASUREMENT NUMBERS & RANGES	-	-	-	-	-	-	-	-	-	-	4R
	- DISPLAY RANGES AND LIMITS	-	-	-	-	-	-	-	-	-	-	4R
	- DISPLAY DISCRETES (STATUS & C/W)	-	-	-	-	-	-	-	-	-	-	4R
	- CONTROLS, CONTROLLED COMPONENTS & INTERFACES	-	5R	-	-	-	-	-	-	-	-	4R
	- TERMINAL BOARD IDENTIFICATION & LOCATION	-	-	-	-	-	-	-	-	-	4P	4R
	- PIN NUMBERS AND CONNECTIONS	-	-	-	-	-	-	-	-	-	4P	4R
	- ASSEMBLY/SUBASSEMBLY INDENTURING	-	-	-	-	-	-	-	-	4R	4R	4P

FIGURE 6 INFLIGHT MAINTENANCE HARDWARE REQUIREMENTS ANALYSIS WORKSHEET

INFLIGHT MAINTENANCE CORRECTIVE MAINTENANCE MODE: ______________________

IFM Hardware Resource Req's	IFM Corrective Maintenance	IFM Preparations and Post IFM Ops			Translation	Preparations Worksite	Restoring Actions		Repair or Replace Actions		Subassy Level	
		IFM Prep.	Orb. & P/L's Systems Ops (IFM Prep. & Post)	Airlock Ops. (Prep. & Post)	(To and From)	Prep - Worksite Stab. - EV Systems / Deprep	Site Assess and/or "Open Up" "Close Out"	Servicing and Prevent. Maint. Actions	Systems Lvl.	Assy Lvl.	Correct. Maint.	Trouble Shooting
● Remote Manipulator Unit												
Life Support	● Space Suit (EMU)											
Life Support	● Portable Life Support (PLSS)											
Life Support	● Secondary Oxy Package (SOP)											
Life Support	● Airlock Servicing & Cooling Umb (SCU)											
Life Support	● Life Support Umbilical (LSU)											
Life Support	● Life Support Umbilical Control Unit											
Translation Aids – Fixed	● Handholds											
Translation Aids – Fixed	● Handrails											
Translation Aids – Portable – No Pwr.	● Extendible Boom											
Translation Aids – Portable – Powered	● Electroadhesive Handholds											
Translation Aids – Portable – Powered	● Astronaut Maneuvering Unit (AMU)											
Translation Aids – Portable – Powered	● "Cherry Picker" Station on RMU											
Safety Restraints	● Suit Tether											
Safety Restraints	● AMU Tether											
Safety Restraints	● RMU Tether											
Worksite Stab. Aids – Fixed – To S/C or P/L	● Foot Restraints											
Worksite Stab. Aids – Fixed – To S/C or P/L	● Leg/Seat Restraints											
Worksite Stab. Aids – Fixed – To S/C or P/L	● Attach Pts. for Restraints											
Worksite Stab. Aids – Fixed – RMU	● Foot Restraints											
Worksite Stab. Aids – Fixed – RMU	● Attach. Pts. for Restraints											
Worksite Stab. Aids – Portable	● Electroadhesive Restraints											
Worksite Stab. Aids – Portable	● Chemoadhesive Restraints											
Worksite Stab. Aids – Portable	● Space Stab. Platform AMU (Standoff)											
Worksite Stab. Aids – Portable	● AMU → SC/PL Attach. Device											
Site Monitoring – TV	● P/L Bay Installed Cameras											
Site Monitoring – TV	● RMS Installed Camera											
Site Monitoring – Spacecraft View	● Windows											
Site Monitoring – Spacecraft View	● Hatches											
Lighting – IV	● Fixed											
Lighting – IV	● Portable											
Lighting – EV – Attached	● Fixed											
Lighting – EV – Attached	● Directional Control											
Lighting – EV – Portable	● Hand Carried											
Lighting – EV – Portable	● RMS Installed											
Lighting – EV – Portable	● Work Station Installed											
Maint. Equip. Transfer – Suit Attachments	● Tools, Spares, Other Equip.											
Maint. Equip. Transfer – Suit Attachments	● Checklists											
Maint. Equip. Transfer – AMU Attachments	● Tools, Spares, Other Equip.											
Maint. Equip. Transfer – AMU Attachments	● Checklists											
Maint. Equip. Transfer – RMU Attachments												
Work Station	● Stowage Space (Tools, Materials, Spares, Etc.)											
Work Station	● Zero-G Containment											
Work Station	● Parts Securing for Maint. (Vise)											
Work Station	● Power Supply											
Work Station	● Crew Stab. Aids (Leg, Ankle)											
Work Station	● Attachment Device											
Work Station	● Veh. Attachment Pts.											
Tools, Hand &/or Power	● Drilling											
Tools, Hand &/or Power	● Sawing/Cutting											
Tools, Hand &/or Power	● Torquing											
Tools, Hand &/or Power	● Impact											
Tools, Hand &/or Power	● Clamping and Gripping											
Tools, Hand &/or Power	● Measurement Device (Length, Angle)											
Special Process Equip.	● Soldering or Brazing											
Special Process Equip.	● Welding											
Special Process Equip.	● Bonding											
Special Process Equip.	● Coating (Thermal) - Paint - Foam											
Special Process Equip.	● Cleaning											
Maint. Materials	● Soldering, Brazing, Welding											
Maint. Materials	● Bonding											
Maint. Materials	● Lubricants											
Maint. Materials	● Sealants											
Maint. Materials	● Electric Wire											
Maint. Materials	● Electric and Other Tape											
Maint. Materials	● Cleaning Agents											
Maint. Materials	● Coating Agents											
Maint. Materials	● Nuts, Bolts, Screws, Etc.											
Special Test Equip.	● Electrical											
Special Test Equip.	● Fluid - Liquid - Gas											
Other												

FOLDOUT FRAME

7.0 INFLIGHT CORRECTIVE MAINTENANCE (IFCM) JOB PERFORMANCE AIDS SPECIFICATION DEVELOPMENT

The identified Inflight Corrective Maintenance (IFCM) information requirements, served as a basic design reference for the development of supportive data concepts for IFCM. In addition to this reference, state-of-the art data concepts being used by Department of Defense and other equipment maintenance and assembly task data were examined to determine optimum configurations of data for mechanical, fluid-mechanical and electrical/electronic systems.

Eight different types of Job Performance Aid Data concepts were developed. These data types were developed to satisfy different information requirements that were associated with (1) levels of complexity of the specific corrective maintenance task being performed, (2) the amount of training the crew has had on systems or equipment mock-ups prior to flight, (3) the type of system equipment being repaired (mechanical, fluid-mechanical, or electrical-electronic) and, (4) the criticality of the task being performed for mission success and crew safety. After development of the various data concepts for IFCM Job Performance Aids, a specification was developed to satisfy the contractual requirements of Paragraph 3.5 of the Statement of Work and line item 3 of the Data Requirements List. The resulting General Specification, SE-P-0089, for Crew Inflight Corrective Maintenance Job Performance Aids Requirements is included as Appendix B of this study report.

8.0 INFLIGHT MAINTENANCE SUPPORT EQUIPMENT AND LOGISTICS PROVISIONING

Originally the provisioning for inflight maintenance was a study topic of concern due to the fact that, during the Apollo and Skylab programs, requirements for inflight maintenance appeared very late in the program development cycles, and this resulted in inefficient panic efforts (some of which were inadequate) to:

1) Identify the systems or payloads/experiment requirements for IFM.
2) Establish the hardware support elements required for the IFM tasks.
3) Provision the IFM Support Equipment.
4) Coordinate the verification of IFM procedural requirements with support equipment provisions.
5) Assure adequate stowage and preparations for IFM equipment.

These inefficient efforts were largely a result of early program decisions to "design for no inflight maintenance" but then to admit late in the program that some inflight maintenance would be required. From this "No IFM" program decision, it naturally followed that no one organization would have the responsibility of coordinating and monitoring all aspects of IFM. In reviewing Skylab program history, it can be observed that in general IFM was planned for but not in an efficient manner. Those scheduled tasks planned for occured infrequently and the majority of tasks performed were unplanned prior to flight and had to be planned by the crew and ground elements during the mission.

To address the improvement of the IFM provisioning for future missions of necessity required the detailed examination of the inflight processes and related ground preparation activities being planned for the Shuttle program. The review of present planning in these areas for the Shuttle Orbiter and Payloads reveals major changes in these inflight processes that are a function of new mission concepts for the reuse of the space vehicle and rapid turnaround preparation requirements. The plans to make the flight crew more self-sufficient and less dependent upon ground control for systems status monitoring and troubleshooting also has implications for more definitive preparation prior to flight for contingency activities than has been the case in previous programs.

In particular, the need for rapid turnaround of the Orbiter vehicle has resulted in the examination of new concepts for provisioning of loose equipment (general stowage as well as IFM support equipment). These provisioning processes are still in a developmental stage which makes the development of a recommended specification related to IFM support equipment provisioning inappropriate at this time. However, it does appear worthwhile to provide study data and observations about these loose equipment provisioning concepts being developed.

During the Phase IIIB study, a review and analysis of concepts being developed for the Shuttle stowage and loose equipment provisioning process was conducted. A summary of the results of this analysis is presented in Figure 7 as a preliminary flow-diagram description of the Shuttle Stowage/Loose Equipment Management Process. The basic functions in this process and their interrelationships are identified along with a definition of stowage documentation that is required within the process and the functional interfaces of these documents within the subsequent process elements.

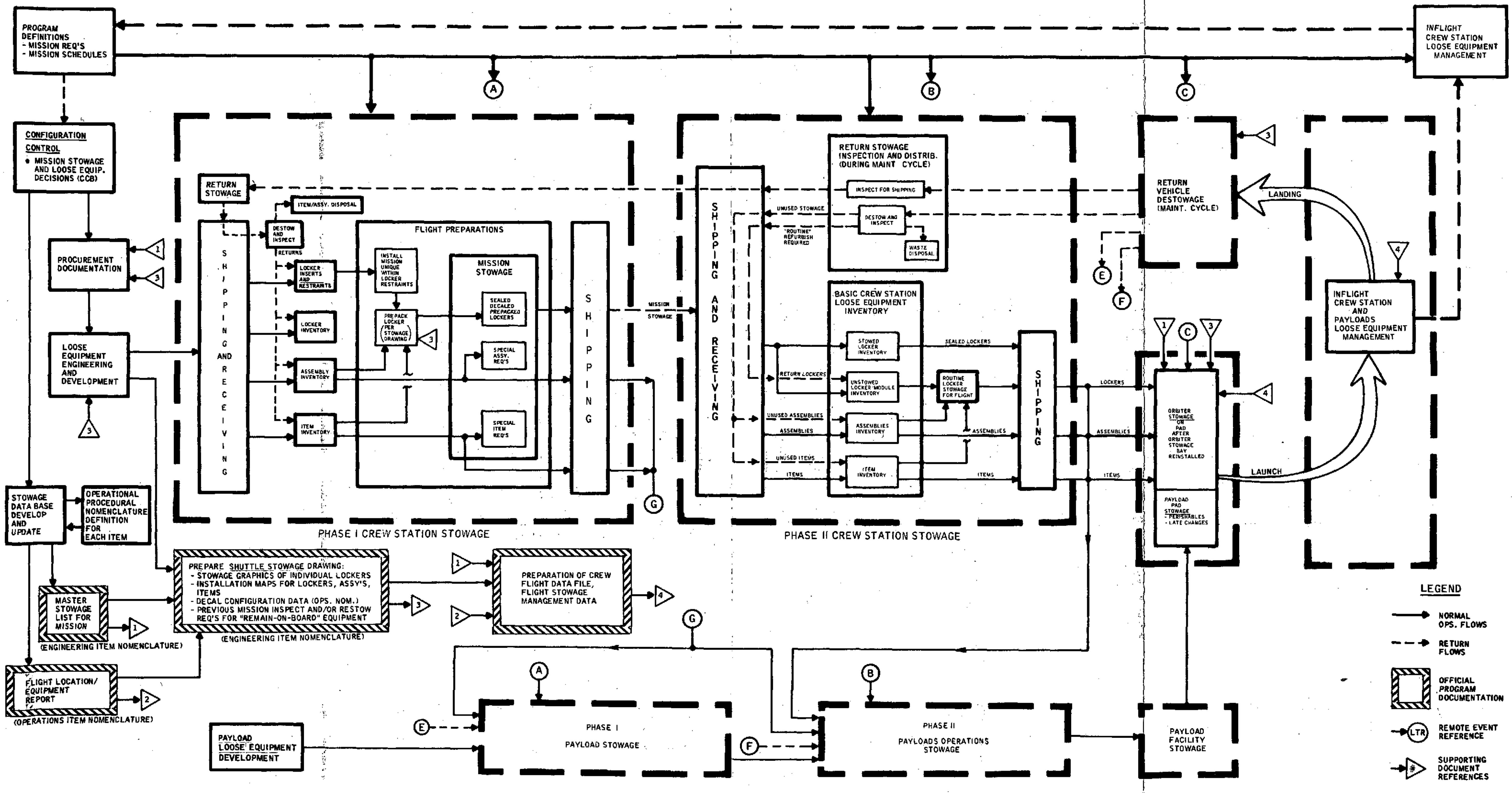
In analyzing this process, some factors requiring early attention and resolution were identified and are disucssed in the following paragraphs of this section.

One problem of concern that must be resolved is the establishment of a system of parts nomenclature that can serve the needs of Configuration Management as well as the operational needs of the flight crew during flight. This problem at first seems to be a trivial concern but when examined in context of the process elements involved it becomes a major concern.

For configuration management and related quality assurance approvals, it is important that the Master Stowage List contain identifying nomenclature in the exact form that appears on the controlling design engineering drawing defining the part. Unfortunately, the designers that supply the drawing do not follow any predictable pattern in naming parts. To standardize and control this part nomenclature at the design engineering level would be a very costly process. As a result, the process has been established to utilize the part nomenclature appearing on the design drawing (Engineering Nomenclature) for the Master Stowage List, the basic authorizing document for the inventory of on-board loose equipment for each mission. This engineering part nomenclature also is utilized on the Shuttle Stowage Drawing which is the basic reference drawing for the Stowage of lockers and installation of on-board equipment. Quality control of the actual stowage will also use engineering part nomenclature so that, up to this point in the process, engineering nomenclature is consistently used.

Unfortunately, the engineering nomenclature is too cumbersome and inconsistent for usage within the flight procedures. As a result, a standard procedural part nomenclature method is planned for usage with flight procedures. This method involves usage of two part nomenclature conventions ("adjective, noun" and "noun, adjective" formats). Both nomenclature conventions are required within the inflight alphabetical listing of on-board loose equipment. These conventions are used for normal operations that usually will require the crew to enter the listing to determine a group of equipments associated with a particular purpose (e.g., a particular experiment) and other operations where it is necessary to determine the inventory of a common category of equipment (e.g., bags, etc.).

FIGURE 7 PRELIMINARY SHUTTLE STOWAGE/LOOSE EQUIPMENT MANAGEMENT PROCESS DESCRIPTION



FOLDOUT FRAME

FOLDOUT FRAME

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The Phase IIIB Crew Interface Specification Development Study has provided NASA with additional specifications for supporting data products for crew interface inflight operations. These data have been submitted to the Technical monitors at the NASA-Johnson Space Center and are in the process of review by Center personnel.

The Crew Interface Specification Study for Phase III has been largely directed toward the investigation of Crew Inflight Maintenance activities and the related information and support data product requirements. From these investigations, the following observations about Inflight Maintenance in future space programs seem appropriate.

The Skylab Program provided a dramatic demonstration of the importance and value of an on-board flight crew maintenance capability to enhance crew safety and the accomplishment of mission objectives. This was a major "Skylab Lesson Learned." However, "good fortune" played a significant part in the fact that real-time planning for inflight maintenance was able to "save" these missions. The pre-flight planning for inflight maintenance resulted in the inclusion of an on-board basic tool set for the crew that was used "creatively" by the crew to perform a wide range of unscheduled and unplanned contingency IFM tasks. In using this basic tool capability, the crew and missions were able to demonstrate many things about IFM that were originally not thought possible. From this experience the following conclusions are appropriate:

(a) Failures of spacecraft, payloads and experiments systems equipment will occur in flight.

Despite the extensive reliability and design redundancy efforts of the Apollo and Skylab Programs, many failures occurred inflight with spacecraft as well as experiment equipments. Historical experience now tells us that even though the stresses on hardware systems are different for spaceflight than for aerodynamic flight, systems still have a "classic" failure pattern. Namely, early "burn-in" failures followed by a decreasing number of random failures until a slightly higher "wear-out" function occurs. The Shuttle Program will present significantly different, and in many cases a more complex, stress pattern than has been the case for Apollo or Skylab. However, since many spacecraft and payload equipments will be developmental in nature, unanticipated failures during flight are predictable particularly since the "reusable" concept for space vehicles must be explored and validated. Planning for an IFM capability for the Shuttle Program that will utilize the demonstrated capability of the crew to perform IFM tasks of significance to deal with inflight failures is essential.

In order for these nomenclature conventions to be effective and to be coordinated with engineering nomenclature, it is necessary that the Stowage Data Base include provisions for these two types of Procedural Part Nomenclature. It is also appropriate that these part nomenclatures should be provided by the procedural organizations at the time of initialization of the Data Base or when additional items are added for inclusion in the on-board inventory.

These Engineering and Operational Part Nomenclatures also require coordination in another area, namely, Stowage Location Decal Preparation. Since the Decal of a stowage location is the principal method used by the flight crew to find things on-board it should describe contents with the nomenclature used within flight procedures. However, the responsibility of preparing decals should be closely associated with the organization responsible for defining the stowage concepts and stowage drawings - all of which contain engineering nomenclature. The fact remains that these drawings are required to contain data defining the form and content of the decals - which use procedural nomenclature. This requires the early provisioning of the Flight Location Equipment Report from the Stowage Data Base in order to provide decal drawing data in a timely manner.

Another aspect of the Shuttle Stowage/Loose Equipment Management Process that becomes apparent from examining the process description chart is the need for a close coordination of all facets of the stowage process. Phase I and Phase II Crew Station Stowage functions must establish mutually supportive functions such that the mission return stowage is processed in a manner that minimizes shipping requirements, where possible, while simplifying the destowage of the vehicle and subsequent preparation of that vehicle for the next flight. In addition, the interfaces between the orbiter crew station stowage and the payloads stowage function should be well defined and supportive of a consistent method of stowage preparation and inflight management.

Another facet of the process that should be given planning attention is the method for integration of inflight maintenance requirements with this Shuttle stowage process. Recommendations are provided within Section 9.0 of this report for considerations to be given to inflight maintenance planning and provisioning. However, one specific aspect of the IFM support process is the requirement for additional on-board equipment which must be stowed. As a result, early attention should be given to optimum locations for IFM equipment and provisions for operational efficiency.

(b) "With proper tools, worksites, restraints, accessibility, illumination, supporting data and procedural aids, man can perform tasks as readily in a zero-gravity environment as he can on earth."

The Skylab missions, as they evolved, allowed the crews to demonstrate a significant capability for the "man" component of the system to fix failures. The problems anticipated with the zero-g environment, such as performing complex tasks, utilizing tools, applying torque, transporting and managing large numbers of parts of different sizes and masses, etc., were dealt with successfully. It can now be deduced that with proper planning and provisioning, the flight crew in future missions can be a major IFM "system" resource that can greatly increase systems reliability and crew safety.

(c) "Indenturing into complex systems and performing very complex and intricate repair tasks is possible provided systems are designed for accessibility and safe procedures are worked out for accomplishing the repair tasks."

The Skylab flight crew performed tasks of indenturing into systems and fixing many that were of amazing complexity. The guidance system (replacing the rate gyro package) and the environmental control system repairs (replenishing the coolant supply) are demonstrable examples of what is possible. This "potential" for "saving" an expensive and valuable spacecraft or experiment with IFM should be planned for and used maturely and effectively to optimize results of future spaceflights.

(d) Planning for inflight maintenance should include planning for a predicted group of preplanned scheduled and unscheduled tasks but it also should include rational planning for a contingency IFM capability.

Planning for the Skylab Program, as in previous NASA manned programs, did not include detailed recommendations for the possibility of inflight maintenance. The design mediums of reliability and design redundancy were supposed to eliminate the need for inflight maintenance. However, during the later phases of the Skylab hardware developments it became apparent that some inflight maintenance might be required. In a departure from previous practice, an ad-hoc committee of NASA and contractor representatives was formed to study inflight maintenance and to recommend a list of candidate tasks and related tools and spares. A set of tools was recommended based upon the task justification for each tool which resulted in the deletion of some tool items of a continuous set. (This proved to be unwise since resupplies had to be requested in almost all cases with every tool on-board being used by the flight crew. In addition, the crew also ingeniously fabricated or "jury rigged" needed parts or tools that were not in the inventory.)

The selected Scheduled IFM tasks for Skylab involved predominantly simple replacement chores (changing light bulbs and filters) and other replacement type tasks. The selections resulted largely from the fact that consideration for including IFM occurred too late to really consider indenturing into systems due to lack of accessibility and because there was a concern for man performing IFM tasks in zero-g and in an oxygen rich environment. With the Skylab program experience and the use of a more "earth-like" cabin environment on the Shuttle program these concerns should be greatly reduced thus permitting mature planning for a general capability for IFM which can deal with predicted as well as contingency situations.

9.2 RECOMMENDATIONS

The above noted conclusions have attempted to identify significant aspects of past Spaceflight programs that have implications for inflight maintenance. In view of these conclusions the following recommendations for future space programs are offered.

(a) Inflight Maintenance Planning and Provisioning should be an in-line program function that is focused in a designated responsible NASA and contractor organization that participates in the design, development and operational phases of future space programs.

The functions of this organization would be to:

(1) Monitor systems design and identify candidate inflight maintenance tasks and related support items (data and hardware).

The recent austerity in spaceflight programs has been accompanied with a natural program management response of delaying until later in the program those activities that are not directly involved in hardware development which includes many aspects of operational planning. However, past spaceflight experience has shown that delaying such efforts can prove a much more costly approach to the problem. It is admitted that the severe economic constraints of a program must be reckoned with but it is important that real-world operational conditions and requirements be considered in a timely fashion. Even though the Program efforts are austere, it is recommended that at least a minimal effort is applied to the planning and preparation for an inflight maintenance capability early in program development.

(2) Direct the development of total vehicle/payloads-experiments inflight maintenance capability.

This function would include the definition of requirements of an on-board tool inventory made up largely of off-the-shelf tool items that would provide a capability for accomplishment of almost any IFM task anticipated. This capability should then be evaluated by all groups providing payloads and experiments to determine whether any special tool, not included in the early defined tool set, should be included as a special on-board requirement. This function will also involve the maintenance of a tools weight budget as a part of vehicle weights trade-offs such that as extensive a tool capability and inventory as possible can be maintained. This weight budget would also consider possible allocations of special tool weight budgets as well. Another aspect of this functional responsibility should be to conduct integrated procedural/tool evaluations as the program progresses closer toward operational program phases.

(3) Direct and monitor a test program designed to establish in a progressive fashion acceptable zero-g maintenance and assembly related special processes.

The performance of many inflight maintenance tasks are contingent upon being able to perform special manufacturing-related processes in the zero-g environment of space. Such processes as soldering, welding, use of debris producing power tools (drills, saws, etc.), bonding, etc. should be established as feasible for performance in zero-g prior to defining a flight crew IFM requirement to perform such tasks. This program would be the logical precursive step in establishing technology that could later be used in assembly and servicing operations on space base, payloads and retrieveable satellite vehicles.

(4) Direct the coordination of payloads and retrieveable satellite refurbishing and servicing requirements with on-board vehicle and payload inflight maintenance capabilities (tools and support items as well as manipulator and check-out capabilities).

This function is defined to establish a systematic approach to the integration of an inflight maintenance capability with payloads and experiments requirements.

(b) Two-way video between the spacecraft and the ground should be considered as a technique to support inflight troubleshooting and corrective maintenance activities.

The use of two-way video would greatly enhance inflight troubleshooting and corrective maintenance activities particularly for contingency and unplanned tasks. This would allow rapid graphics and pictorial data transfer between the flight crew and ground systems experts. Furthermore, the systems experts would be placed "at the anomaly scene," and unplanned graphics data needed by the crew, but not part of their flight data file, could be made readily available to them rather than their having to receive extensive verbal instructions from the ground in order to complete their tasks.

(c) <u>A simple cross referencing system between inflight troubleshooting tasks and IFCM tasks should be developed</u>.

Once a failure is isolated through the use of inflight troubleshooting procedures, the appropriate corrective maintenance procedures to repair the failure should be cross-referenced and the IFCM procedures should be readily accessible. As IFM is essentially the integration of these two functions, their data should be effectively integrated as well.

10.0 SUMMARY

The purpose of the Crew Interface Specification Development Program for Inflight Maintenance, Assembly, Servicing and Stowage functions has been to develop new supportive data concepts for crew inflight operations and to specify the related format and content requirements for such data concepts. The Phase IIIB study has added two additional inflight maintenance specifications to the previously developed specifications on Operational Location Coding, Maintenance Management, and Stowage. In the course of this study certain requirements for crew inflight maintenance activities in future space programs seemed evident and in relation to these requirements conclusions and recommendations for future programs have been provided.

SE-T-0090

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

HOUSTON, TEXAS

GENERAL SPECIFICATION

CREW INFLIGHT TROUBLESHOOTING

JOB PERFORMANCE AIDS

REQUIREMENTS

This proposed specification has not been approved by the Johnson Space Center and is subject to modification.

FOREWORD

Prior to the Skylab Program only a limited amount of inflight maintenance (IFM) was performed on spacecraft by crewmen. The Skylab Program was the first space program for which a significant number of IFM tasks were planned prior to flight as well as on the ground during real-time operations and then effectively carried out by the crewmen on-board.

In previous programs contingency events in flight were managed using abort, emergency or malfunction procedures provided to the flight crew in their flight data files. Abort and emergency procedures are not elements of this specification as there are no repair/restore (IFM) activities involved in these procedures. The ground mission support crews played a significant part in the management of malfunctions by virtue of the telemetry information at their disposal and their resultant ability to monitor the status and trends of various spacecraft system parameters. However, in future manned spaceflight programs ground mission support crews will perform much less of the systems monitoring function, since much more of the systems monitoring and troubleshooting functions is now being planned for on-board performance by flight crews. This change in focus making the flight crew the major troubleshooting center dictates a distinct requirement for the definition of standard supporting procedures to enable the crew to perform effective systems troubleshooting in flight.

The crew Inflight Troubleshooting Job Performance Aid data types specified herein provide format and content guidelines for standard systematic methods of including "decisional" or "logic type" information as an integral part of the on-board troubleshooting support data.

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1.0 INTRODUCTION

1.1 SCOPE

This document defines basic crew procedural data concepts for Job Performance Aids (JPA's) to support Inflight Troubleshooting activities on all manned spacecraft, unmanned satellites and payloads on which orbital or in-space troubleshooting will be performed by flight crewmen.

1.2 PURPOSE

The purpose of this specification is to establish standard format and content requirements for a family of job performance aids (crew procedural checklists and reference data) to support crew performed inflight troubleshooting activities on manned spacecraft, their payloads and unmanned satellites requiring crew troubleshooting. Different types of job performance aid data for inflight troubleshooting support are identified and specifications for preparation of these data types are provided. The use and selection of the particular data type for any specific crew inflight troubleshooting task shall be as specified by the NASA organizational elements that are responsible for flight crew procedures development.

This document should be used with and supplemented by NASA-JSC specification SE-P-0089; General Specification, Crew Inflight Corrective Maintenance Job Performance Aids Requirements in the preparation of Job Performance Aids to support the full spectrum of crew inflight maintenance activities.

1.3 APPLICABLE DOCUMENTS

The following documents, of the issue in effect on the date of invitations for bids or procurement, form a part of this specification to the extent specified herein.

1.3.1 NASA SPECIFICATIONS

SC-C-0009	General Specification, Operations Location Coding System for Crew Interfaces
SE-P-0089	General Specification, Crew Inflight Corrective Maintenance Job Performance Aids Requirements

1.3.2 OTHER DOCUMENTS

MIL-STD 15-1A	Graphic Symbols for Electrical and Electronics Diagrams

1.4 DEFINITIONS

For the purposes of this specification, the following definitions shall apply:

a. Failure - the inability of an item to perform within previously specified limits.

b. Failure analysis - the logical, systematic examination of an item or its diagram(s) to identify and analyze the probability, causes, and consequences of potential and real failures.

c. Item - used to denote any level of hardware assembly; i.e., system, segment of a system, subsystem, equipment component, part, etc.

d. Inflight Maintenance (IFM) - those crew actions required, during spaceflight for safety or mission reasons, to (a) retain the spacecraft or payload system in an operable condition (scheduled IFM), (b) troubleshoot and isolate failed equipment items (inflight diagnostics), and (c) restore failed items to an operable status (corrective maintenance).

e. Inflight Corrective Maintenance (IFCM) - those crew actions performed to restore an item to a satisfactory operable condition after a malfunction has caused degradation of the item below the specified performance level. The major tasks associated with IFCM are:

   Localization and Isolation - determining the location of a failure with or without the use of accessory support equipment on the subsystem level of inflight maintenance.

   Alignment - performing any alignment, minimum tests, and/or adjustments made necessary by the repair action.

   Verification Checkout - performing the minimum checks or tests required to verify that the equipment has been restored to satisfactory performance.

f. Inflight Maintenance Levels - a division of inflight maintenance tasks based upon the level of indenturing into systems and equipment hardware required by the maintenance task. There are three levels of inflight maintenance.

   (1) Subassembly Level - Tasks performed at a level that requires the crew to "open up" a normally sealed or totally enclosed unit, drawer or chassis, and replace or repair parts and/or subassemblies.

(2) Assembly Level - Tasks performed at this level require replacement of a modularized item, i.e., assembly, unit, drawer or chassis. Assembly level tasks are essentially interchange actions of removing a defective item and installing the replacement.

(3) System Level - Tasks performed at this level are addressing total systems problems and do not involve parts or module replacement, but are associated with such activities as leak detection and repairs, glycol replacement, etc., that are not normally scheduled activities.

g. Inflight Scheduled or Preventive Maintenance - the actions performed on a time scheduled basis that attempts to retain a spacecraft or payload item in a specified condition by providing systematic refurbishment inspection, detection, and prevention of incipient failure. This also includes servicing operations.

h. Job Performance Aid Data Types - data used in Job Performance Aids can be classified as (a) textual or verbal information or (b) graphics or pictorial information.

(a) Textual or Verbal Information: Data in word and numerical form that utilizes a style of "directively" identifying or specifying (1) the job or tasks and their proper sequence of performance, (2) the controls, equipment and tool elements that are involved in the tasks and (3) the responses anticipated from the tasks. Tabular data in chart form is also used in conjunction with the textual data for describing performance criteria, etc. Data in this textual checklist form has been the major Job Performance Aid used for on-the-job performance of operations and maintenance by flight or ground crew of aircraft and spacecraft. The extensive use of this JPA form has been due to its compactness, ease of producibility and ease of change.

(b) Graphic or Pictorial Information - data that conveys information through pictorial representation of three-dimensional forms. This type information is uniquely suited for the representation of equipment shape, form, fit, and location within other assemblies and equipments. It's usage within Job Performance Aids in the past has been limited due to the greater costs of preparing the material and the difficulty in making rapid changes to such data.

i. Job Performance Aids - devices and/or data that facilitate task performance by man in the operation and/or maintenance of equipment systems. These aids may be data storage devices (microfilm, computer, film, etc.), display devices (movie projector, computer data terminal, etc.), audio tape and play back devices and printed copy storage (flight data procedures, schematics, etc.). These devices or data specify actions to be taken, equipment to be used or worked upon, and criteria for decision-making events. These aids may be used cooperatively, or concurrently with task performance or can be used as reference data for training and operations.

j. Maintenance - all actions necessary for retaining an item in or restoring it to a specified condition.

k. Redundancy - the existence of more than one means for accomplishing a given function. Each means of accomplishing the function need not necessarily be identical.

l. Reliability - the probability that an item will perform its intended function for a specified interval under stated conditions.

m. Servicing - the replenishment of consumables needed to keep an item in operating condition.

n. Troubleshooting Types of Operations - Job Performance Aid support data requirements to support troubleshooting operations will vary dependent upon the configuration of controls/displays and the inclusion of onboard checkout and monitoring equipment. The types of troubleshooting operations include:

Type 1 - using installed onboard automatic troubleshooting equipment such as the Performance Monitor System on the Shuttle Orbiter.

Type 2 - using spacecraft controls/displays and crew diagnostic procedures

Type 3 - using special test equipment

Type 4 - visual inspection of failure site and/or failed equipment

2.0 RESPONSIBLITIES

The National Aeronautics and Space Administration, Lyndon B. Johnson Space Center (JSC) shall insure compliance to this specification by contractor(s) or designated government organizations responsible for development, preparation and verification of job performance aids provided flight crews to support inflight troubleshooting activities.

Requests for deviations, additions or deletions to this specification shall be forwarded to the applicable NASA/JSC Spacecraft Program Office.

3.0 REQUIREMENTS FOR CREW JOB PERFORMANCE AIDS FOR INFLIGHT TROUBLESHOOTING

3.1 GENERAL DESCRIPTION

Job Performance Aids (JPA's) that support the flight crew in their performance of Inflight Troubleshooting tasks include Checklist data in "sequential" or "logic-type" form that specifies the task, task sequences, the network of logic decisions and the branching criteria necessary for determining the appropriate branch of task sequences to follow. Reference data or background information, such as wiring diagrams, system schematics, test point locations, and test values, are also included that provide support of troubleshooting tasks onboard spacecraft, payload or unmanned satellite vehicles.

Checklist data that supports inflight crew operations has in the past been characteristically "textual" in content (i.e., words and numerical data) and "sequential" in form for normal operations or, for contingency operations, in a "logic-text" form that asks, "IF" a condition exists, THEN directs the next sequence of steps based upon the observed condition.

These textual forms have generally been satisfactory for use in crew operations from crew station consoles where troubleshooting has been limited to safing, malfunction analysis, and switching to alternate modes where possible. However, as systems increased in complexity this logic-text form has proven unwieldy and a new graphic form of logic-text type data was developed for the Apollo Program. This form has proven very effective for spaceflight training and real-time operations wherein spacecraft controls and displays are used in assessing systems status in troubleshooting to identify failed functional loops and components.

If inflight maintenance necessary to correct the failures requires indenturing into an assembly, additional support data appears necessary for troubleshooting on this level. Simple textual checklist data is not adequate except in certain limited cases. Graphics to include test point locations, system schematics, nominal electrical/electronic scope dynamics, etc. are required for accurate and clear communications to the crew in order to assist them in performing effective troubleshooting inflight.

This specification is designed to provide guidelines for the systematic usage of logic-tree, logic-text and graphics data in the preparation of Job Performance Aids for inflight troubleshooting task support. Different types of troubleshooting Job Performance Aid data are identified and specified in the following paragraphs of this specification along with a discussion of the basic purpose of each troubleshooting type and guidelines for its use.

It is important to emphasize that the type classification of the Job Performance Aids for Crew Inflight Troubleshooting task support is not intended to limit the type of data provided the crew on any specific task sequence but merely to standardize the data so that troubleshooting types will have definitized data standards for appropriate information support. The usage of a combination of these data types in support of any specific task sequence is permitted but should be governed by the type of information required to support the task, the amount of crew training time available on the task and failure/criticality relationships.

The determination of the specific troubleshooting data type(s) selected for any given task should be made in conjunction with and with the approval of the NASA organizational element responsible for flight crew procedures development.

3.2 DEFINITION OF CREW JOB PERFORMANCE AID (JPA) DATA TYPES FOR INFLIGHT TROUBLESHOOTING

The crew requirements of Inflight Troubleshooting tasks are a function of the type of equipment being used to assess system status (e.g., (1) automatic built-in test equipment, (2) spacecraft controls/displays, (3) special carry-on test equipment and (4) basic visual inspections with no support equipment). Each of these troubleshooting task types require unique supporting information and a special Job Performance Aid Data Type. The relationship between these troubleshooting type requirements and the Job Performance Data Types is shown in Figure 1. The five crew inflight troubleshooting JPA data types discussed in subsequent paragraphs are:

- Type A: Sequential procedural data format for crew interface with automatic troubleshooting equipment.
- Type B: Troubleshooting "Logic-Text" format
- Type C: Troubleshooting "Logic-Tree" format
- Type D: Troubleshooting data format for crew interface with special test equipment on a subassembly level of maintenance (Type "E" inflight corrective maintenance data format).
- Type E: Integrated text/graphics data format for presenting visual troubleshooting criteria and procedures.

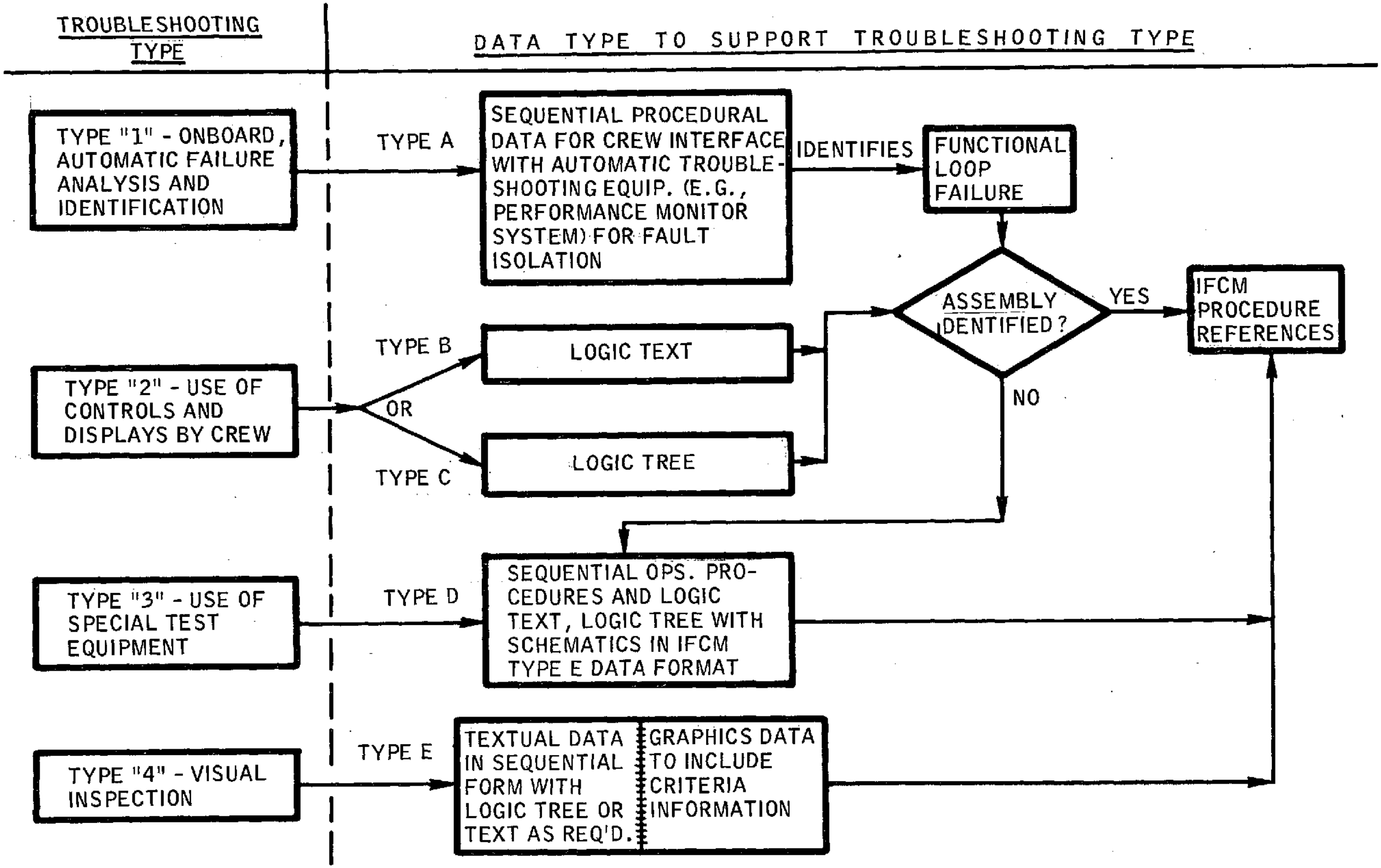


FIGURE 1. RELATIONSHIP BETWEEN TROUBLESHOOTING TYPES AND DATA REQUIREMENTS

3.3 FORMAT AND CONTENT REQUIREMENTS FOR CREW INFLIGHT TROUBLESHOOTING JPA DATA TYPES

The format and content requirements for each of the crew inflight troubleshooting JPA data types are presented within the subsequent paragraphs of this section. The specifications for each data type include the following information:

(a) General description of the inflight troubleshooting data type.

(b) Usage guidelines.

(c) Data elements of the inflight JPA troubleshooting data type.

(d) Example of the JPA troubleshooting data type.

(e) Amplifying examples (when necessary).

All inflight troubleshooting JPA data types specified herein shall be in accordance with the current crew checklist standard nomenclature requirements as specified by the NASA organization responsible for flight procedures.

3.3.1 Type "A" Inflight Troubleshooting Crew JPA Requirements

(a) General Description

The Type "A" inflight troubleshooting JPA data format provides a columnar page format on which data enabling the crew to interface with an automatic troubleshooting system is presented. Entries on this columnar page are made to conform to the most frequent actual sequence of procedural steps the crewman performs when interfacing with automatic troubleshooting equipment. The format provides for categories of keyboard entry (Functions, Data and Command) that allow selection of program functions, data entry and execution (command) of the specific entries made. It is a simple format that standardizes procedural data supplied to flight crewmen for tasks requiring their active interface with a computerized system using keyboard-type equipment.

The structure of this format is dependent upon the specific crew interface operations required by the particular type of automatic on-board checkout equipment or performance monitoring system that is installed. The example provided for Type "A" troubleshooting data is based upon the present concept for the Orbiter Performance Monitor System.

(b) Type "A" Data Usage Guidelines

Type "A" JPA data is designed for use with automatic troubleshooting equipment containing a keyboard, computer(s), sensors, appropriate computer software, a display system and a visual and audible alarm capability.

(c) Type "A" Data Elements (See Example, Figure 2)

A DATA TO BE DISPLAYED - The type of data to be displayed, normally either system status or failure history information.

B SEQUENCE NUMBER - Crew keyboard/computer interface operational sequence.

C FUNCTION - The basic function select operation required by the automatic checkout equipment or performance monitor equipment to SELECT equipment software programs that will perform computer operations which will subsequently provide displayed systems data when appropriate Data and Command entries are made.

D DATA - Numerical inputs in a form required by the on-board checkout equipment software that defines in conjunction with the "Function" selected the particular type of data displayed.

E COMMAND - The keyboard entry to execute the previous selected function and data entries and energize the computer software so that the display selected is displayed.

F DISPLAY - The display that results from the keyboard entries delineated.

G REMARKS - Amplifying remarks.

(d) Example

A typical example of Type "A" data and the recommended form for its presentation are depicted in Figure 2.

(e) Amplifying Examples

Figures 3 and 4 are amplifying examples of typical keyboard/display relationships.

FIGURE 2
EXAMPLE OF TYPE "A" TROUBLESHOOTING DATA

A	B	C	D	E	F	G
	SEQ. NO.	FUNCTION	DATA	COMMAND	DISPLAY	REMARKS
	1	DIS		ENTR	TOP LEVEL "LIBRARY"	
SYSTEM STATUS	2		2	ENTR	SECOND LEVEL "LIBRARY"	
SYSTEM STATUS	OR, 2A	DIS	2	ENTR	SECOND LEVEL "LIBRARY"	USED FOR INITIAL ENTRY
SYSTEM STATUS	3		2 4 1 (1)	ENTR	THIRD LEVEL SYSTEM OPS. STATUS	(1) ASSURES FIRST PAGE OF STATUS DATA
SYSTEM STATUS	OR, 3A	DIS	2 4 1	ENTR	THIRD LEVEL - SYSTEM OPS. STATUS	USED FOR INITIAL ENTRY
SYSTEM STATUS	4		+	ENTR		ADVANCES PAGE DISPLAYED
SYSTEM STATUS	5		-	ENTR		PAGE DISPLAYED RECEDES
FAILURE HISTORY	1	FAULT			FAULT HISTORY SUMMARY	LISTING IN INVERSE ORDER WITH TIME

FIGURE 3. TYPICAL OPERATIONAL EXAMPLE OF KEYBOARD/DISPLAY INTERACTION FOR SYSTEM FAILURE ANALYSIS

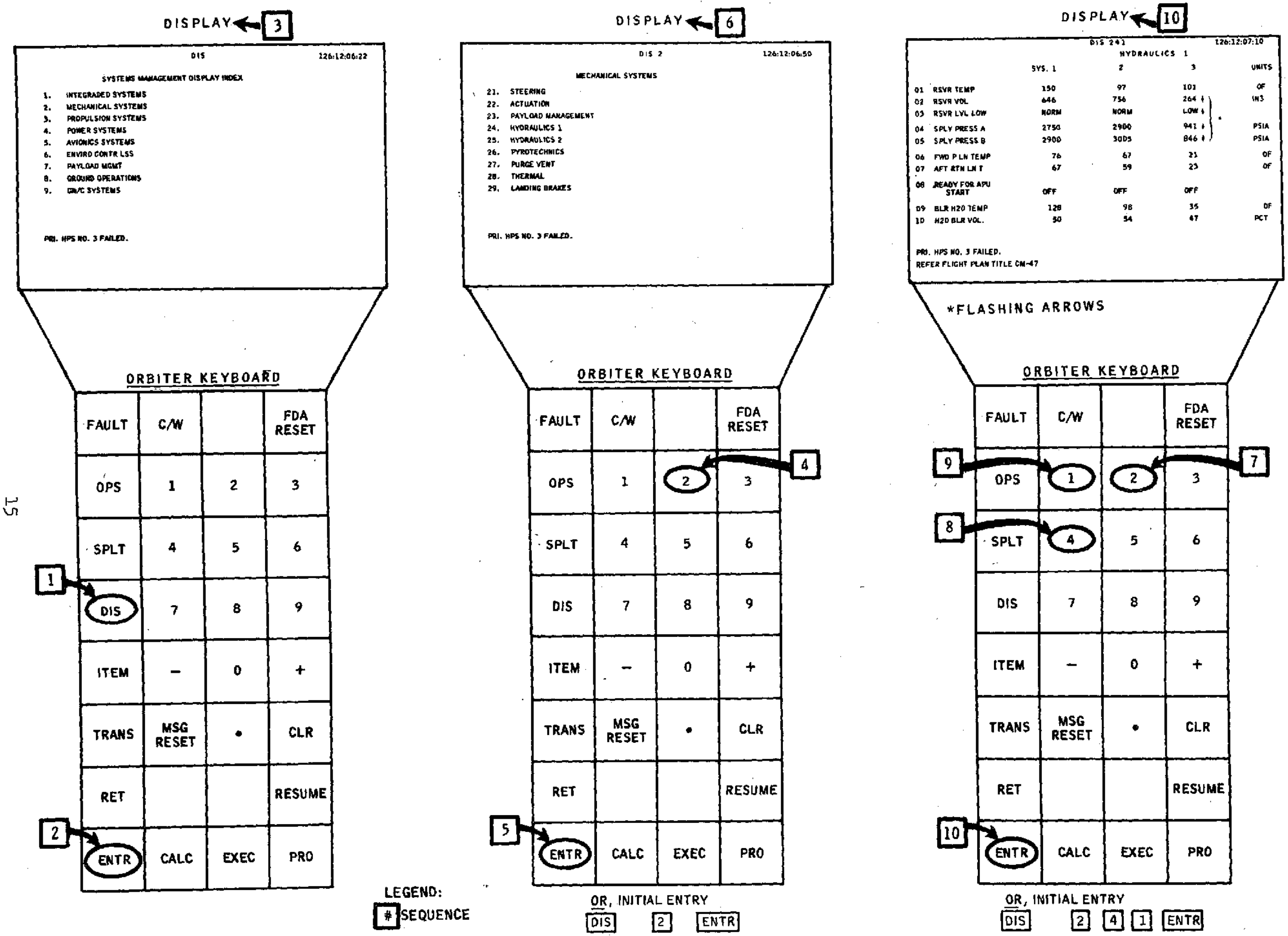
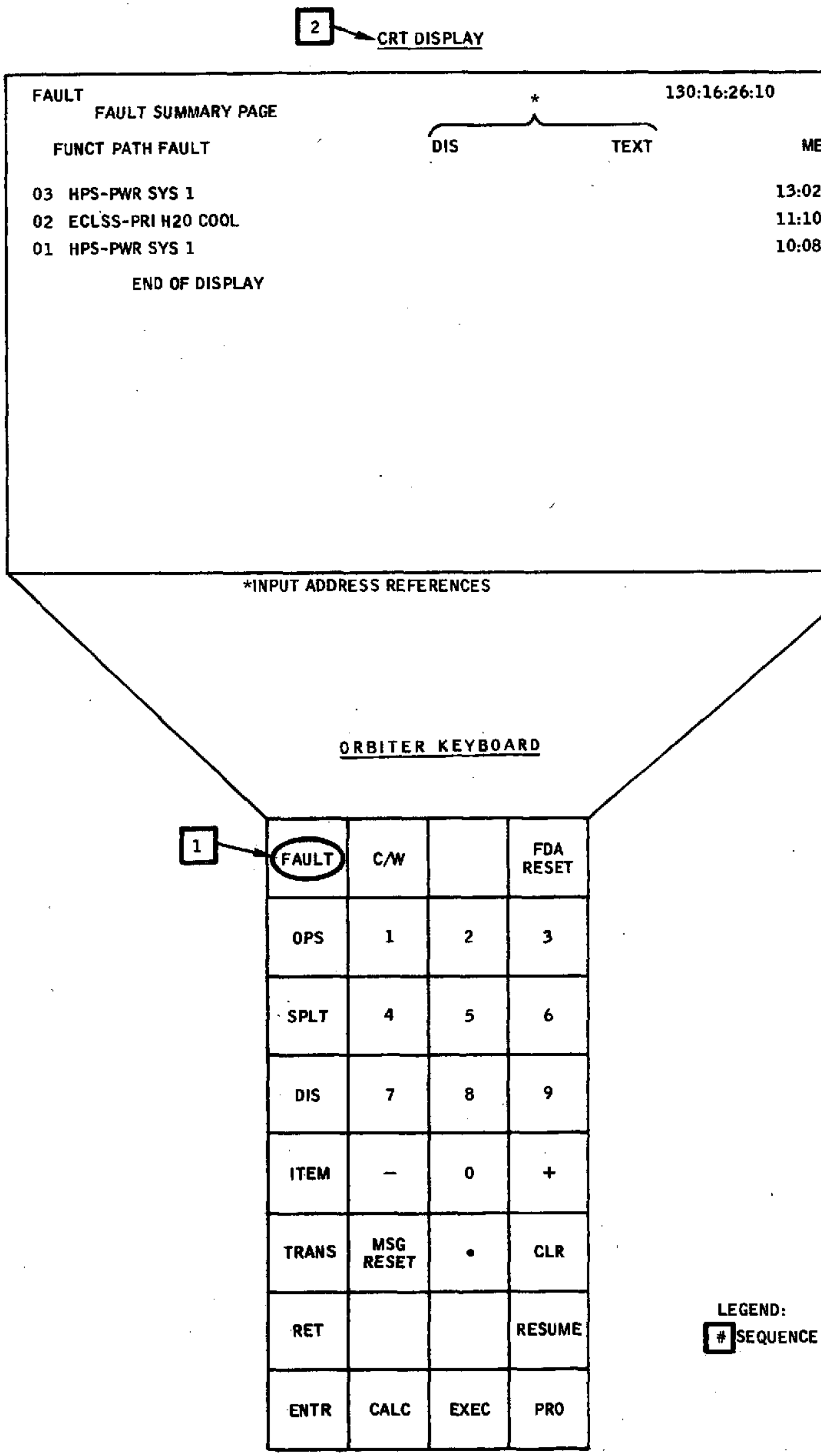


FIGURE 4 TYPICAL FAULT SUMMARY DISPLAY



3.3.2 Type "B" Inflight Troubleshooting Crew JPA Requirements

(a) General Description

Type "B" troubleshooting data is procedural data presented in "Logic-Text" format. This format is essentially textual procedural instructions, listed in numerical order, with the possible results of each procedure accompanying it. The procedural data is usually presented in the form of a question followed by "Yes" or "No" (the possible results). Each unique result yields a specific identified procedure which could be either a referenced Inflight Corrective Maintenance procedure, a referenced troubleshooting procedure (not part of the data being used), or a referenced procedural step to go to in the specific procedures in use.

(b) Usage Guidelines

Type "B" troubleshooting data may be used for brief troubleshooting tasks of inflight troubleshooting Type "2" (using controls and displays). It may also be used in conjunction with appropriate schematic and/or graphics data for brief troubleshooting tasks requiring the use of special test equipment (Type "3") or visual inspection (Type "4").

(c) Data Elements (See Figure 5)

A PROCEDURAL INSTRUCTIONS - Specific instruction steps informing crewman of line task for each procedural step. It is usually presented as a question.

B RESULT OF PROCEDURAL STEP - A simple "Yes" or "No" to the question presented or the result of the specific procedural step.

C NEXT PROCEDURAL STEP DICTATED BY RESULTS OF EACH LOGIC STEP - Informs crewman as to what procedure is to be followed or what step in the logic text is to be carried out next in accordance with the results (B) of each logic step.

D CORRECTIVE MAINTENANCE REFERENCE - Corrective maintenance reference code in order to effect repair when a failure or an anomaly is identified. This reference could also be used to refer to additional troubleshooting procedures when so indicated.

FIGURE 5 EXAMPLE OF TYPE "B" TROUBLESHOOTING DATA

A

1. On navigation control panel does LAT window indicate N3649?

   B
   - Yes - Proceed to step 2.
   - No - Proceed to step 4.

   C

2. On navigation control panel does LONG window indicate W07642?
   - Yes - Proceed to step 3.
   - No - Proceed to step 10.

3. On navigation mode panel set NAV MODE switch to ED. On navigation control panel does LAT window indicate N3649?
   - Yes - End of Procedure.
   - No - Proceed to step 16.

4. Perform step 3. Does LAT window indicate N3649?
   - Yes - Proceed to step 5.
   - No - Proceed to step 8.

5. Using digital voltmeter check for 5 ± 0.01 volts DC at TB002-10. Is voltage correct?
   - Yes - Proceed to step 6.
   - No - Proceed to step 7.

6. Using multimeter check for continuity between TB002-10 and 012P003-5. Is there continuity?
   - Yes - Troubleshoot ballistics computer per CM 26
   - No - Repair defective wire. See CM 32

   D

7. Using multimeter check for continuity between TB002-10 and 0011P002-1. Is there continuity?
   - Yes - Troubleshoot inertial navigation system per CM 27
   - No - Repair defective wire. See CM 32

8. Using digital voltmeter check for 0.01 volts dc at TP1 on ballistics computer test panel. Is voltage correct?
   - Yes - Proceed to step 9.
   - No - Troubleshoot ballistics computer per CM 26

9. Using multimeter check for continuity between 012P005-1. Is there continuity?
   - Yes - Replace navigation control panel. See CM 30
   - No - Repair defective wire. See CM 32

10. On navigation mode panel set NAV MODE switch to ED. On navigation control panel does LONG window indicate W07642?
    - Yes - Proceed to step 11.
    - No - Proceed to step 14.

11. Using digital voltmeter check for 5 ± 0.1 volts DC at TB002-11. Is voltage correct?
    - Yes - Proceed to step 12.
    - No - Proceed to step 13.

12. Using multimeter check for continuity between 012P003-6 and TB002-11 Is there continuity?
    - Yes - Troubleshoot ballistics computer. per CM 26
    - No - Repair defective wire. See CM 32

13. Using multimeter check for continuity between TB002-11 and 011P002-2. Is there continuity?
    - Yes - Troubleshoot inertial navigation system per CM 27
    - No - Repair defective wire. See CM 32

14. Using digital voltmeter check 3 ± 0.01 volts DC at TP2 on ballistics computer test panel. Is voltage correct?
    - Yes - Proceed to step 15.
    - No - Troubleshoot ballistics computer per CM 26

15. Using multimeter check for continuity between 012P005-2 and 014P00l-2. Is there continuity?
    - Yes - Replace navigation control panel. See CM 30
    - No - Repair defective wire. See CM 32

3.3.3 Type "C" Inflight Troubleshooting Crew JPA Requirements

(a) <u>General Description</u>

Type "B" (Logic Text only) inflight troubleshooting crew JPA data has been found to be inefficient for complex and extensive troubleshooting tasks. As a result, a logic tree approach to troubleshooting was developed and used for both the Apollo and Skylab Programs. This troubleshooting format and method was officially referred to as the "Crew Malfunction Procedures," and the use of a graphical logic-tree type format permitted system malfunction procedural data to be presented in a much smaller data package than was necessary using the logic text approach. The Type "C" troubleshooting data uses esentially the basic Crew Malfunction Procedures approach of Apollo and Skylab with minor modifications to permit referencing to appropriate corrective maintenance or additional troubleshooting activities.

(b) <u>Usage Guidelines</u>

Type "C" troubleshooting data can be used where systems are complex and the troubleshooting task can benefit from the greater visibility offered by the graphical logic-tree format. It may be used alone to support troubleshooting tasks for inflight troubleshooting with controls and displays (Type "2"), and in conjunction with schematic or graphic data for troubleshooting with special test equipment (Type "3") or visual means (Type "4").

(c) Data Elements (See Figure 6)

$\boxed{A}$ SYMPTOM - The symptom is the original cue which alerts the crew to an off-nominal condition in a spacecraft system or component. A symptom can be a caution-warning light, a meter reading, or a condition of a system product (engine does not fire, intercom lost, ground reports loss of TV signal, etc.). The symptom is coded by system (ECS, MPS, HYDRAULICS, etc.) and in numerical sequence. This allows referencing to a symptom by system and number (as the procedural process travels through the logic tree) for direct entry into another troubleshooting procedural task.

$\boxed{B}$ PROCEDURES - This data element presents a step-by-step listing of the tasks required to:

1. Gain control of the situation - stop divergent rates, gross leaks; protect threatened components.

2. Determine the source and nature of the problem - find out what failed, what caused it to fail, and the resultant operational status of the subsystem.

3. Establish alternate modes of operation relative to malfunction effects and mission constraints as required.

4. Refer to appropriate corrective maintenance procedure if one exists.

5. Refer to additional troubleshooting if required (e.g., using special test equipment).

$\boxed{C}$ REMARKS - This data element is intended to include information as follows:

1. Amplifying remarks which relate to decision and/or action items (e.g., - why a step is taken, possible system time lags, etc.)

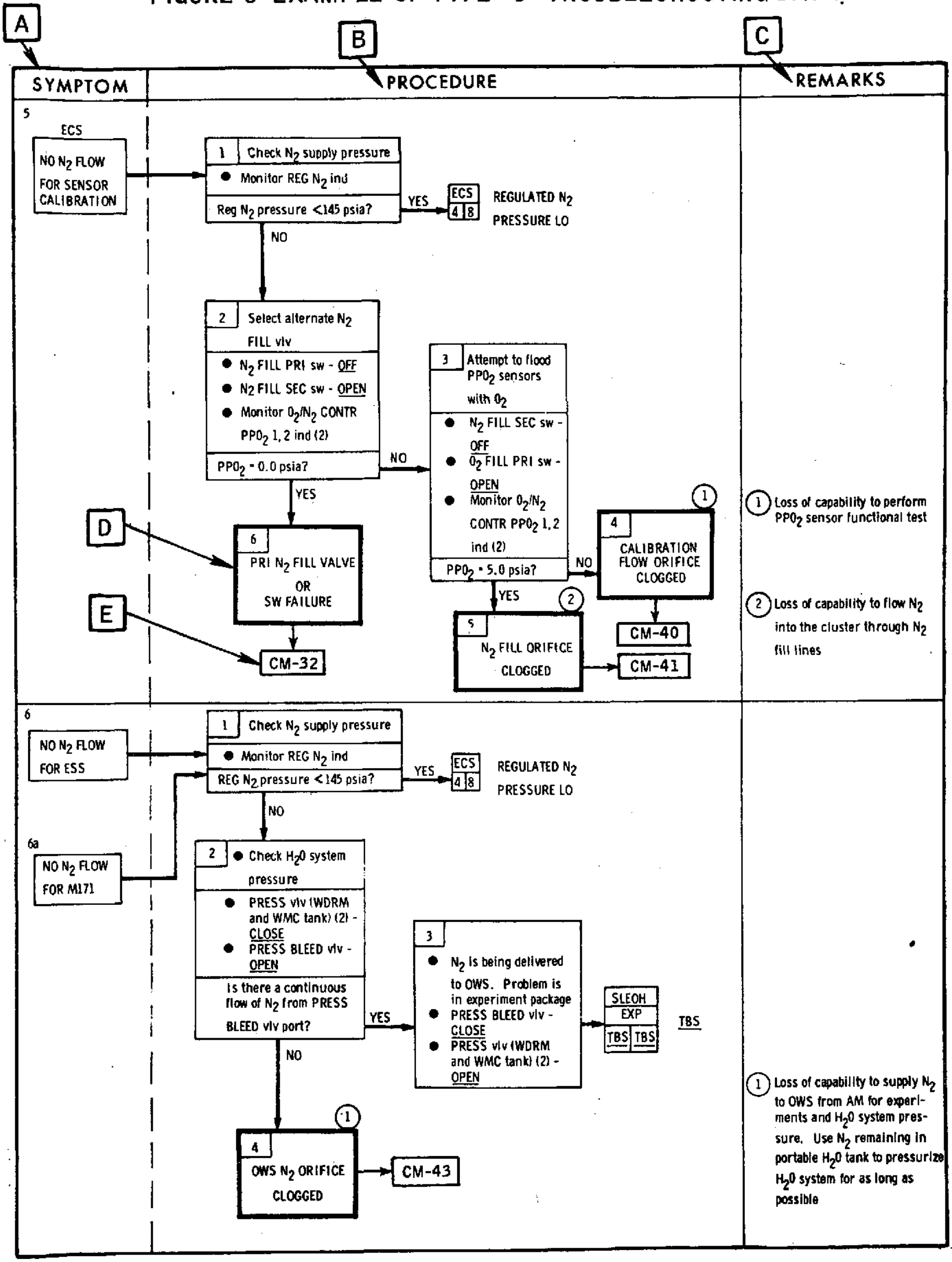
2. The resultant subsystem status or operational capability including conditions of subsequent usage when a failure has been identified.

3. Other remarks which explain or amplify the procedures.

$\boxed{D}$ FAILURE IDENTIFICATION - The failure is identified in a failure block which contains a heavy border and should be on the right side of the procedures column when possible. The failure identified may be a loop or component failure or merely an off-nominal condition. If additional troubleshooting is necessary to determine the failed assembly, an appropriate reference to the proper procedure must be made.

$\boxed{E}$ REFERENCE TO CORRECTIVE MAINTENANCE PROCEDURE - If a corrective maintenance procedure exists for the failure identified, it is referenced using a referencing code such as CM-XX.

FIGURE 6 EXAMPLE OF TYPE "C" TROUBLESHOOTING DATA.



3.3.4 Type "D" Inflight Troubleshooting Crew JPA Requirements

(a) <u>General Description</u>

When inflight maintenance requires subassembly level activities (tasks in which the the crew must "open up" a normally sealed or totally enclosed unit, drawer or chassis and replace or repair parts and/or subassemblies) an integral part of this corrective maintenance activity involves troubleshooting tasks. Type "D" troubleshooting data is designed to support these subassembly corrective maintenance activities. Type "D" data is a combination of sequential operations procedures, Logic Text (Type "B") or Logic Tree (Type "C") troubleshooting data and appropriate schematic data. This data format is delineated as part of Type "E" Inflight Corrective Maintenance (IFCM) data in NASA-JSC Specification SE-P-0089, and is an integral part of Type "E" IFCM.

(b) <u>Usage Guidelines</u>

Type "D" troubleshooting data is used when special test equipment is required at the subassembly level in the troubleshooting process where indenturing within assemblies is an integral part of the inflight maintenance task.

(c) <u>Data Elements</u>

Refer to paragraphs 3.3.2 and 3.3.3 of this specification and Type "E" Inflight Corrective Maintenance data in NASA-JSC Specification SE-P-0089; General Specification, Crew Inflight Corrective Maintenance Job Performance Aids Requirements.

3.3.5 Type "E" Inflight Troubleshooting Crew JPA Requirements

(a) General Description

Type "E" troubleshooting data is a combination of Logic Text (Type "B") and appropriate photographic or graphics data. The photographic or graphics data will contain visual criteria and reference information for examining a failure site and the subsequent logging of the results of the visual inspection and troubleshooting process.

(b) Usage Guidelines

Type "E" data is used when a visual inspection by the crew is required to determine the existence or extent of a failure or anomaly.

(c) Data Elements (See Figure 7)

[A] SEQUENTIAL STEP NUMBER - The numerical sequence number of the procedural step.

[B] PROCEDURAL INSTRUCTIONS - Statements directing the crew to perform actions such as gathering equipment, proceed to worksite, verify restore actions, etc.

[C] LOGIC TEXT PROCEDURES - Procedures presented in logic text format to assist the crewman in isolating the failure in a logical manner. These troubleshooting procedures are appropriately referenced to pictorial or graphics data.

[D] RESULTS OF INSPECTION - Provisions will be made to allow the crewman to log the results of his inspection for future use. This will normally be done near the criteria information for ease in comparison.

[E] PICTORIAL OR GRAPHICS DATA - The site to be inspected will be depicted in the data in a pictorial or graphical manner. Specific areas of interest are identified, and equipment criteria information will be included in order that the crewman can determine if the inspected area is "nominal" or "off-nominal" to a degree that identifies it as a failure or anomaly.

FIGURE 7 EXAMPLE OF TYPE "E" TROUBLESHOOTING DATA

TROUBLESHOOTING PROCEDURE FOR ORBITAL (TS-36) WORKSHOP (OWS) HATCH HANDLE BINDING

1. Obtain metric rule (Location Code) and proceed to OWS HATCH (Location Code).

2. Note Position of OWS HATCH HANDLE (A).

   CLOSE ________   INTERMEDIATE POSITION ________
   OPEN ________

3. Note Position of Release Handle (B).

   LOCK ________   INTERMEDIATE POSITION ________
   UNLOCK ________

4. Does Hatch Handle appear to be bent? (Nominal Clearance: 4 cm.)

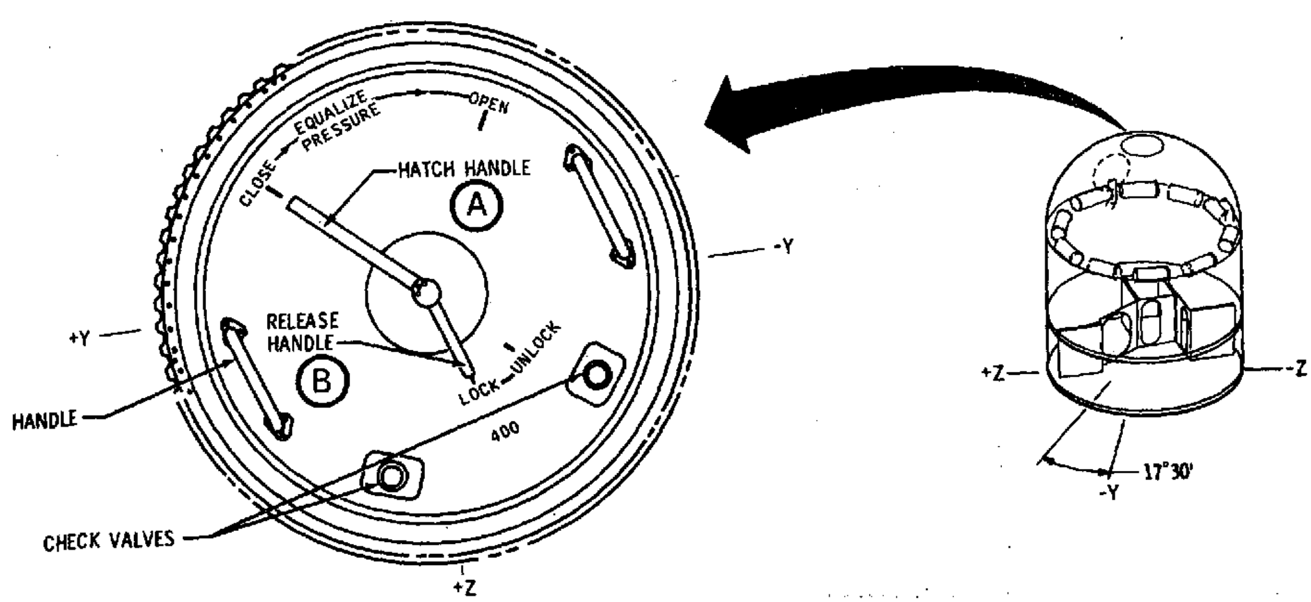
   YES - Refer to CM-47. (Corrective Maint. Procedure Identification Code)
   NO - Proceed to 5.

5. Does Release Handle appear to be bent? (Nominal Clearance: 3.5 cm.)

   YES - Refer to CM-49.
   NO - Proceed to 6.

6. Lubricate Hatch Handle per CM-52.

7. Verify freedom of movement of Hatch Handle.



4.0 SUMMARY

Five data format types have been identified for the support of onboard troubleshooting of manned spacecraft. These data types are designed to support troubleshooting when using an automatic failure analysis system, spacecraft controls and displays, special test equipment, visual inspection, or a combination of these techniques. Procedural data formats supplied in previous spaceflight programs have been used wherever possible and with minimum modification.

Inflight troubleshooting is an integral part of the inflight maintenance process. This specification identifies a referencing technique that permits a rapid transition from the inflight troubleshooting tasks to the proper inflight corrective maintenance tasks - the two basic elements of inflight maintenance.

SE-P-0089

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

HOUSTON, TEXAS

GENERAL SPECIFICATION

CREW INFLIGHT CORRECTIVE MAINTENANCE

JOB PERFORMANCE AIDS

REQUIREMENTS

This proposed specification has not been approved by the Johnson Space Center and is subject to modifications.

FOREWORD

During the Skylab Program a considerable amount of flight crew experience was gained in performing inflight maintenance (IFM) tasks of various levels of complexity from simple to quite complex in both intravehicular and extravehicular environments. Many of these IFM activities were unscheduled events that required real-time mission planning. The IFM crew procedures planned under extremely limited time constraints on the ground either had to be transmitted via the uplink teleprinter or audio uplink to the flight crew or in some cases as hardcopy crew procedures checklist data in the Flight Data File of the next flight.

Operational experience in performing these Skylab IFM tasks emphasized the need for graphical or pictorial type data to support performance of some of the inflight maintenance procedures. Confusion in using only textual crew procedural data did result when the crew task involved relatively complex three-dimensional information such as orientation of equipment, parts nomenclature and location, etc.

The Crew Inflight Corrective Maintenance (IFCM) Job Performance Aid (JPA) data types specified herein provide format and content guidelines for standard systematic methods of including new types of graphical or pictorial data in the crew procedures checklist and reference data for inflight corrective maintenance task support. Guidelines for use of each of the data types on different types of spacecraft systems and for various levels of task complexities are also provided.

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1.0 INTRODUCTION

1.1 SCOPE

This document defines basic crew procedural data concepts for Job Performance Aids (JPA) to support Inflight Corrective Maintenance activities on all manned spacecraft, unmanned satellites and payloads on which orbital or space maintenance will be performed by flight crewmen.

1.2 PURPOSE

The purpose of this specification is to establish standard format and content requirements for a family of job performance aids (crew procedural checklists and reference data) to support crew performed inflight corrective maintenance activities on manned spacecraft, their payloads and on unmanned satellites being serviced by the spaceflight crew. Different types of job performance aid data for inflight corrective maintenance support are identified and specifications for preparation of these data types are provided. Guidelines for the use of each data type are provided as a function of the system being repaired, and its level of task complexity. However, the usage and selection of the particular data type for any specific crew inflight maintenance task shall be as specified by the NASA organizational elements that are responsible for flight crew procedures development.

This document should be used with and supplemented by SE-T-0090; General Specification, Crew Inflight Maintenance Troubleshooting Data Requirements in the preparation of Job Performance Aids to support the full spectrum of crew inflight maintenance activities.

1.3 APPLICABLE DOCUMENTS

The following documents, of the issue in effect on the date of invitations for bids or procurement, form a part of this specification to the extent specified herein.

1.3.1 NASA SPECIFICATIONS

SC-C-0009	General Specification, Operations Location Coding System for Crew Interfaces
SE-T-0090	General Specification, Crew Inflight Maintenance Troubleshooting Job Performance Aids Requirements

1.3.2 Other Documents

MIL-STD 15-1A	Graphic Symbols for Electrical and Electronics Diagrams

1.4 DEFINITIONS

For the purposes of this specification, the following definitions shall apply:

a. Accessibility - a measure of the relative ease of admission to the various areas of spacecraft equipment or items being repaired or refurbished.

b. Failure - the inability of an item to perform within previously specified limits.

c. Failure analysis - the logical, systematic examination of an item or its diagram(s) to identify and analyze the probability, causes, and consequences of potential and real failures.

d. Item - used to denote any level of hardware assembly; i.e., system, segment of a system, subsystem, equipment component, part, etc.

e. Inflight Replaceable Unit (IFRU) - an item which, when unserviceable, can be restored to an operational condition through replacement by the flight crew during flight or space operations.

f. Inflight Maintenance (IFM) - those crew actions required, during spaceflight for safety or mission reasons, to (a) retain the spacecraft or payload system in an operable condition (scheduled IFM), (b) troubleshoot and isolate failed equipment items (inflight diagnostics), and (c) restore failed items to an operable status (corrective maintenance).

g. Inflight Corrective Maintenance (IFCM) - those crew actions performed to restore an item to a satisfactory operable condition after a malfunction has caused degradation of the item below the specified performance level. The major tasks associated with IFCM are:

Preparation - gathering data, tools and spares, configuring systems for inflight maintenance tasks, and airlock operations.

Translation - establishing a movement path throughout (IVA) or over (EVA) the space vehicle to and from the payload or spacecraft maintenance worksite.

Worksite Preparation - establishing crew, tools, and equipment restraints at worksite to enable crew to perform maintenance tasks in zero-g environment.

Restoring Actions:

Disassembly - worksite "open-up" and equipment disassembly to the extent necessary to gain access to the item that is to be replaced.

Localization and Isolation - determining the location of a failure with or without the use of accessory support equipment on the subsystem level of inflight maintenance.

Alignment - performing any alignment, minimum tests, and/or adjustments made necessary by the repair action.

Verification Checkout - performing the minimum checks or tests required to verify that the equipment has been restored to satisfactory performance.

h. Inflight Corrective Maintenance Levels - a division of inflight maintenance tasks based upon the level of indenturing into systems and equipment hardware required by the maintenance task. There are three levels of inflight maintenance.

(1) Subassembly Level - Tasks performed at a level that requires the crew to "open up" a normally sealed or totally enclosed unit, drawer or chassis, and replace or repair parts and/or subassemblies.

(2) Assembly Level - Tasks performed at this level require replacement of a modularized item, i.e., assembly, unit, drawer or chassis. Assembly level tasks are essentially interchange actions of removing a defective item and installing the replacement.

(3) System Level - Tasks performed at this level are addressing total systems problems and do not involve parts or module replacement, but are associated with such activities as leak detection and repairs, glycol replacement, etc., that are not normally scheduled activities.

i. Inflight Corrective Maintenance Modes - Inflight corrective maintenance tasks can be classified into different modes based upon the worksite environment ((1) IVA or (2) EVA) and upon the type of operations being performed (crew direct manual, etc.). These modes include:

Mode 1A: Intravehicular, Crew Direct Manual Operations
Mode 1B: Intravehicular, Remote Manipulator System ("aided") operations
Mode 2A: Extravehicular, Crew Direct Manual Operations
Mode 2B: Not applicable
Mode 2C: Extravehicular, Crew Direct Manual Operations from Remote Manipulator System ("aided" - Cherry Picker operations)
Mode 2D: Extravehicular, Crew Direct Manual from Astronaut Maneuvering Unit. ("aided" operations)

j. Inflight Scheduled or Preventive Maintenance - the actions performed on a time scheduled basis that attempts to retain a spacecraft or payload item in a specified condition by providing systematic refurbishment inspection, detection, and prevention of incipient failure. This also includes servicing operations.

k. Inflight Maintenance Concept - a narrative statement or illustration that defines the theoretical means of maintaining an equipment item or system during spaceflight. The statement relates the tasks that should be performed, the tools, spares, restraint and mobility equipment that should be used to perform the inflight maintenance, and the training requirements of flight personnel necessary for safe task performance.

l. Job Performance Aids - devices and/or data that facilitate task performance by man in the operation and/or maintenance of equipment systems. These aids may be data storage devices (microfilm, computer, film, etc.), display devices (movie projector, computer data terminal, etc.), audio tape and play back devices and printed copy storage (flight data procedures, schematics, etc.). These devices or data specify actions to be taken, equipment to be used or worked upon, and criteria for decision-making events. These aids may be used cooperatively, or concurrent with task performance or can be used as reference data for training and operations.

m. Job Performance Aid Data Types - data used in Job Performance Aids can be classified as (a) textual or verbal information or (b) graphics or pictorial information.

(a) Textual or Verbal Information: Data in word and numerical form that utilizes a style of "directively" identifying or specifying (1) the job or tasks and their proper sequence of performance, (2) the controls, equipment and tool elements that are involved in the tasks and (3) the responses anticipated from the tasks. Tabular data in chart form is also used in conjunction with the textual data for describing performance criteria, etc. Data in this textual checklist form has been the major Job Performance Aid used for on-the-job performance of operations and maintenance by flight or ground crew of aircraft and spacecraft. The extensive use of this JPA form has been due to its compactness, ease of producibility and ease of change.

(b) Graphic or Pictorial Information - data that conveys information through pictorial representation of three-dimensional forms. This type information is uniquely suited for the representation of equipment shape, form, fit, and location within other assemblies and equipments. It's usage within Job Performance Aids in the past has been limited due to the greater costs of preparing the material and the difficulty in making rapid changes to such data.

n. Onboard Loose Equipment - those equipment items that must be developed and/or procured and stowed onboard the spacecraft as additional equipment for (a) crew operations support (checklists, etc.), (b) crew life support (space suits, food, etc.), and (c) crew inflight maintenance support (tools, spares, restraint devices).

o. Maintainability - a characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources.

p. Maintenance - all actions necessary for retaining an item in or restoring it to a specified condition.

q. Redundancy - the existence of more than one means for accomplishing a given function. Each means of accomplishing the function need not necessarily be identical.

r. Reliability - the probability that an item will perform its intended function for a specified interval under stated conditions.

s. Servicing - the replenishment of consumables needed to keep an item in operating condition.

t. Systems Types of Job Performance Aids - the nature of information and the format required within JPA's for inflight corrective maintenance support will vary as per the type of spacecraft or payload system being repaired or fixed. The classification of systems based upon unique data requirements is as follows:

E = Electrical/Electronic Data Types
M = Mechanical/Electro-mechanical Data Types
F = Fluid/Fluid Mechanical Data Types

u. Troubleshooting Types of Operations - Job Performance Aid support data requirements to support troubleshooting operations will vary dependent upon the configuration of controls/displays and the inclusion of onboard checkout and monitoring equipment. The types of troubleshooting operations include:

Type 1 - using installed onboard automatic troubleshooting equipment such as the Performance Monitor System on the Shuttle Orbiter.

Type 2 - using spacecraft controls/displays and crew diagnostic procedures

Type 3 - using special test equipment

Type 4 - visual inspection of failure site and/or failed equipment

2.0 RESPONSIBILITIES

The National Aeronautics and Space Administration, Lyndon B. Johnson Space Center (JSC) shall insure compliance to this specification by contractor(s) or designated government organizations responsible for development, preparation and verifications of job performance aids provided the flight crew to support <u>inflight corrective maintenance</u> activities.

Requests for deviations, additions, or deletions to this specification shall be forwarded to the applicable NASA/JSC Spacecraft Program Office.

3.0 REQUIREMENTS FOR CREW JOB PERFORMANCE AID'S (JPA'S) FOR INFLIGHT CORRECTIVE MAINTENANCE

3.1 GENERAL DESCRIPTION

Job Performance Aid's (JPA's) that support the flight crew in their performance of Inflight Corrective Maintenance (IFCM) tasks include both Checklist data, that specifies the task and task sequences required, and Reference data or background information, such as functional schematics, that provide indirect support of the corrective maintenance tasks onboard the spacecraft, payload or unmanned satellite being serviced.

Checklist data that supports inflight crew operations has in the past been characteristically "textual" in content (i.e., words and numerical data). This textual form has generally been satisfactory for use in crew operations from crew station consoles where task types are few (i.e., switch positioning and display and monitoring) or when performing relatively simple maintenance tasks involving few parts. However, when corrective maintenance activities involve different kinds of tasks, numerous parts, complex configurations, and functional relationships, supplementary graphics (checklist and reference data) are required for accurate and clear communications to the crew of task and part requirements during performance of the corrective maintenance task.

This specification is designed to provide guidelines for the systematic inclusion of graphics data in the preparation of Job Performance Aids for inflight corrective maintenance task support. Different types of IFCM Job Performance Aid data are identified and specified in the following paragraphs of this specification along with a discussion of the basic purpose of each data type and it's usage guidelines.

It is important to emphasize that the type classification of the Job Performance Aids for Crew Inflight Corrective Maintenance task support is not intended to limit the type of data provided the crew on any specific task sequence but merely to standardize the data so that if a task sequence requires a particular type of information to support it there is a standard data form for including such information. The usage of a combination of these data types in support of any specific task sequence is permitted but should be governed by the type of information required to support the task, the amount of crew training time available on the task and the criticality of the task with respect to crew safety and mission success.

The determination of the specific data type(s) selected for any given task sequence should be made <u>in conjunction with</u> and <u>with the approval</u> of the NASA organizational element responsible for flight crew procedures development.

3.2 DEFINITION OF CREW JOB PERFORMANCE AID DATA TYPES FOR INFLIGHT CORRECTIVE MAINTENANCE TASKS

Job Performance Aid data (checklists and reference data) for use in support of inflight corrective maintenance tasks of the flight crew shall include, but not be limited to the following data types:

- Type A: Task Text Data Only
- Type B: Single Page Format - Task Texts/Graphics
- Type C: Double Page Format - Task Texts/Facing Page Graphics
- Type D: Triple Page Format - Task Texts/Graphics/Folded Graphics
- Type E: Complex Integrated Format - Task Text/Chart-Graphics/
Folded Parts Data/
Functional-Detail Schematics

A brief summary description of these Job Performance Aid data types is presented in Figure 1. A detailed specification of the format and content requirements for each of these data types is included within the subsequent paragraphs of this specification along with a discussion of the basic purpose of the data type and usage guidelines.

3.3 FORMAT AND CONTENT REQUIREMENTS FOR CREW IFCM JPA DATA TYPES

The format and content requirements for each of the crew IFCM JPA data types are presented within the subsequent paragraphs of this section. The specifications for each data type include the following information:

a) Format size and configuration requirements

b) General description of the IFCM JPA data type

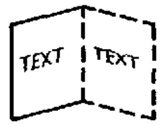
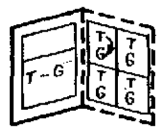
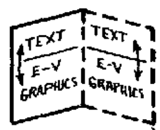
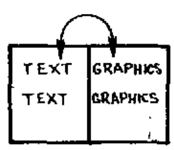
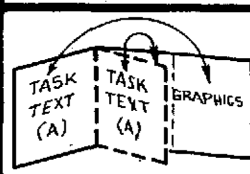
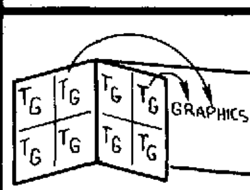
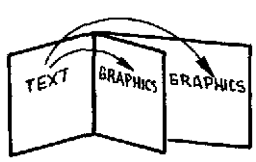
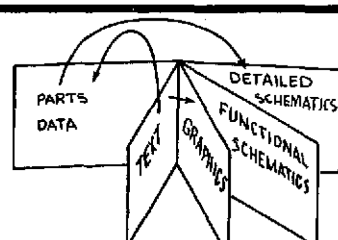
c) Usage guidelines

d) Data elements of the JPA data type

e) Example of the JPA data type

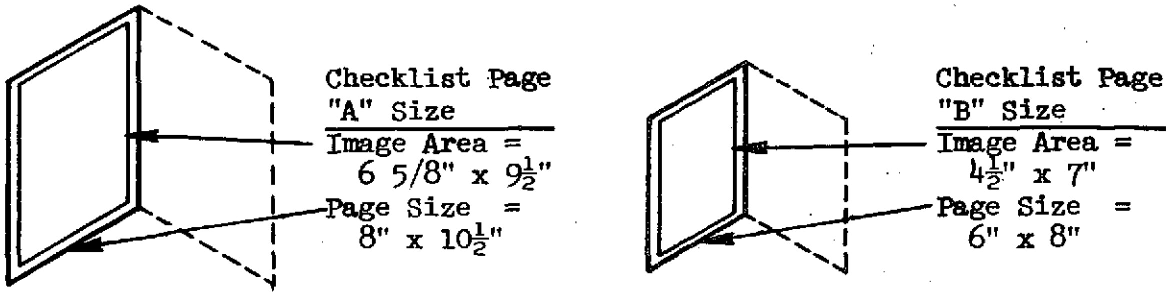
All IFCM JPA data types specified herein shall be in accordance with the current crew checklist standard nomenclature requirements as specified by the NASA organizational elements that are responsible for flight crew procedures development.

FIGURE 1 -
SUMMARY OF CREW INFLIGHT CORRECTIVE MAINTENANCE
JOB PERFORMANCE AID DATA TYPES

JOB PERFORMANCE AID DATA TYPES		TYPE DESCRIPTION: CROSS-INDEXING INDICATED BY ARROWS ←→	
TYPE "A" ●SINGLE PAGE FORMAT ●TASK TEXT			●SINGLE PAGE FORMAT ●TASK TEXT AS PER NASA/JSC CREW PROCEDURAL STANDARDS ●FRONT/BACK PRINTING ●PAGE SIZES: A = 8" X 10 1/2" B = 6" X 8"
TYPE "B" ●SINGLE PAGE ●TEXT/GRAPHICS	TYPE "B1" ●SINGLE PAGE FORMAT ●BLOCKED TASK TEXT/ TASK GRAPHICS		●SINGLE PAGE FORMAT ●TASK TEXT AND TASK TEXT ILLUSTRATING GRAPHICS INCLUDED WITHIN ENCLOSED BLOCKS ON PAGE ●FRONT/BACK PRINTING ●PAGE SIZE: 8" X 10 1/2" ●TASK/GRAPHICS CROSS-INDEXED BY PART CODE
	TYPE "B2" ●SINGLE PAGE FORMAT ●TASK TEXTS/ EXPLODED-VIEW GRAPHICS		●SINGLE PAGE FORMAT ●TASK TEXTS (GROUPED TOGETHER) ●EXPLODED-VIEW GRAPHICS, PART NAMES AND CODES ●FRONT/BACK PRINTING ●PAGE SIZE: 8" X 10 1/2" ●TASK/GRAPHICS CROSS-INDEXED BY TASK NUMBER, PART CODE
TYPE "C" ●DOUBLE PAGE FORMAT ●TASK TEXTS/(FACING PAGE) GRAPHICS			●DOUBLE PAGE FORMAT ●TASK TEXTS ON LEFT-HAND PAGE CROSS-INDEXED TO GRAPHICS ON RIGHT HAND PAGE BY PART CODE AND TASK NUMBER ●FRONT/BACK PRINTING ●PAGE SIZE: 8" X 10 1/2"
TYPE "D" ●TRIPLE PAGE FORMAT ●TEXT/(GRAPHICS) FOLDED GRAPHICS	TYPE "D1" ●TRIPLE PAGE FORMAT ●TASK TEXT (TYPE A)/ FOLDED GRAPHICS		●TRIPLE PAGE FORMAT (ALLOWS VIEWING OF 3 DATA PAGES SIMULTANEOUSLY) ●TASK TEXT(TYPE A FORMAT) PAGE SIZE: 8" X 10 1/2" ●FOLDED GRAPHICS PAGE SIZE: 16" X 10 1/2" ●CROSS-INDEXED BY TASK NUMBER, PART CODE
	TYPE "D2" ●TRIPLE PAGE FORMAT ●BLOCKED TASK TEXT/ TASK GRAPHICS/ FOLDED GRAPHICS		●TRIPLE PAGE FORMAT ●BLOCKED TASK TEXT/GRAPHICS: 8" X 10 1/2" FOLDED GRAPHICS 16" X 10 1/2" ●CROSS-INDEXED BY TASK NUMBER, PART CODE
	TYPE "D3" ●TASK TEXT/FACING PAGE GRAPHICS/ FOLDED GRAPHICS		●TRIPLE PAGE FORMAT ●TASK TEXT/FACING PAGE GRAPHICS: 8" X 10 1/2" ●FOLDED GRAPHICS: 16" X 10 1/2" ●CROSS-INDEXED BY TASK NUMBER, PART CODE
TYPE E ● COMPLEX INTEGRATED FORMAT ● TASK TEXT/CHART-GRAPHICS PARTS DATA/FUNCTIONAL AND DETAILED SCHEMATICS			● COMPLEX INTEGRATED FORMAT ● TASK TEXT/GRAPHICS 8" X 10-1/2 " ● FOLDED SCHEMATICS 10-1/2" X 16" OR UP TO 39" ● CROSS-INDEXED THRU PART CIRCUIT CODES

3.3.1 Type "A" IFCM Crew JPA Data Requirements

(a) Format Size and Configuration Requirements



(b) General Description of Type "A" IFCM JPA Data

Type "A" IFCM Crew JPA Data utilizes a single page type format and is printed on both the front and back of the checklist pages. The paper stock to be used shall be in accordance with the Checklist Standards preparation that are currently specified by the NASA organizational elements responsible for flight crew procedures development.

Type "A" Data contains textual (word and numerical) descriptions of the crew inflight corrective maintenance task requirements in the standard "checklist" data form that has been developed and used successfully in support of the Skylab Program crew inflight maintenance activities. The Type "A" textual data shall be in accordance with current JSC-CTPD checklist standard nomenclature for maintenance tasks. This data shall specify tasks to be performed by the crew utilizing the basic checklist statement from:

"Action Verb" "Action Object" "Amplifying Data"

If, during the maintenance task, control position reconfiguration is required, then standard checklist "operations" type checklist statement form shall be used which includes:

"Control/Display Object" "New Control Position or Display Value to Check"

The information presented on Type "A" JPA data is basically the description of tasks to be performed and task sequences to be followed. The Type "A" data elements necessary to support Inflight Corrective Maintenance tasks are identified and discribed in section (d) of this paragraph.

(c) Type "A" Data Usage Guidelines

The majority of inflight maintenance tasks to be performed by the flight crew can be sufficiently supported thru the use of Type "A" IFCM JPA Data provided sufficient training time is made available on mockups or simulators of reasonable fidelity such that equipment nomenclature and the location and orientation of parts involved in the maintenance task are "familiar" data to the flight crew. Type "A" textual data is then used as a reminder of the task or task sequences to be followed.

3.3.1.4 Type "A" Data Elements (see Example Figure 2)

A CREW PROCEDURES TITLE - The official CTPD title for this set of inflight corrective maintenance procedures.

B FLIGHT PLAN TITLE - This is the code by which the specific task sequence is identified and referred to when cross referencing from troubleshooting of operation or procedures and for flight planning purposes.

C TASK SEQUENCING - Tasks are numbered to indicate task order. Task numbering can be by individual tasks or by task groups at the discretion of the CTPD Book Manager. However, when the Type "A" data is used in conjunction with graphics data, all tasks to be illustrated must be numbered.

D TASK LOCATION - The location within the spacecraft or payload for each task is designated utilizing the crew station operations location coding system as applied to the crew interface areas.

E OBTAIN: (IFCM PREPARATIONS DATA) - This information is included prior to the procedural steps of any IFCM procedural set. Support elements (tools, spares, etc.) are identified along with their stowed location in the spacecraft.

F INFLIGHT MAINTENANCE TASK DIRECTIONS - Tasks to be performed shall be identified in CTPD Standard Checklist nomenclature for maintenance tasks which requires beginning the Checklist statement with a stated "Action Verb". Tools and spares required for each task are in parenthesis after task description.

G CONTROL/DISPLAY RECONFIGURATIONS - Within an IFCM Procedural Set, control/display reconfigurations and monitoring checks may be required. When describing these tasks, normal standard "operations" checklist nomenclature is utilized which does not require "Action Verb" since it is understood.

H DATE - The CTPD approval date of the IFCM procedures are indicated on the left side for front pages and right side for back pages.

I PAGE NO. - The page number of the procedures within the flight configured books are indicated at the top of the page as noted in the example.

J CAUTION, WARNING AND NOTES - These data are included as illustrated within the task sequences. This is amplifying information to alert the crew to hazardous or special conditions of which they should be aware.

K CONTINGENCY PROCEDURES - These procedures are the means whereby integral troubleshooting and/or verification tasks are included within inflight corrective maintenance procedural sets. This allows for definition of "criteria" data that can define launching sequences dependent upon the relationship of the observed value of condition to the criteria that is defined.

L EXPLANATORY NOTES - Notes are included as illustrated to provide amplifying comments and explanatory information about procedures and tasks.

FIGURE 2

EXAMPLE IFCM TYPE "A" JPA DATA

D C A I B

2-23

<u>MDA POWER UMBILICAL REPLACEMENT</u> <u>HK 80A</u>

E

M144 1 Obtain:
7/16 deepwell socket 1 (first use only)
Ratchet handle 1 (first use only)
Red tape (1 piece) 2
M124 Spares pallet (restrain at ATM tool restraint) (large expando pin)
F
M157, M151 MDA power umbilical

2 Open container (contingency power cable)
(ratchet handle, 7/16 deepwell socket - first use only)
Remove contingency power cable from container
Remove dust caps from contingency power cable and stow in container

G

CM230 3 cb CSM/SWS DRAG (10) - open (verify)
Open DRAG THRU RECEPTACLE door
Connect CSM P593 connector of contingency power cable to DRAG THRU RECEPTACLE
M102 Remove dust cap from CONTINGENCY POWER TRANSFER connector and temporarily stow
Connect MDA P12 connector of contingency power cable to CONTINGENCY POWER TRANSFER connector in MDA tunnel

J

4 <u>CAUTION:</u> Verify that piercing tip of Saddle valve is fully retracted (CCW)

5 If duct heater failed:

K

TCS HTR DUCT 1 1*3 sw - OFF
TCS HTR DUCT 1 2*4 sw - OFF
cb TCS DUCT 1 FANS (4) - OPEN

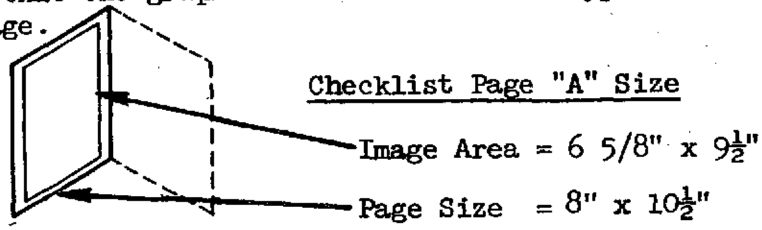
L

<u>NOTE</u>: Use tape, straps, etc., to restrain loose parts.

3.3.2 Type "B1" IFCM Crew JPA Data Requirements

(a) <u>Format Size and Configuration Requirements</u>

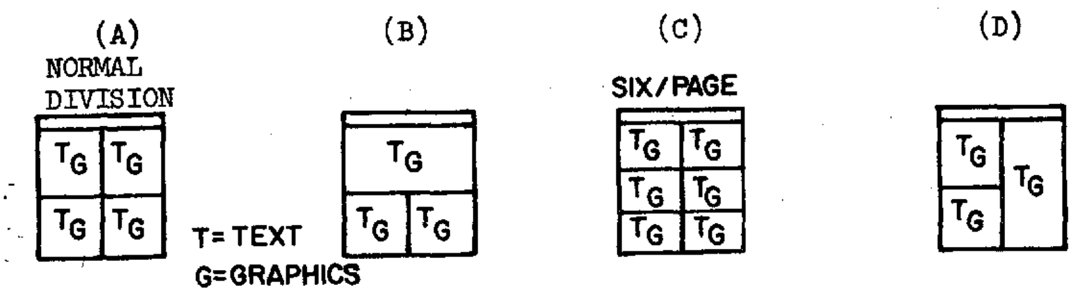
Type "B1" IFCM JPA Data requires the use of a checklist page "A" size. This is due to the fact that the graphics included in this type data requires the larger checklist page.



(b) <u>General Description of Type "B1" IFCM JPA Data</u>

Type "B1" IFCM JPA data shall utilize a single page type format and is printed on both the front and back of checklist pages. The paper stock to be used shall be in accordance with current checklist preparation standards of the NASA organizational elements responsible for flight crew procedures development.

Type "B1" Data shall contain textual (word and numerical) descriptions of the crew inflight corrective maintenance task requirements in the standard CTPD checklist nomenclature for maintenance tasks plus graphical illustrations of the specific task or task groups being identified by the text. Each of these task text and task graphics information groups are framed on the page with boundary lines. In general four (4) such task text/task graphics can be presented on one page. However, the graphic information within each task grouping may require different area shapes so that image area divisions can vary. Typical page division examples are:



The purpose of the Type B1 IFCM data format is to present task text and task graphics for those mechanical tasks that are critical or have a relative complex relationship of parts or tools. By including the text and graphics within the same area, the crew search time in reading the text and graphics is minimized and the cross-indexing involved between text and graphics is simplified. The Type "B1" data elements necessary to support Inflight Corrective Maintenance tasks are identified and specified in section (d) of this paragraph.

(c) <u>Type "B1" Data Usage Guidelines</u>

Type "B1" JPA data provides the capability to illustrate with detailed graphics each specific task of an inflight corrective maintenance task sequence. This type of data can be used for a total sequence if it is considered to involve very critical or complex tasks or it can be used only for selected tasks within a sequence that is covered mainly with Type "A" (Text only) Data.

(d) Type "B1" Data Elements (See Example Figure 3)

A CREW PROCEDURES TITLE - The official CTPD title for this set of inflight corrective maintenance procedures.

B FLIGHT PLAN TITLE - This is the code by which the specific task sequence is identified and referred to when cross referencing from troubleshooting or operational procedures and for flight planning purposes.

C TASK SEQUENCING - Tasks are numbered to indicate corrective maintenance task order.

D OBTAIN: (IFCM PREPARATIONS) - This information is included prior to the procedural steps of any IFCM Procedural Set. All support elements (tools, spares, etc.) required for the task set are identified along with their stowed location in the spacecraft.

E TASK LOCATION - The location within the spacecraft or payload of the site for each task is designated utilizing the crew station operations location coding system as applied to the crew interface area.

F INFLIGHT MAINTENANCE TASK DEFINITIONS - Tasks to be performed are identified in CTPD standard checklist nomenclature for maintenance tasks which includes stated "Action Verb" as initial word in task description.

G TASK GRAPHICS - Each task or Task group shall be illustrated using graphics of the equipment being maintained or repaired and selective illustration of tools and manual operations required to perform the tasks. These graphics can be line drawings or half-tone pictures (as illustrated in the example) and should provide a clear illustration of the task to be performed. Part codes (alphabetical) and part nomenclature can be used as is appropriate to illustrate the task.

FIGURE 3

EXAMPLE TYPE B1 DATA

CM-1 ← B   E   HUB DISASSEMBLY ← A

A: OBTAIN:

(M144) NARROW BLADE SCREWDRIVER
HOOK SPANNER WRENCH

(M021) VISE

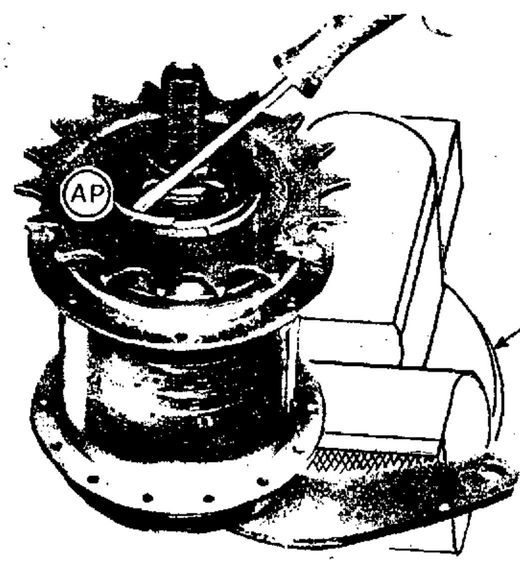
(M021) NOTE: ALL HUB DISASSEMBLY TASKS PERFORMED AT WORK STATION LOCATION

D

1) CLAMP HUB ASSY. BY AXLE FLATS IN "SOFT-JAWED" VISE

2) PRY SPROCKET LOCK RING (AP) FROM RECESS (NARROW BLADE SCREWDRIVER) AND REMOVE FROM SPROCKET

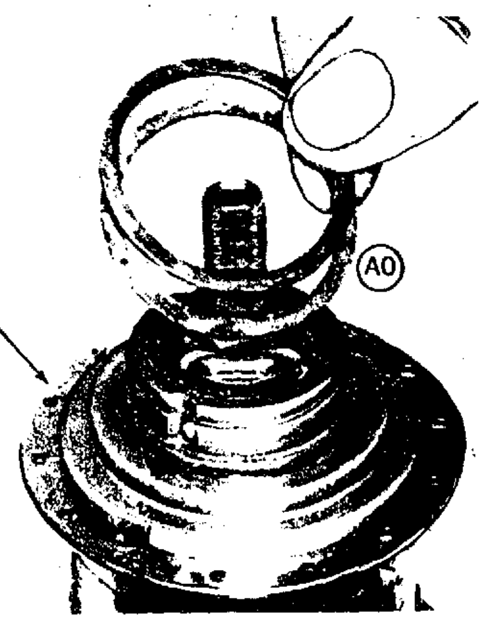
C



G

3) REMOVE SPROCKET (AN) AND SPACERS (AO) FROM ASSY.

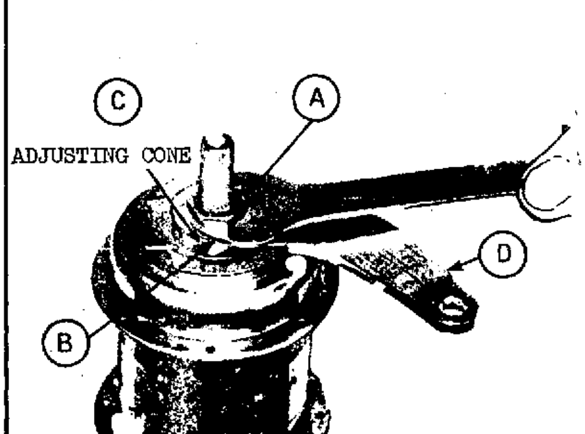
F



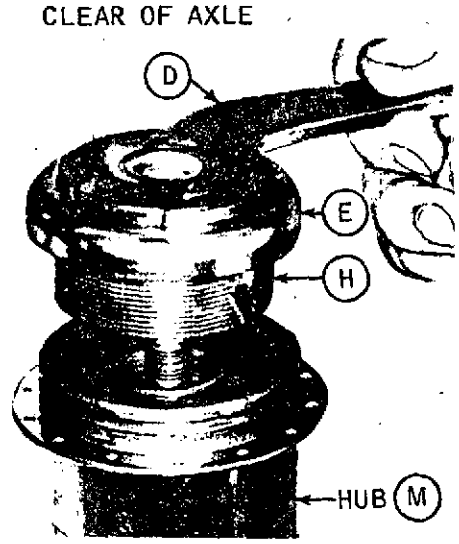
4) REVERSE HUB TO SPROCKET-END IN VISE

5) REMOVE LOCKNUT (A), LOCK WASHER (B)

6) REMOVE CONE ADJUSTING NUT (C) USING (HOOK-SPANNER WRENCH)



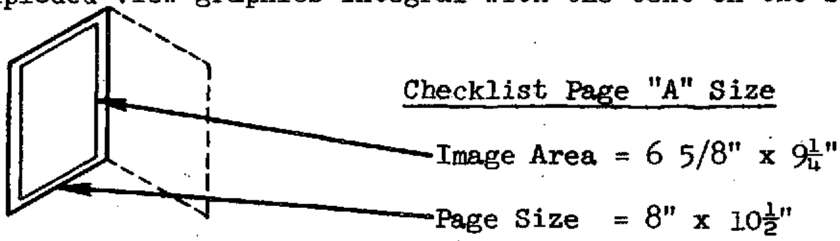
7) REMOVE BRAKE ARM ASSY. (D,E,F,G,H) BY ROTATING ARM (D) CCW UNTIL CLEAR OF AXLE



3.3.3 Type "B2" IFCM Crew JPA Data Requirements

(a) Format Size and Configuration Requirements

Type "B2" IFCM JPA Data shall be presented on a single page format that utilizes a Checklist "A" size page. This page size is required due to the greater area required for exploded view graphics integral with the text on the same page.



(b) General Description of Type "B2" IFCM JPA Data

Type "B2" IFCM JPA Data shall utilize a single page type format and can be printed on both the front and back of checklist pages. The paper stock used shall be in accordance with current checklist preparation guidelines of the NASA organizational elements responsible for flight crew procedures development.

Type "B2" Data shall contain a group or set of corrective maintenance procedures in textual form (words and numerical data) supported by exploded view graphics of an equipment assembly that is being disassembled, repaired and/or reassembled The exploded view graphics shall contain illustrations of the parts in a manner that defines the assembly order, orientation and fit of parts. Part nomenclature and part codes (alphabetical) shall also be included so that cross referencing within the text is easily accomplished through referencing to part name and code

The purpose of the Type B2 IFCM data format is to provide support data for tasks that involve mechanical or electro-mechanical systems that are relatively complex in structure and contain a considerable number of parts. If the parts involved become too numerous for single page graphics then Type "D" JPA data may be required in which a double-size folded page is used.

The basic data elements of Type "B2" JPA data are identified and specified in Section (d) of this paragraph.

(c) Type "B2" Data Usage Guidelines

Type "B2" JPA data provides the capability to illustrate with detailed graphics the the total number of parts involved in an assembly of medium complexity on a single page format integral with the checklist text that describes the tasks to be performed. The Type "B2" data concept is mainly suited for usage with mechanical assemblies and equipment.

(d) Type "B2" Data Elements (See Example Figure 4)

A TITLE OF IFCM PROCEDURE - The official CTPD title for this set of inflight corrective maintenance procedures.

B FLIGHT PLAN TITLE - This is the code by which the specific task sequence is identified and referred to when cross-referencing from troubleshooting or operational procedures and for flight planning purposes.

C TASK SEQUENCING - Tasks are numbered to indicate order of corrective maintenance task to be accomplished.

D OBTAIN: (IFCM PREPARATIONS) - This information is included prior to the procedural steps of any IFCM Procedural Set. All support elements (tools, spares, etc.) required for the task set are identified along with their stowed location in the spacecraft.

E TASK LOCATION - The location within the spacecraft or payload of the site for each task is designated utilizing the crew station operations Location Coding System as applied to the crew interface areas. If no location code appears by the task it is assumed that the task is performed at the last designated location.

F INFLIGHT MAINTENANCE TASK DEFINITIONS - Tasks to be performed are identified in CTPD Standard Checklist nomenclature for maintenance tasks which includes stated "Action Verbs" as the initial word of the task description.

G TASK GRAPHICS - Exploded view graphics of the assembly being repaired shall include part nomenclature and part codes (alphabetical) arranged for easy search as well as graphics to illustrate the part relationships and fits.

FIGURE 4

EXAMPLE TYPE B2 DATA

E F A B

WHEEL REMOVAL CM-2

(M106), 1. LOOSEN LOCKNUT (A)

2. REMOVE THE CABLE ADJUSTING BARREL (B)
   FROM INDICATOR SPINDLE (C)

3. REMOVE PLASTIC PROTECTOR (D) FROM RIGHT HAND AXLE NUT (K)

4. REMOVE THE MOUNTING SCREW (E) AND LOCKNUT (F)
   FROM BRAKE ARM STRAP (G)

5. SLIDE BRAKE ARM (H) FREE OF STRAP (G)

6. LOOSEN BOTH AXLE NUTS (I) (K) (COUNTERCLOCKWISE)

7. REMOVE INDICATOR SPINDLE (C) FROM AXLE (P)

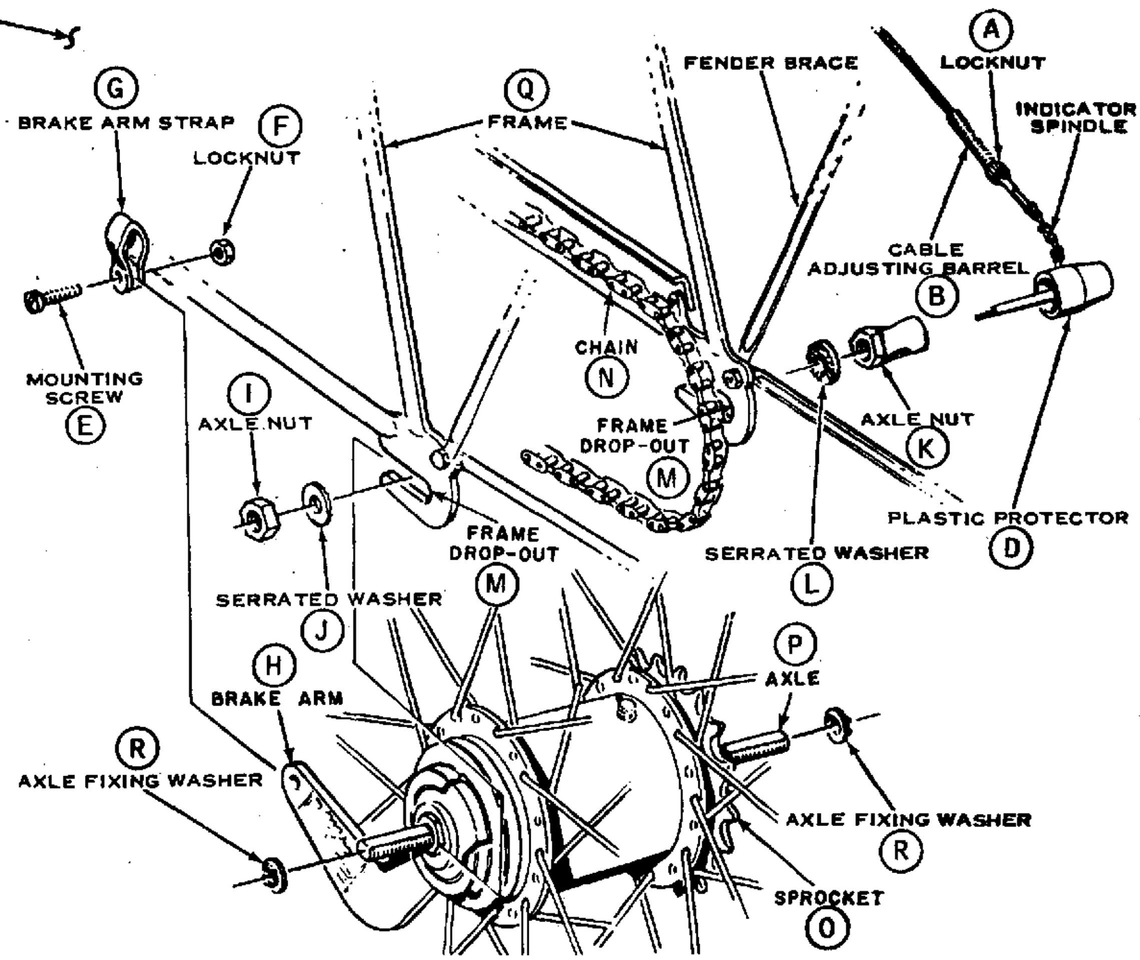
8. REMOVE AXLE NUTS (I) (K) AND SERRATED WASHERS (J) (L)
   FROM AXLE (P)

9. MOVE WHEEL FORWARD IN FRAME DROPOUTS (M)

10. REMOVE CHAIN (N) FROM SPROCKET (O)
    (HOOK OVER FRAME)

11. GUIDE WHEEL FREE OF FRAME

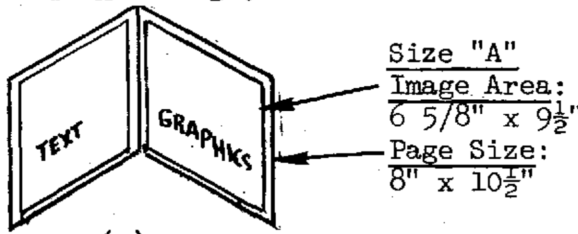
G

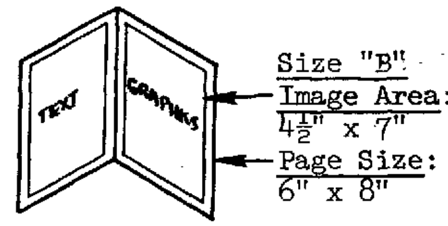


3.3.4 Type "C" IFCM Crew JPA Data Requirements

(a) Format Size and Configuration Requirements

Type "C" Data shall be presented in a Double Page Format on either Checklist Page Sizes "A" or "B".





(b) General Description of Type "C" IFCM JPA Data

Type "C" IFCM JPA data shall utilize a Double Page Type format and is printed on both the front and back of Checklist pages. The Double Page Format design shall be a "book-type" format, i.e., the left hand and right hand facing pages of the Checklist can be viewed simultaneously such that the graphic illustrations on the right hand page will refer to the textual checklist data presented on the left and facing page. This "C" type format has been utilized successfully in Department of Defense maintainability studies and provides illustrative graphics as an integral part of the corrective maintenance checklist data. The graphics can be both task graphics or other types of equipment graphics to illustrate part nomenclature and location.

The major purpose of the Type "C" IFCM data format is to provide integral textual and graphics support for mechanical, electromechanical, and electrical systems requiring inflight corrective maintenance. This "C" type format provides a significant capability for illustrating task performance, equipment locations within the spacecraft, equipment nomenclature, part codes and other three-dimensional information that can amplify and clarify the basic textual data of the Checklist. The graphics data generally will provide illustrations of equipment and performance elements of the task specified on the facing page. However, the graphics need not be limited to just task elements. Additional clarifying graphics may be provided to illustrate aspects of corrective maintenance elements such as location and orientation of equipment modules within the spacecraft, location of hazardous conditions within the work area, etc.

The important factor in Type "C" Data is that the crew's search time to find supporting graphics is greatly reduced. The graphics data to support a particular task will always appear on the facing page. The cross-indexing system shall be quite simple. The tasks are identified by numbers. This orders the task sequence and also serves as the reference code for identifying the related task graphics on the facing page. All equipment within the task graphics are identified with alphabetical codes. These also serve as reference codes within the task procedures to identify the equipment involved in the task.

The basic data elements of the Type "C" data are identified and specified in section (d) of this paragraph.

(c) Type "C" Data Usage Guidelines

Type "C" Data provides task graphics as an integral part of the Checklist. As a result it may be used to support medium to very complex inflight corrective maintenance tasks. However, in general it is more suited for mechanical or electromechanical systems. It can be used to support electrical systems corrective maintenance when the task involves relative simple part replacement activities.

(d) Type "C" Data Elements (See Figure 5, Pages 1 and 2)

A TITLE OF IFCM PROCEDURE - The official CTPD title for this set of inflight corrective maintenance procedures.

B FLIGHT PLAN TITLE - This is the code by which the specific task sequence is identified and referred to when cross-referencing from troubleshooting or operational procedures and for flight planning purposes.

C TASK SEQUENCING - Tasks are numbered to indicate the order of corrective maintenance tasks that are to be accomplished. The numerical designation of the task also serves as a cross-referencing code between text and graphics data.

D OBTAIN: IFCM PREPARATION) - This preparation information shall include a list of tools and support equipment that must be collected prior to the procedural steps of any IFCM procedural set. All support elements required for the total task sequence shall be identified. The stowed location code of these support items shall be provided in the column for task location. Additional location data may also be provided in parentheses that follow the item name.

E TASK LOCATION - The location of each task shall be provided as a coded entry in the location column of the format. This code shall be in accordance with the Crew Station Operations Location Coding System as applied to the particular spacecraft vehicle.

F INFLIGHT MAINTENANCE TASK DESCRIPTION - Tasks to be performed shall be identified in standard CTPD Checklist nomenclature for inflight maintenance tasks. Task procedures shall begin with an "Action Verb" and shall identify equipment items involved in the task by both item name and alphabetical code in parenthesis following the name. This alphabetical code refers to the illustration of the particular item as it appears within the graphics on the facing page.

G TASK GRAPHICS - Each task or group of tasks that are identified within the task sequence of Type "C" corrective maintenance data shall be illustrated on the facing page with graphics that depict the salient or important elements of the task. The task being illustrated shall be designated with the respective number of the task on the facing page. The number shall be placed within a hexagon symbol and can be attached to an arrow that designates the direction of movement involved in the task. Equipment nomenclature shall be included within the graphics of those parts that are directly involved in the tasks. The part names shall be coded alphabetically and enclosed within a circle. These codes are these that are used within the procedural text to refer to the part. These equipment codes are used to reduce the search time of the user.

The task graphics shall be placed on the page at a location roughly equivalent to the location of the task procedures on the facing page. Division lines, as illustrated, within the procedural text on the left and the graphics data on the right hand facing page shall be used to group the information for easier reading.

FIGURE 5 (Page 1 of 2)

EXAMPLE TYPE "C" DATA (Back Page Printing)

B

CM-2

MET ASSEMBLY ← A

C D

1. OBTAIN: MET ASSEMBLY

LM EXTERIOR DESCENT STAGE

F

2. REMOVE THERMAL BLANKET (A)

3. PULL WHEELPIN LANYARD #3 (B) AND REMOVE BOTH WHEEL LOCK PIP PINS #4 AND #5 (C). (THIS UNLOCKS WHEELS FROM FRAME).

E

4. DEPLOY WHEELS: LIFT UPPER WHEEL UNTIL LOCKED.

4a. PUSH LOWER WHEEL DOWN UNTIL LOCKED.

---

5. GRASP LOOP, PULL AND DISCARD LEG/HANDLE PIP PIN #6 AND BRACKET (D)

6. PARTIALLY DEPLOY HANDLES FOR LEG DEPLOYMENT CLEARANCE

7. PULL MET LEFT LEG (E) "UP" UNTIL LOCKED IN PLACE

8. PUSH MET RIGHT LEG (F) "DOWN" UNTIL LOCKED IN PLACE

---

9. ROTATE DRAW-BAR HANDLE (G) INTO POSITION, FOLD AND LOCK INTO PLACE INTO RIGHT DRAW BAR ASSEMBLY (H)

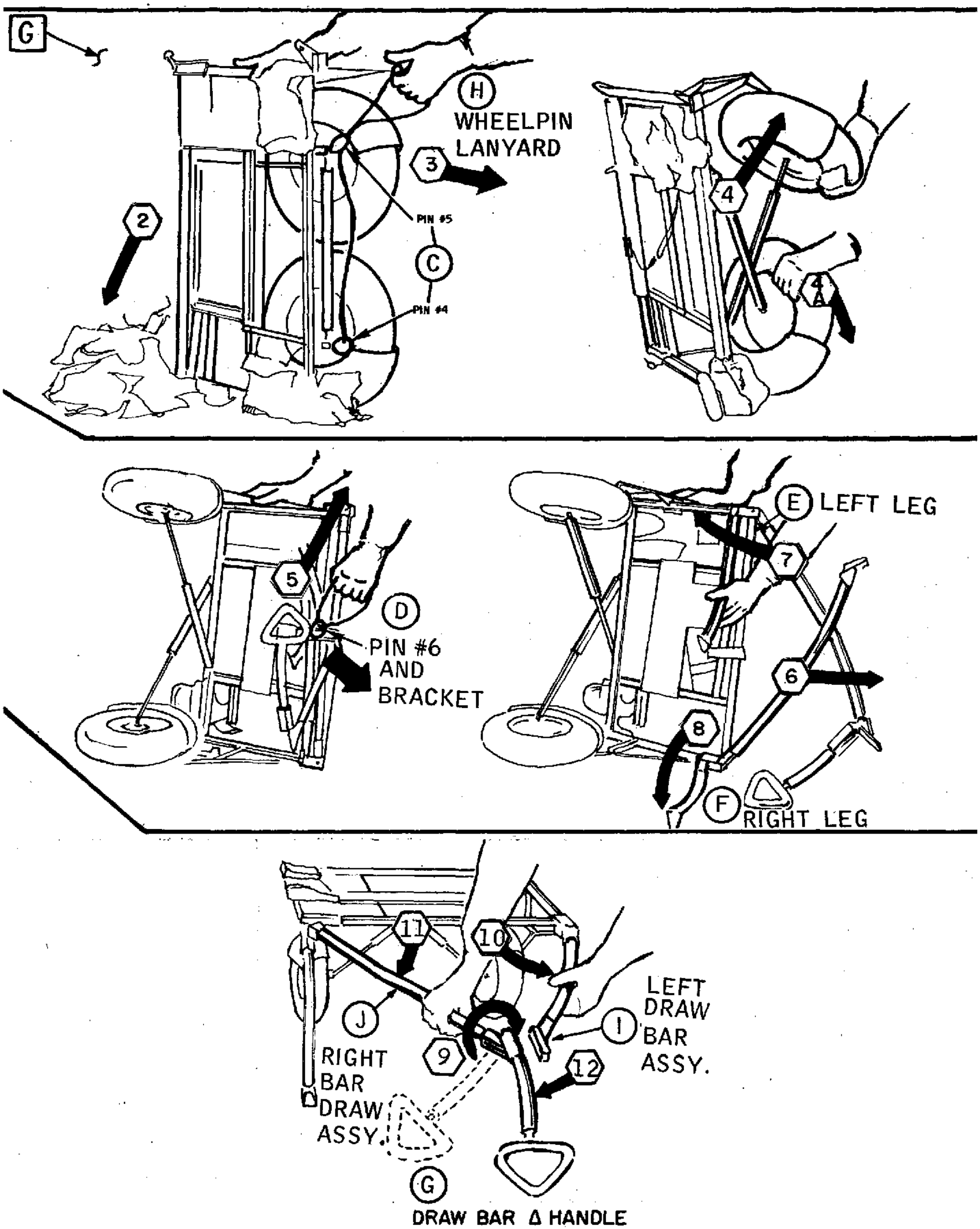
10. UNFOLD LEFT DRAW-BAR ASSEMBLY (I)

11. UNFOLD RIGHT DRAW-BAR ASSEMBLY (J)

12. LOCK LEFT DRAW-BAR INTO RIGHT DRAW-BAR AND HANDLE

FIGURE 5 (Page 2 of 2)
EXAMPLE TYPE "C" DATA (Front Page Printing)

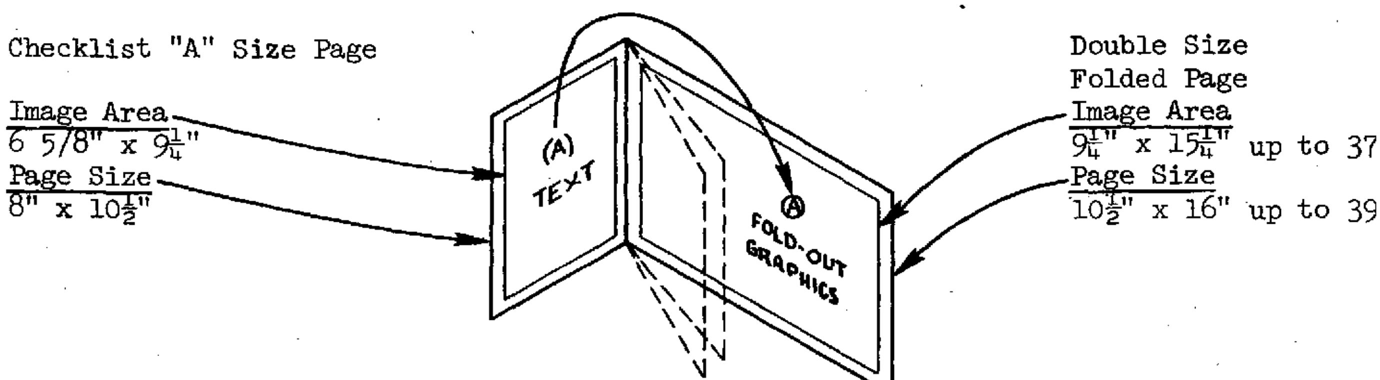
MET ASSEMBLY CM-2



3.3.5 Type "D1" IFCM Crew JPA Data Requirements

(a) Format Size and Configuration Requirements

All Type "D" data shall be presented on a Triple Page format that utilizes a Checklist "A" size page. This page size is required due to the large amount of graphics data presented in the "D" type data formats.



(b) General Description of Type "D1" IFCM JPA Data

Type "D1" corrective maintenance data shall include an integrated presentation of textual procedural checklist data (per CTPD Checklist Standards), on standard "A" sized pages, that is cross-indexed to exploded view or other type of graphics presentations on an oversized fold-out page. The fold-out page is presented as the last page in a procedural set. This allows the simultaneous viewing of text and the folded graphics page. By placing the folded page as the last of the procedural set, all pages of procedural text can then be supported by the folded overview graphics. This fold-out page graphics provides the area for detailed exploded view illustration of all the parts of complex mechanical or electro-mechanical type assemblies or equip ment being repaired.

The purpose of the Type "D1" data format is to supplement the Checklist procedural data with illustrated parts data. This amplifies the textual data with illustrations of the shape, form, and relative size of each part and part name. It also clarifies how the parts fit together to make up the final equipment assembly. By providing illustrations of the total inventory of parts of an assembly, it assists in the management of all parts involved in the repair sequence and in understanding the physica and mechanical aspects of the corrective maintenanct task.

(c) Type "D1" Data Usage Guidelines

The "D1" type corrective maintenance data, is appropriate for usage with medium to very complex mechanical or electro-mechanical spacecraft or payloads systems. It is a simple method of amplifying the textual checklist data with a single overview graphic illustration that provides the crew with a significant increase in definitive mechanical data that can greatly assist the performance of the corrective maintenance task.

C-2

(d) Type "D1" Data Elements (see Figure 6, Pages 1, 2, and 3)

Type "D1" data utilizes the basic textual elements of Type "A" data in conjunction with folded graphics that provide an illustrated parts break-down of the equipment being disassembled, repaired, and reassembled.

A - CREW PROCEDURES TITLE - The official CTPD title for this set of inflight corrective maintenance procedures.

B - FLIGHT PLAN TITLE - The code by which the specific task sequence is identified for flight planning purposes or when cross-referencing from troubleshooting or operational procedures.

C - TASK SEQUENCING - Tasks are numbered to indicate the order of corrective maintenance tasks that are to be accomplished. The numerical designation of the task also serves as a cross-referencing code between text and fold-out graphics data.

D - TASK LOCATION - The location within the spacecraft or payload for each task shall be designated utilizing the crew station operations location coding system as applied to the crew interface areas.

E - OBTAIN: (IFCM PREPARATIONS DATA) - This information shall be included prior to the procedural steps of any IFCM procedural set. Support elements (tools, spares, etc.) are identified along with their stowed location in the spacecraft

F - INFLIGHT MAINTENANCE TASK DIRECTIONS - Tasks to be performed shall be identified in CTPD Standard Checklist nomenclature for maintenance tasks. This requires beginning the task statement with an "Action Verb". Equipment items utilized in the tasks shall be referred to by name and a following code in parenthesis. This code is the alphabetic code for that equipment that appears on the illustrated parts graphics included on the fold-out page that shall be provided as the last page of the total task sequence.

DATA ELEMENTS G through L are described in Type "A" data. (Par. 3.3.1(d))

M - FOLD-OUT EQUIPMENT GRAPHICS - Type "D1" data shall include, as the last page of the task sequence, fold-out graphics of the equipment being disassembled, repaired, and reassembled. These graphics shall include three-dimensional pictorial exploded view drawings of this equipment and shall include part nomenclature and part codes as illustrated in the example. Parts are identified using the symbol (N)→. The Part Code shall be alphabetical and presented within the circle of the symbol. If more than 26 parts are illustrated, the notation convention AA, AB, AC, etc. shall be utilized for the additional parts. The codes shall be used in a manner that allows an efficient search pattern when looking for a particular code. The graphics shall provide a visual description of the parts within the equipment. Numerical identification of the task number in which the part is handled shall be provided for assembly and disassembly type of task sequences.

FIGURE 6 (Page 1 of 3)

EXAMPLE TYPE "D1" DATA (Back Page Printing)

A

CM-1 B   HUB DISASSEMBLY

E

M021   Obtain:
- Vise
- Narrow blade screwdriver
- Hook spanner wrench
- Drift punch
- screwdriver

D

M061   NOTE: All Tasks performed at work station

F

C
1. Clamp hub assembly by axle flats in vise
2. Pry sprocket lock ring (AP) from recess (narrow blade screwdriver)
3. Remove sprocket (AN) and spacers (AO) from assy.
4. Reverse Hub to sprocket end in vise
5. Remove locknut (A) Lock Washer (B)
6. Remove cone adjusting nut (C) (hook spanner wrench)
7. Remove brake arm assy. (D-H) by rotating arm (D) CCW until clear of axle
8. Lift out the drive side expander (J) until threads engage
9. Thread off axle (CCW)
10. Remove low gear pawl cage assy. (K) from hub shell
11. Reverse Hub assy. in vise, grip the flange of Hub Assy.
12. Rotate right hand ball cup assy. (CCW) until free of threads (hammer, drift punch)
13. Lift right hand ball cup/gear assy. (O-AM) out of Hub
14. Remove Hub (14) from vise

FIGURE 6 (Page 2 of 3)

EXAMPLE TYPE "D1" DATA (Front Page Printing)

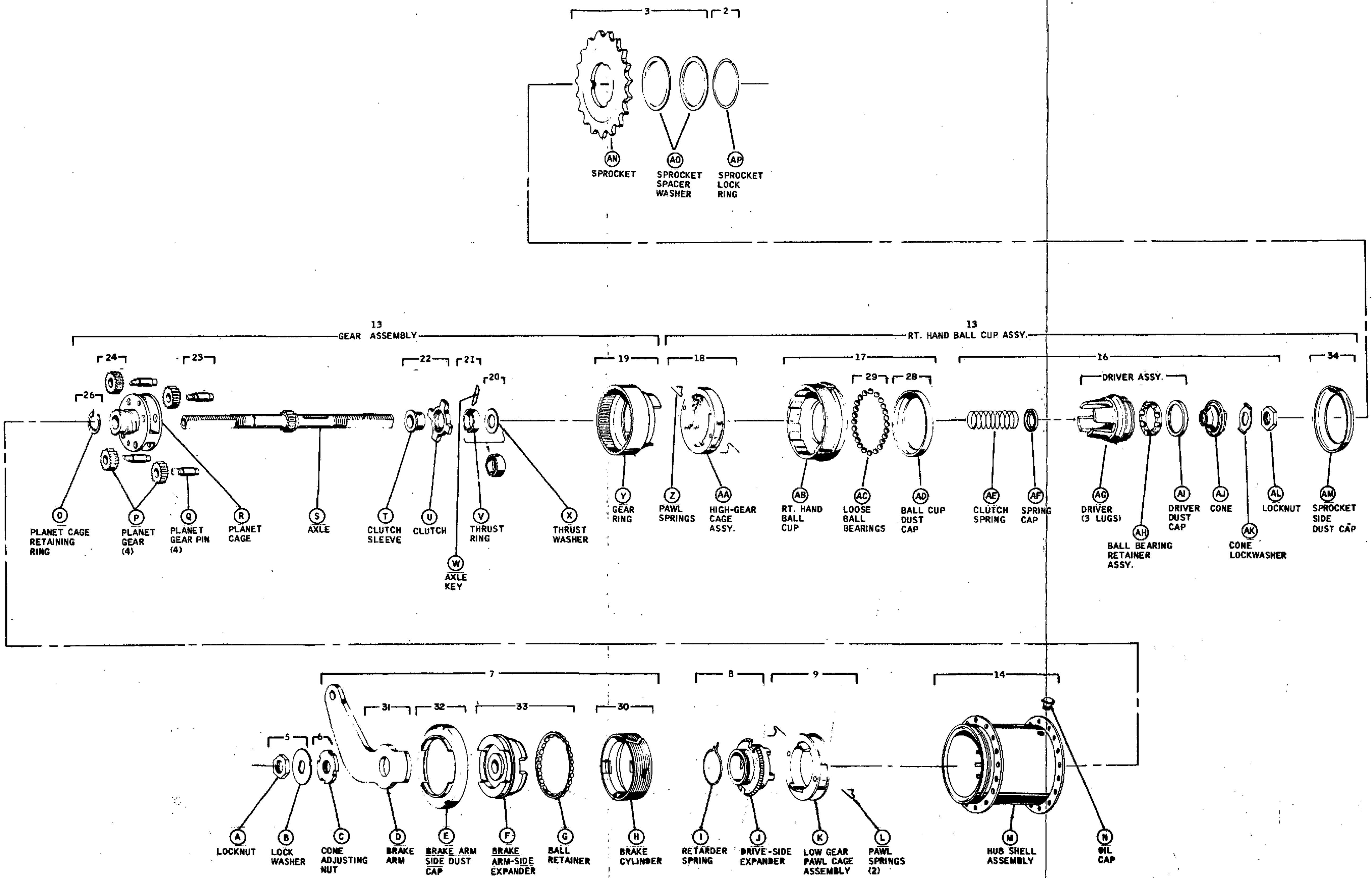
HUB DISASSEMBLY A B CM-1

F

15. Clamp Assy. in vise by axle flats
16. Remove: Locknut (AL)
    Cone lockwasher (AK)
    Cone (AJ)
    Driver Assy. (AG, AH, AI)
    Spring Cap (AF)
    Spring (AE)
17. Lift right hand ball cup (AB) off high gear pawl assy. (AA)
18. Remove high gear pawl assy. (AA) from gear ring (Y)
19. Lift gear ring (Y) straight up to disengage gear teeth
20. Remove thrust ring (V) off axle (S)
21. Pull axle key (W) out of axle (S) keeway.
22. Remove: Clutch (U) from axle
    Clutch sleeve (T) axle
23. Lift out planetary gear pins (4) (Q)
24. Slide out planetary gears (P) out of cage
25. Turn assy. end for end, grasp in vise by axle flats
26. Pry planetary cage retaining ring (O) from axle (S) (narrow bladed screwdriver)
27. Remove planetary cage (R) from axle (S)
28. Pry dust cap (AM) from right hand ball cup (AB) (screwdriver)
29. Remove and count ball bearings (AC)
30. Remove brake cylinder (H) from expander (F)
31. Pry brake arm (D) from dust cap (E)
32. Separate dust cap (E) from expander (F) by striking center with hammer
33. Remove ball retainer (G) from expander (F)
34. Pry sprocket side dust cap (AM) from driver assy. (AG)

FIGURE 6 (Page 3 of 3)

EXAMPLE TYPE "D1" DATA [FOLDED GRAPHICS] ← M



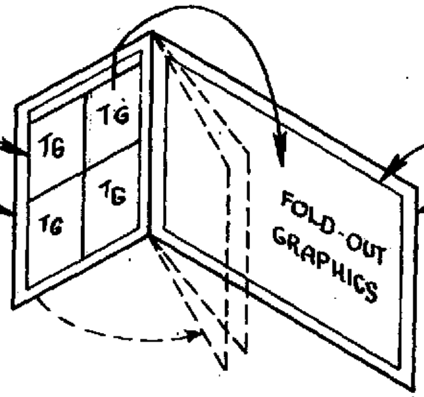
3.3.6 Type "D2" IFCM Crew JPA Data Requirements

(a) Format Size and Configuration Requirements

All Type "D" data shall be presented on a Triple Page format that utilizes a Checklist "A" size page. This page size is required due to the large amount of graphics data presented in the "D" type data formats.

Checklist "A" Size Page

Image Area
6 5/8" x $9\frac{1}{4}$"
Page Size
8" x $10\frac{1}{2}$"



Double Size
Folded Page
Image Area
$9\frac{1}{4}$" x $15\frac{1}{4}$" up to 37 3/4"
Page Size
$10\frac{1}{2}$" x 16" up to 39"

T = TEXT
G = GRAPHICS

(b) General Description of Type "D2" IFCM JPA Data

Type "D2" IFCM JPA data shall include an integrated presentation of task text, task graphics and supporting exploded view graphics of the equipment involved in the corrective maintenance task sequence. The "D2" type data essentially combines the Type "B1" blocked task text/graphics data with exploded view illustrated parts data of the equipment being repaired. This exploded view data shall be presented on a fold-out page that is included as the last page of the total task data sequence. Cross-indexing between the text and the exploded view parts information shall be provided through the use of the alphabetical coding of the parts. Within the procedural text each part involved in the task shall be referred to by name and by alphabetical code in parenthesis following the part name. The alphabetical code will be the same code that is used for that part on the fold-out exploded view graphics as illustrated in the following sample. By cross-indexing, information is provided the crew relative to where the particular part, involved in the task, fits within the total assembly which assists the crew in overall parts management of the corrective maintenance sequence.

In addition to the cross-indexing between text and folded graphics, it occasionally will be required to identify a particular part within the task illustrations. The same method of using a part code for referencing shall be used as noted above.

The purpose of the Type "D2" data format is to provide detailed graphics support to the description of each corrective maintenance task to be performed while also providing definitive overview graphics data on all parts involved in the equipment repair tasks. Cross-indexing between the detailed and overview data reduces the crew's search time and assists in the crew's comprehension of the total task sequence to be performed and the related problems of parts management.

(c) Type "D2" Data Usage Guidelines

The "D2" type corrective maintenance data is appropriate for usage with very complex and critical inflight maintenance mechanical and electromechanical type tasks. Some electrical systems tasks involving mainly component replacement can be supported with Type "D2" data. In general, those tasks involving complex disassembly, part replacement and assembly type tasks are well supported by Type "D2" data. In addition, if very little flight crew training time is available to spend in mockup training and simulations of the corrective maintenance task, usage of Type "D2" data should be seriously considered.

(d) Type "D2" Data Elements (see Figure 7, Pages 1, 2, and 3)

Type "D2" data utilizes the basic data elements of Type "B1" data in conjunction with folded graphics that provide illustrated parts breakdown data of the equipment being disassembled, repaired and reassembled.

A - CREW PROCEDURES TITLE - The official CTPD title for this set of inflight corrective maintenance procedures.

B - FLIGHT PLAN TITLE - The code by which the specific corrective maintenance task sequence is identified for flight planning purposes or when cross-referencing to this sequence from troubleshooting or operational procedures.

C - TASK SEQUENCING - Tasks are numbered to indicate the order of corrective maintenance tasks that are to be accomplished. The numerical designation of the task also serves as a cross-referencing code between text and graphics data.

D - TASK LOCATION - The location of each task shall be provided as a coded entry in the location column of the format. This code shall be in accordance with the Crew Station Operations Location Coding System as applied to the particular spacecraft vehicle.

E - OBTAIN: (IFCM PREPARATION) - This preparation information shall include a procedural steps of any IFCM procedural set. All support elements required for the total task sequence shall be identified. The stowed location code of these support items shall be provided in the column for task location. Additional location data may also be provided in parenthesis that follow the item name.

F - INFLIGHT MAINTENANCE TASK DESCRIPTION - Tasks to be performed shall be identified in standard CTPD Checklist nomenclature for inflight maintenance tasks. Task procedures shall begin with an "Action Verb" and shall identify equipment items involved in the task by both item name and alphabetical code in parenthesis following the name. This alphabetical code refers to the illustration of the particular item as it appears within the graphics on the facing page and on the fold-out graphic.

G - TASK GRAPHICS - Each task or task group shall be illustrated using graphics of the equipment being maintained or repaired and selective illustration of tools and manual operations required to perform the tasks. These graphics can be line drawings or half-tone pictures (as illustrated in the example), and should provide a clear illustration of the task to be performed. Part codes (alphabetical) and part nomenclature can be used as is appropriate to illustrate the task.

H - FOLD-OUT EQUIPMENT GRAPHICS - Type "D2" data shall include, as the last page of the task sequence, fold-out graphics of the equipment being disassembled, repaired and reassembled. This graphics shall include three-dimensional pictorial exploded view drawings of this equipment and shall include part nomenclature and part codes as illustrated in the example. Parts are identified using the symbol N→. The Part Code shall be alphabetical and presented within the circle of the symbol. If more than 26 parts are illustrated, the notation convention AA, AB, AC, etc. shall be utilized for the additional parts. The codes shall be used in a manner that allows an efficient search pattern when looking for a particular code. The graphics shall provide a visual description of the parts within the equipment. Numerical identification of the task number in which the part is handled shall be provided for assembly and disassembly type of task sequences.

FIGURE 7 (page 1 of 3)
EXAMPLE TYPE D2 DATA

CM-1 ← B   E   HUB DISASSEMBLY ← A

A: OBTAIN:

(M144) NARROW BLADE SCREWDRIVER
NOOK SPANNER WRENCH

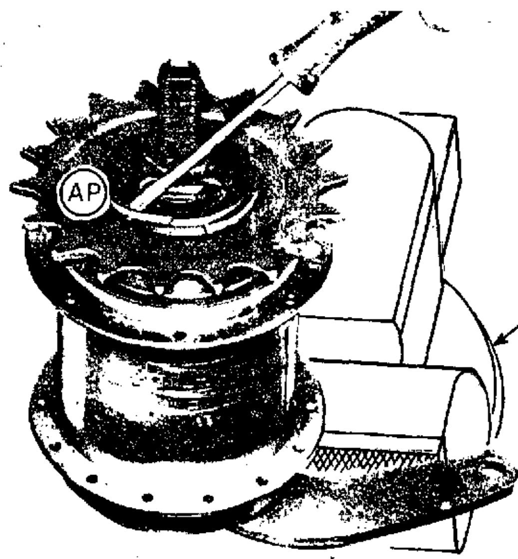
(M021) VISE

(M021) NOTE: ALL HUB DISASSEMBLY
TASKS PERFORMED AT WORK
D STATION LOCATION

1) CLAMP HUB ASSY. BY AXLE FLATS
IN "SOFT-JAWED" VISE

2) PRY SPROCKET LOCK RING (AP) FROM
RECESS (NARROW BLADE SCREWDRIVER)
AND REMOVE FROM SPROCKET

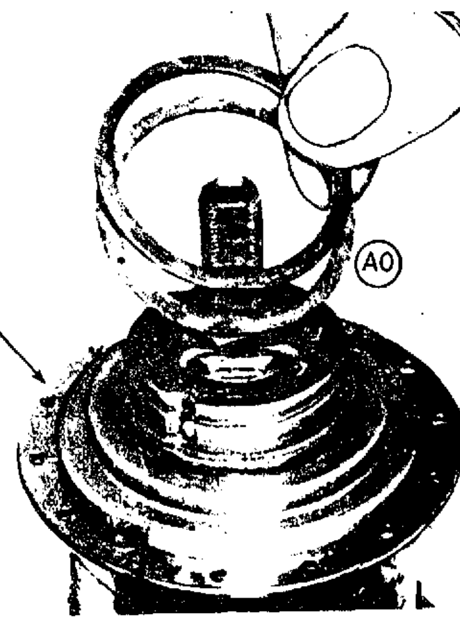
C



G

3) REMOVE SPROCKET (AN) AND
SPACERS (AO) FROM ASSY.

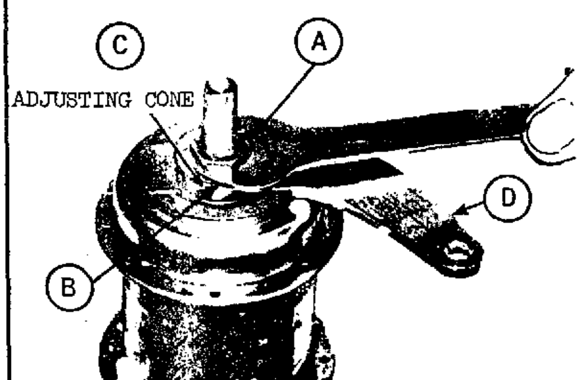
F



4) REVERSE HUB TO SPROCKET-END IN VISE

5) REMOVE LOCKNUT (A), LOCK WASHER (B)

6) REMOVE CONE ADJUSTING NUT (C) USING
(HOOK-SPANNER WRENCH)



7) REMOVE BRAKE ARM ASSY. (D,E,F,G,H)
BY ROTATING ARM (D) CCW UNTIL
CLEAR OF AXLE

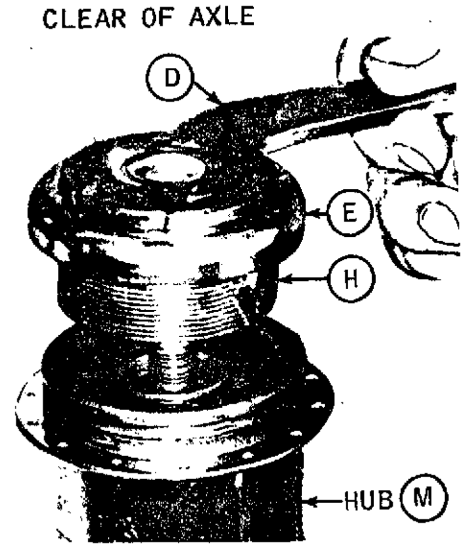


FIGURE 7 (Page 2 of 3)
EXAMPLE TYPE "D2" DATA

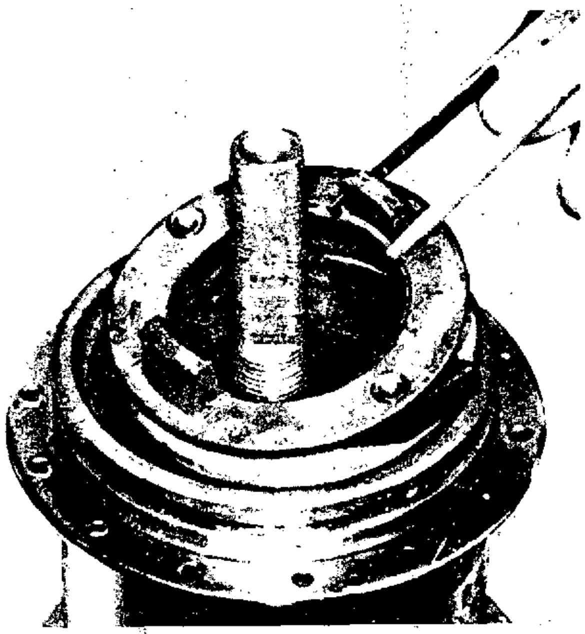
HUB DISSASSEMBLY

CM-1

8) LIFT OUT THE DRIVE SIDE EXPANDER (J) UNTIL THREADS ENGAGED

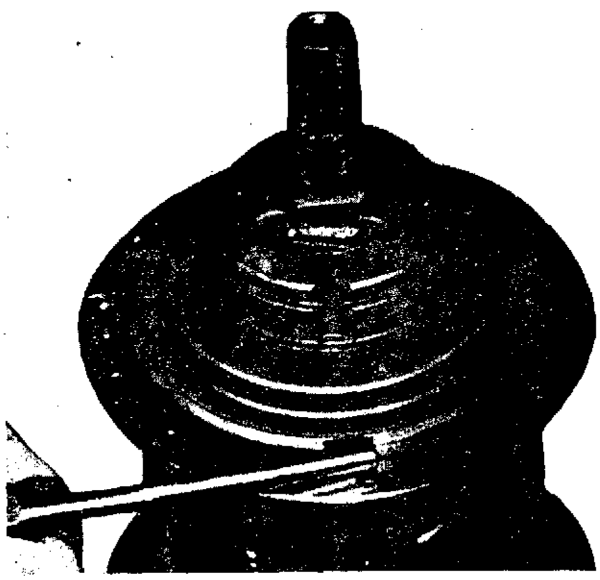
9) THREAD OFF AXLE (CCW)

10) REMOVE LOW GEAR PAWL CAGE ASSY. (K) FROM HUB SHELL.



11) REVERSE HUB ASSY. IN VISE GRIP THE FLANGE OF HUB ASSY.

12) ROTATE RIGHT HAND BALL CUP ASSY (AB) (CCW) UNTIL FREE OF THREADS (HAMMER, DRIFT PUNCH)



13) LIFT RT. HAND BALL CUP/GEAR ASSY. (O-AM) OUT OF HUB

14) REMOVE HUB FROM VISE

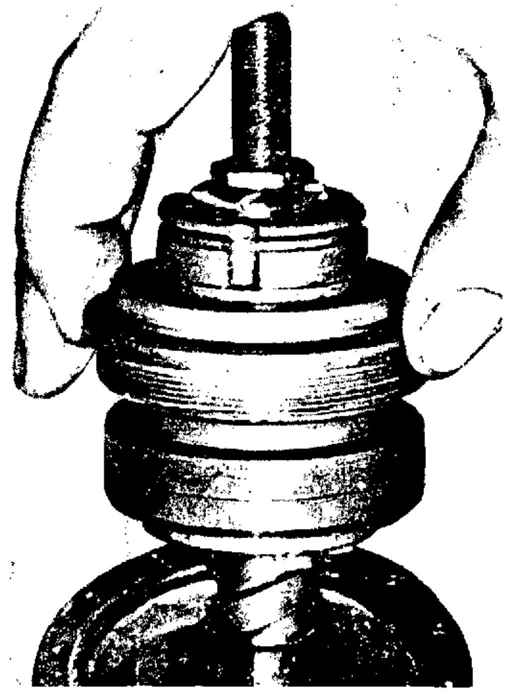
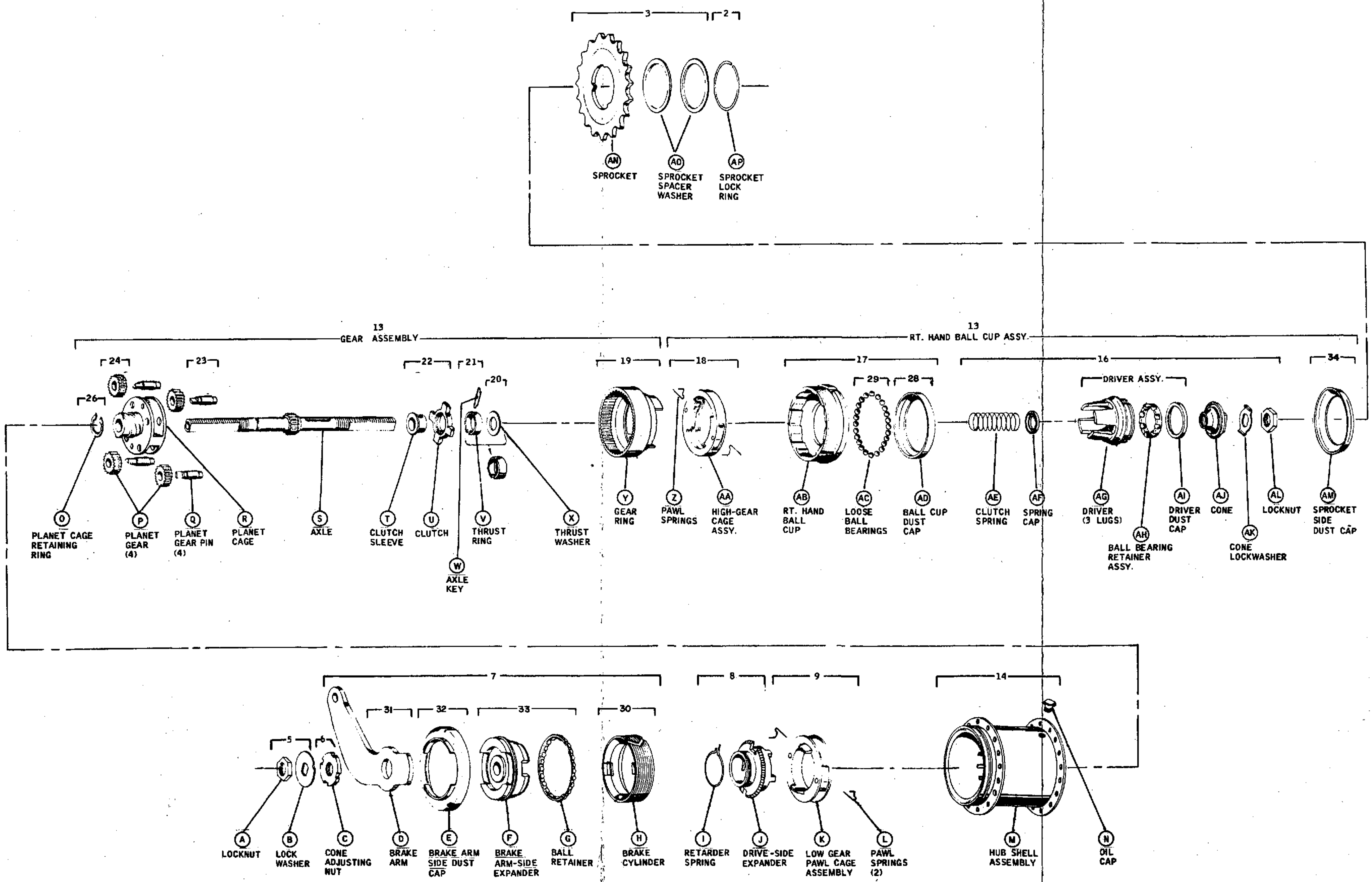


FIGURE 7 (Page 3 of 3)

EXAMPLE TYPE "D2" DATA [FOLDED GRAPHICS] H



FOLDOUT FRAME

FOLDOUT FRAME

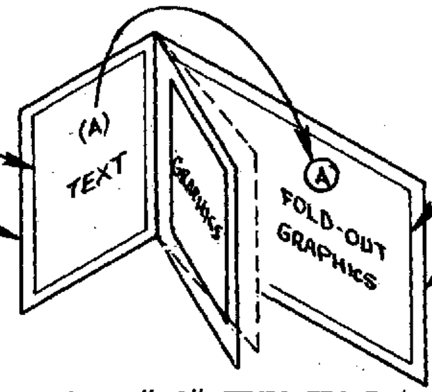
3.3.7 Type "D3" IFCM Crew JPA Data Requirements

(a) Format Size and Configuration Requirements

All Type "D" data shall be presented on a Triple Page format that utilizes a Checklist "A" size page and a double size fold-out page as illustrated below.

Checklist "A" Size Page

Image Area
6 5/8" x $9\frac{1}{4}$"
Page Size
8" x $10\frac{1}{2}$"



Double Size Folded Page
Image Area
$9\frac{1}{4}$" x $15\frac{1}{4}$"
Page Size
10" x 16" up to 39"

(b) General Description of Type "D3" IFCM JPA Data

Type "D3" crew IFCM JPA data shall include an integrated presentation of task text, task graphics and supporting exploded view graphics of equipment involved in the corrective maintenance task sequence. The "D3" type data essentially combines the Type "C" task text and facing page graphics with exploded view illustrated parts data of the equipment being assembled, disassembled or repaired. The exploded view data shall be presented on a fold-out page that is included as the last page of the total task data sequence. Cross-indexing between the text and the exploded view parts information shall be provided through the use of the alphabetical coding of the parts. Within the procedural text each part involved in the task shall be referred to by name and alphabetical code in parenthesis following the part name. The alphabetical code will be the same code that is used for that part on the fold-out exploded view graphics as illustrated in the following example. By this cross indexing, information is provided the crew relative to where and how the particular part involved in the task, fits within the total assembly which assists the crew in overall parts management of the corrective maintenance sequence.

The Type "D3" data shall include procedural text data on a left-hand registered page that faces illustrative task graphics on the right-hand registered page. This data is cross-indexed through the numerical task numbers which are used to identify the task graphics. This type of cross-indexing also assists in quick interpretation of the data by the crew.

(c) Type "D3" Data Usage Guidelines

The "D3" Type corrective maintenance data, is suited for support of medium to complex mechanical or electro-mechanical corrective maintenance tasks. Disassembly, replacement and reassembly type tasks are well supported by "D3" Type data.

(d) Type "D3" Data Elements (See Figure 8, Pages 1, 2 and 3)

Type "D3" Data utilizes the basic data elements of the Type "C" data format in conjunction with folded graphics that provide an illustrated parts break-down of the equipment being disassembled, repaired, and reassembled.

A - CREW PROCEDURES TITLE - The official CTPD title for this set of inflight corrective maintenance procedures.

B - FLIGHT PLAN TITLE - The code by which the specific corrective maintenance task sequence is identfied for flight planning purposes or when cross-referencing to this sequence from troubleshooting or operational procedures.

C - TASK SEQUENCING - Tasks are numbered to indicate the order of corrective maintenance tasks that are to be accomplished. The numerical designation of the task also serves as a cross-referencing code between text and graphics data.

D - TASK LOCATION - The location within the spacecraft or payload for each task shall be designated utilizing the crew station operations location coding system as applied to the crew interface areas.

E - OBTAIN: (IFCM PREPARATIONS DATA) - This information shall be included prior to the procedural steps of any IFCM procedural set. Support elements (tools, spares, etc.) are identified along with their stowed location in the spacecraft.

F - INFLIGHT MAINTENANCE TASK DIRECTIONS - Tasks to be performed shall be identified in CTPD Standard Checklist nomenclature for maintenance tasks. This requires beginning the task statement with an "Action Verb". Equipment items utilized in the tasks shall be referred to by name and a following code in parenthesis. This code is the alphabetic code for that equipment that appears on the illustrated parts graphics included on the fold-out page that shall be provided as the last page of the total task sequence.

G - TASK GRAPHICS - Each task or group of tasks that are identified within the task sequence of Type "C" or "D3" maintenance data shall be illustrated on the facing page with graphics that depict the salient or important elements of the task. The task being illustrated shall be designated with the respective number of the task on the facing page. The number shall be placed within a hexagon symbol and can be attached to an arrow that designates the direction of movement involved in the task. Equipment nomenclature shall be included within the graphics of those parts that are directly involved in the tasks. The part names ahall be coded alphabetically and enclosed within a circle. These codes are those that are used within the procedural text to refer to the part. These equipment codes are used to reduce the search time of the user. The task graphics shall be placed on the page at a location roughly equivalent to the location of the task procedures on the facing page. Division lines, as illustrated, within the procedural text on the left and the graphics data on the right-hand facing page shall be used to group the information for easier reading.

H - FOLD-OUT EQUIPMENT GRAPHICS - Type "D3" data shall include, as the last page of the task sequence, fold-out graphics of the equipment being disassembled, repaired and reassembled. This graphics shall include three-dimensional pictorial exploded view drawings of this equipment and shall include part nomenclature and part codes as illustrated in the following example. Parts are identified using the symbol N→. The Part Code shall be alphabetical

H - FOLD-OUT EQUIPMENT GRAPHICS (continued)

and presented within the circle of the symbol. If more than 26 parts are illustrated, the notation convention AA, AB, AC, etc. shall be utilized for the additional parts. The codes shall be used in a manner that allows an efficient search pattern when looking for a particular code. The graphics shall provide a visual description of the parts within the equipment. Numerical identification of the task number in which the part is handled shall be provided for assembly and disassembly type of task sequences.

FIGURE 8 (Page 1 of 3)

EXAMPLE TYPE D3 (Back Page Printing)

CM-4 ← B MET ASSEMBLY ← A

C F

1. REMOVE THERMAL BLANKET (A)

D 2. PULL WHEELPIN LANYARD #3 (H) AND REMOVE BOTH WHEEL LOCK PIP PINS #4 & #5 (G). (THIS UNLOCKS WHEELS FROM FRAME).

3. DEPLOY WHEELS: LIFT UPPER WHEEL UNTIL LOCKED.

3a. PUSH LOWER WHEEL DOWN UNTIL LOCKED.

---

4. GRASP LOOP, PULL AND DISCARD LEG/HANDLE PIP PIN #6 AND BRACKET (O).

5. PARTIALLY DEPLOY HANDLES FOR LEG DEPLOYMENT CLEARANCE.

6. PULL MET LEFT LEG (P) "UP" UNTIL LOCKED IN PLACE.

7. PUSH MET RIGHT LEG (Q) "DOWN" UNTIL LOCKED IN PLACE.

---

8. ROTATE DRAW BAR Δ-HANDLE (R) INTO POSITION, FOLD AND LOCK INTO PLACE INTO RIGHT DRAW BAR ASSEMBLY (U)

9. UNFOLD LEFT DRAW-BAR ASSEMBLY (T)

10. UNFOLD RIGHT DRAW-BAR ASSEMBLY (U)

11. LOCK LEFT DRAW BAR INTO RIGHT DRAW BAR AND HANDLE

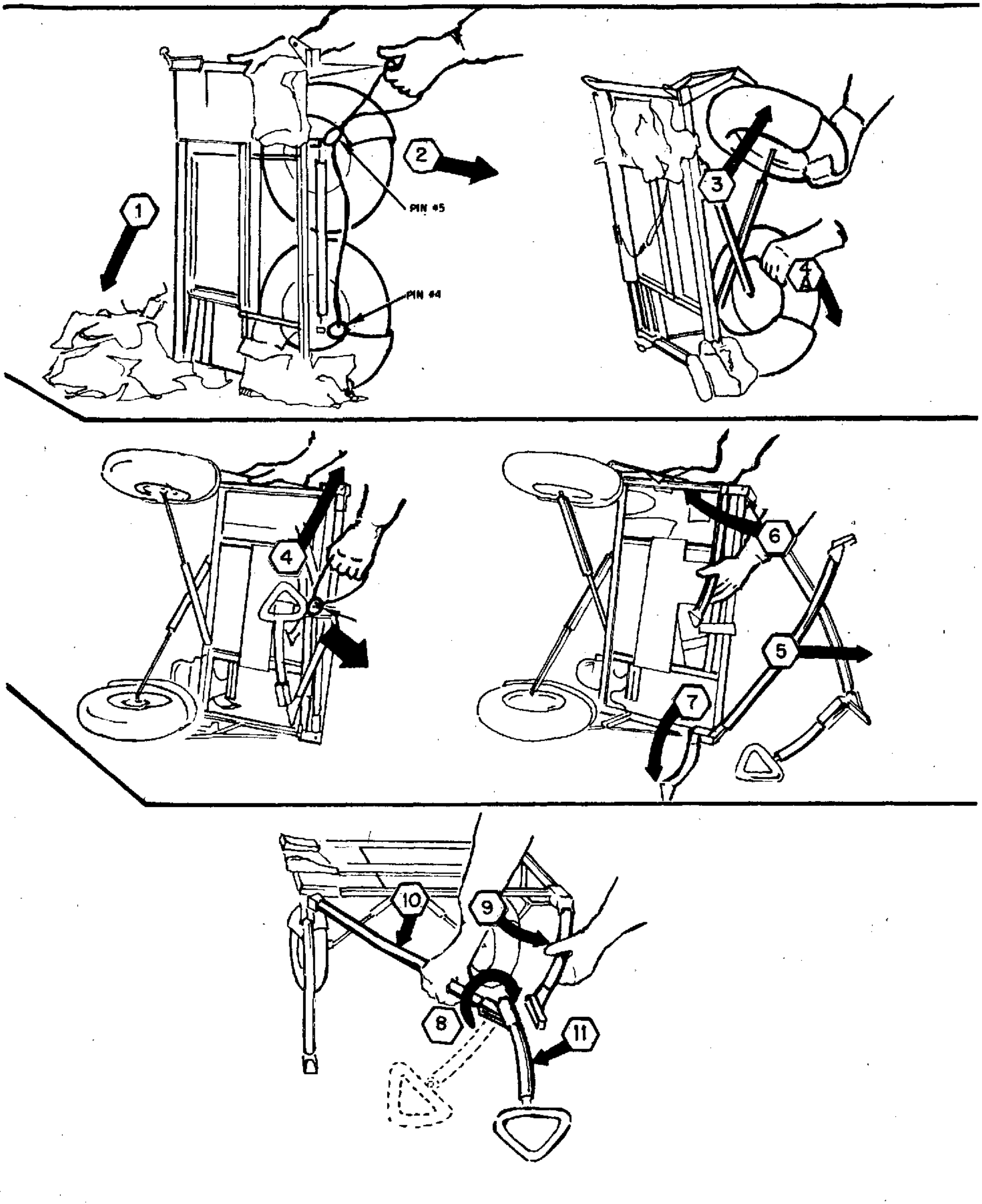
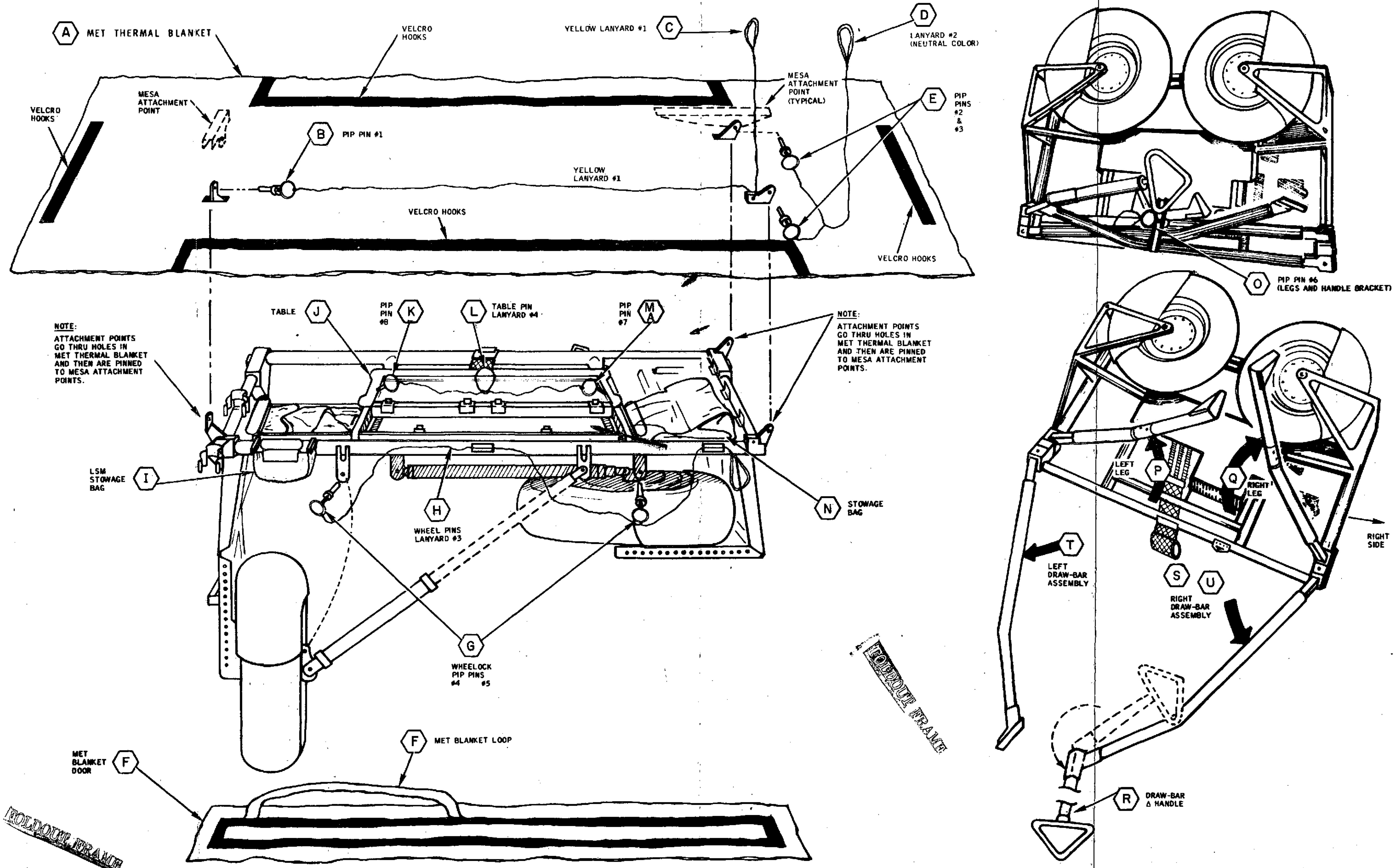

1
2
PIN #5
PIN #4
3
4A
4
6
5
7
10
9
8
11

FIGURE 8 (Page 3 of 3)

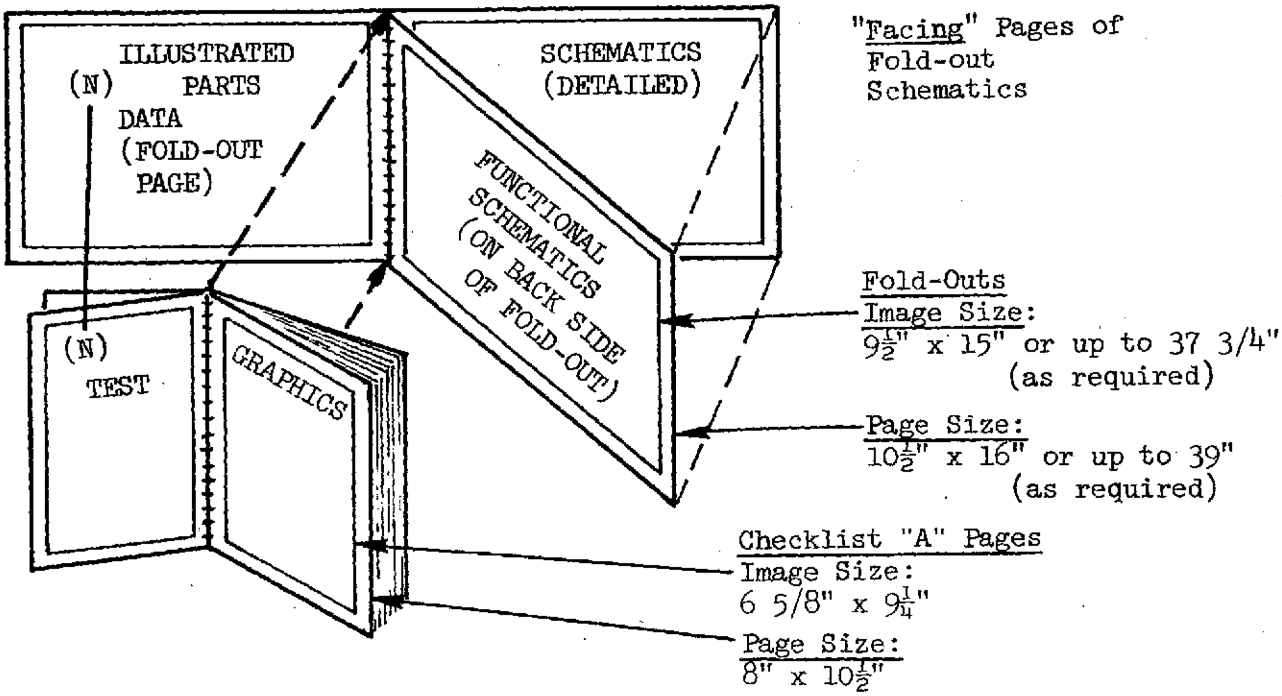
EXAMPLE TYPE "D3" DATA (FOLDED GRAPHICS)



3.3.8 Type "E" IFCM Crew JPA Data Requirements

(a) Format Size and Configuration Requirements

Type "E" data shall be presented on a cross-referenced integrated combination of fold-out pages and standard Checklist "A" size pages as indicated below.



IFCM PROCEDURAL TEST/GRAPHICS

Contents:

		Format Type
o General data on special processes Used in all IFCM tasks	- - -	A, B1 and B2
o Assembly/Disassembly Data	- - -	B1, B2
o Subassy. Troubleshooting Data	- - -	C

(b) General Description of Type "E" IFCM JPA Data

Type "E" IFCM shall utilize a cross-referenced integrated combination format of fold-out pages and standard Checklist "A" size pages configured in Type A, B1, B2, or C formats. This format provides the capability for almost simultaneous viewing by the crew of procedural corrective maintenance text data and related reference data.

The initial fold-out page of the set shall contain illustrated parts reference data that allows the crew to identify accurately the parts involved in a task. The parts data on this sheet is cross-referenced from the procedural text and to the detailed schematic with a simplified coding system that is described in section (d).

The last two pages of the procedural sequence shall contain a set of fold-out schematics of the equipment to be repaired. The final frontward facing page shall contain detailed schematic data which is used concurrently with the procedural text data and therefore shall be placed as illustrated so that simultaneous viewing of both text and schematic data is possible thus reducing the page turning and search time of the crew. The backward facing fold-out page shall contain functional schematic data. The layout of the functional schematics data shall generally replicate the layout of the detail schematics and shall contain explanations of the function of each major hardware grouping in a simplified fashion. This provides a method for quickly becoming familiar with the layout of the detailed schematic and the purposes of the hardware. The functional schematic shall face the detailed schematic data since they are used in support of each other. However, since little references between the functional schematic and procedural text data is made, the functional schematic shall be configured as a backward facing page as noted in the previous format description.

The Type "E" data shall include procedural textual data and related supporting graphics and reference data. This data shall be presented on "A" size pages that are included between the front and back fold-out pages of a corrective maintenance procedural set as noted in the previous format illustration. This allows almost simultaneous viewing of textual and fold-out graphical support data so that cross-referencing is simplified with few page turnings required. The textual data shall contain the basic step-by-step procedures involved in the disassembly, troubleshooting, replacement or repair, and reassembly of electrical/electronic systems hardware. This procedural text shall be cross-referenced to the illustrated parts data which in turn is referenced to the detailed schematic data on the fold-out pages. The procedural text and graphics can be presented in a variety of formats. Recommended format data types for various corrective maintenance procedural requirements are presented in the Section (a) Format Size and Configurational Data. These data types contain graphics to support the procedures as defined in the previous sections of this specification.

The major purpose of the Type "E" IFCM data format is to provide a data device for supporting complex electrical/electronic systems repair tasks in which indenturing to the subassembly level of repair is required. This may require integral troubleshooting procedures which are covered through contingency procedures and supported with test point identification, physical location and test point performance criteria data.

(c) Type "E" Data Usage Guidelines

Type "E" JPA Data is a relatively complex data format and is appropriate for usage mainly to support medium to very complex electrical/electronic spacecraft or payload systems corrective maintenance tasks. When subassembly level repair is involved that requires troubleshooting as an integral part of the IFCM, then Type "E" data should be considered for usage. This type of data provides the most comprehensive data support of all of the IFCM JPA data types. With little or no training, flight crewmembers should be able with this JPA data to satisfy most of the inflight corrective maintenance software support requirements.

(d) Type "E" Data Elements (see Figure 9, Pages 1 thru 8)

Type "E" data shall utilize basic data elements of Types A, B1, B2, and C data format in conjunction with folded graphics data formats that provide illustrated parts description and location data and engineering and functional schematics data of the equipment being repaired.

ILLUSTRATED PARTS DATA: (See Figure 9, Page 1).
Illustrated parts data shall be provided on all spare parts carried onboard or re-supplied to the spacecraft.

[A] - CIRCUIT PART CODES - A unique alphanumeric code shall be used to identify a part within the equipment circuit being repaired. This part code is used on the detailed schematics and on the illustrated parts descriptive and location data as a designator that identifies the physical and functional location of the part within the equipment and equipment data. This code shall be in keeping with accepted electronic coding practices (i.e., C = Capacitors, R = Resistors, etc.)

[B] - PART NAME AND DESCRIPTION - Data shall be provided that identifies the part and describes it in such a manner that a relative "novice" to electronic repair work can identify the part accurately. It shall include items [C] through [G]

[C] PART TYPE CLASS - Data shall be provided within the Part Name and Description to identify the particular class of components being described.

[D] PART TYPE GRAPHIC SYMBOL - The schematic symbol utilized on the detail schematic for the Part Type shall be provided adjacent to the Part Type nomenclature. This data will serve as a reference data for reading the detailed schematic.

[E] ILLUSTRATION OF PART - A pictorial line drawing or half-tone illustration of the part shall be provided for assistance in part recognition and selection.

[F] TEXTUAL DESCRIPTIVE DATA ON PARTS - Detailed Textual data shall be provided to allow an accurate identification of the part and it's installation (if unique).

[G] PARTS LOCATION DATA - Graphic line drawings or half-tone pictorials shall be provided that will illustrate the installed location of the part. This can be symbolic data as illustrated on Figure 9, Page 1 or can be of a grid overlay type, in which case a Locations Column must be added to the Part Name and Description Data. Parts shall be identified on the Parts Location Data using the circuit part codes.

TYPE "E" IFCM PROCEDURAL TEXT/GRAPHICS:

Type "E" Procedural Text/Graphics shall utilize A, B1, B2, and C type data formats as is appropriate for the particular task being supported.

[H] GENERAL DATA ON SPECIAL IFM PROCESSES - Figure 9, Page 2 contains an example of a combined format of A, B1, and B2 type data that shall be utilized in the Type "E" data format. Data elements for these individual data types are specified in the Paragraphs 3.3.1, 3.3.2, and 3.3.3 of this specification.

[I] ASSEMBLY/DISASSEMBLY DATA - Figure 9, Pages 3 and 4 contain an example of the application of Type B1 and B2 data for electronic assembly or disassembly corrective maintenance tasks that shall be utilized in the Type "E" data format. Data elements for the B1 and B2 type data are specified in Paragraph 3.3.2 and 3.3.3 of this specification.

[J] TROUBLESHOOTING DATA - Figure 9, Pages 5 and 6 contain an example of the application of the Type C data format to integral subassembly troubleshooting procedure for corrective maintenance that shall be utilized in the Type "E" data format. The example illustrates typical troubleshooting procedures supported by graphics data that shall be provided to define the location of test points and the nominal test values anticipated at these points. The procedural data provided shall utilize this graphics test data to support the process of isolation of failures on the subassembly level until the failed component is identified. In addition the Type "E" procedural data shall include the steps necessary to hook-up and operate the test equipment necessary to verify the test values indicated. The other data elements for this type format are specified in Paragraph 3.3.4 of this specification.

TYPE "E" SCHEMATICS DATA:

[K] FUNCTIONAL SCHEMATIC DATA - Figure 9, Page 7 contains an example of the functional schematic data that shall be provided as an integral part of the Type "E" data format. This type of schematics data is provided to give a functional overview of the detail schematic and to describe the purposes of the basic schematic assemblies in the operation of the equipment. The functional schematic shall be structured to reflect the basic arrangement of the detailed schematic to assist in easier user interpretation. The schematic shall provide summary functional description of the modules and assemblies involved in the equipment.

[L] DETAILED ENGINEERING SCHEMATIC DATA - Figure 9, Page 8 contains an example of the detailed engineering schematic data that shall be provided as an integral part of the Type "E" data format. This schematic data shall be prepared utilizing acceptable electronic equipment symbology as illustrated in Figure 9, Page 8 . In addition to the standard equipment descriptive data, the Type "E" detailed schematic shall include the following data elements:

[M] TEST POINT LOCATIONS AND NOMINAL TEST VALUES - The location of designated test points and the nominal values anticipated at these test points shall be indicated within an elipse symbol ( ) that is placed within the schematic at the appropriate test point. Additional test points where oscilloscope test measurements are made are designated by the symbol N . The number within this symbol corresponds to the oscilloscope pattern provided within the troubleshooting procedures.

[N] NOTES - The detailed schematic shall contain notes that assist in the location of parts within the schematic as noted in the Example Figure 9, Page 8. Other information shall also be presented to clarify the troubleshooting and corrective maintenance procedures as is appropriate to the task.

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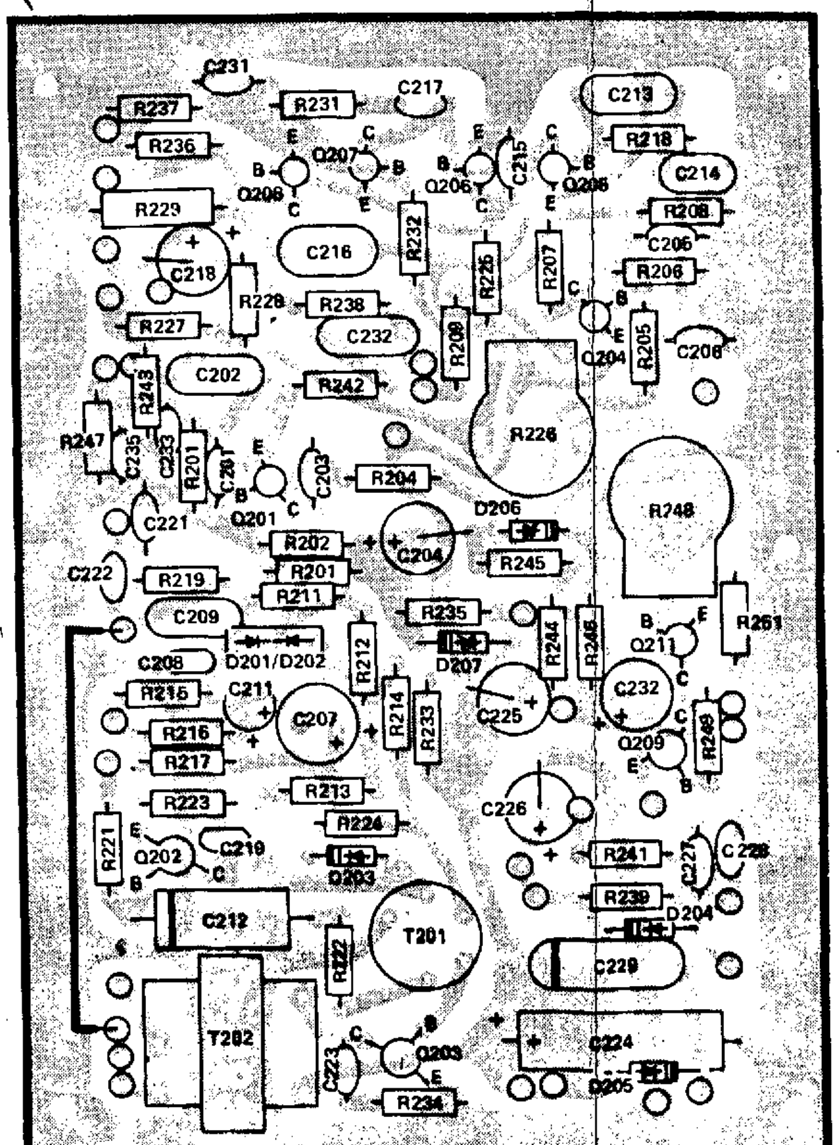
FIGURE 9 (Page 1 of 8)
EXAMPLE: TYPE "E" DATA
TYPICAL ILLUSTRATED PARTS DATA

PARTS LOCATION DATA

G



(SHOWN FROM COMPONENT SIDE)

CIRCUIT PART CODES (A)	PART NAME AND DESCRIPTION (B)			
	(C) CAPACITORS (D)			
		VALUE	# OF SPARES	STOWAGE LOCATION
C201,C205,C206 C205,C217,C227 C228	(E) DISC:	(F) 3.3 pF 5 pF .001µ F	2 3 1	M106 M106 M106
C20,C21,C22 C105,C109 C262	MICA:	7.5 pF 100 pF	3 2	"
C211,219	MYLAR:	.1µF .22µF	1 2	"
C204,207	ELECTROLYTIC:	10µF VERTICAL	1	"
	DIODES			
D201,D202	MFG. PART #1N4951			
D301	MFG. PART #S160			
	TRANSISTORS — BASE, COLLECTOR, EMITTER (PNP); BASE, COLLECTOR, EMITTER (NPN)			
Q101,Q102	LOCATING TAB; 1/4"; LOCATING TAB	1. CAREFULLY IDENTIFY E,B,C LEADS OF TRANSISTOR		
Q104	E, B AND C STAMPED ON THIS TRANSISTOR TYPE ONLY; FLAT SIDE; 1/4"; E B C	2. INSTALL IN CIRCUIT BOARD IN CORRESPONDING E,B,C LOCATION FOR TRANSISTOR		
Q205	FLAT SIDE; 1/4"; TRIANGULAR	3. POSITION TRANSISTOR		
	RESISTORS — VARIABLE			
R101 R136	1/4 WATT, TOLERANCE = ± 10% (SILVER) 4.7 OHMS (YELLOW-VIOLET-GOLD) 10 OHMS (BROWN-BLACK-BLACK)			
R238 R216	1/2 WATT, TOLERANCE ± 5% (GOLD) 390 OHMS (ORANGE-WHITE-BROWN) 560 OHMS (GREEN-BLUE-BROWN)			
R229	1 WATT, TOLERANCE ± 5% (GOLD) 5.6 OHMS (GREEN-BLUE-BLACK)			

1ST FIGURE
2ND FIGURE
NO. OF ZERO'S

COLOR	#	TOLERANCE
BLACK	0	
BROWN	1	
RED	2	
ORANGE	3	
YELLOW	4	
GREEN	5	
BLUE	6	
VIOLET	7	
GRAY	8	
WHITE	9	
SILVER	.1	10%
GOLD	.0	5%
NONE		20%

FIGURE 9 (Page 2 of 8)

EXAMPLE TYPE "E" DATA

(Usage of Combined Type "A", "B1", and "B2" Data in Type E Format)

H

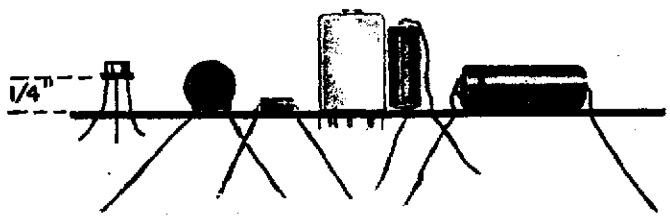
GM-1 **TYPICAL IFCM GENERAL PROCESS DATA** GM-1

ASSEMBLY:

1. Cut leads on replacement parts to approximate length of parts being replaced.

2. Clean old connections by heating and quickly wiping away melted solder.

3a. Mount circuit board parts tightly against board (unless directed differently in procedures)



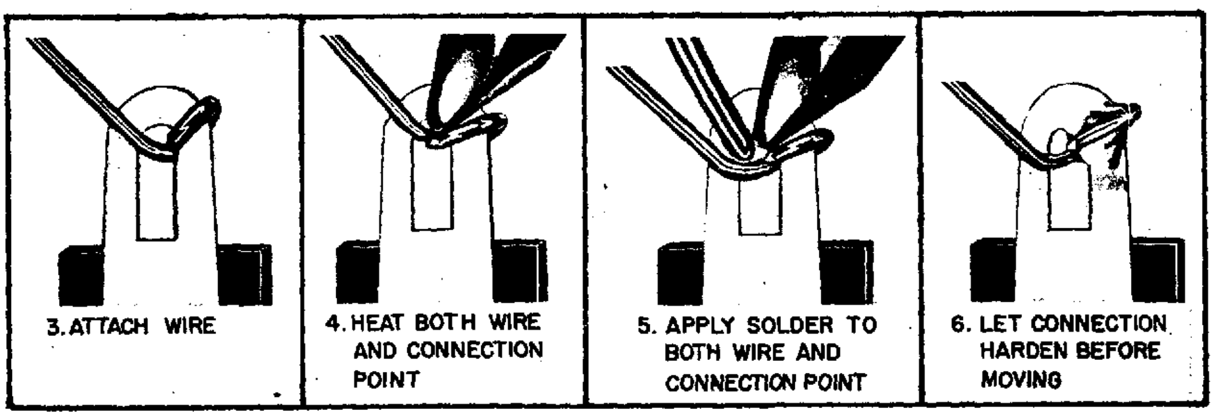
3b. Insert part leads thru correct holes in boards, then bend lead slightly outward to hold part in place prior to soldering.

SOLDERING:

CAUTION: Soldering in zero-G requires careful attention to the manner in which solder is applied. Watch for excess solder that may float away from assembly during soldering.

1. Make sure connection is clean.

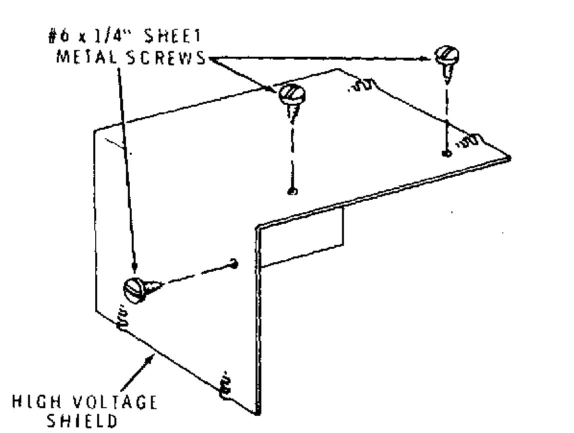
2. Keep tip of soldering iron clean by wiping with damp cloth.



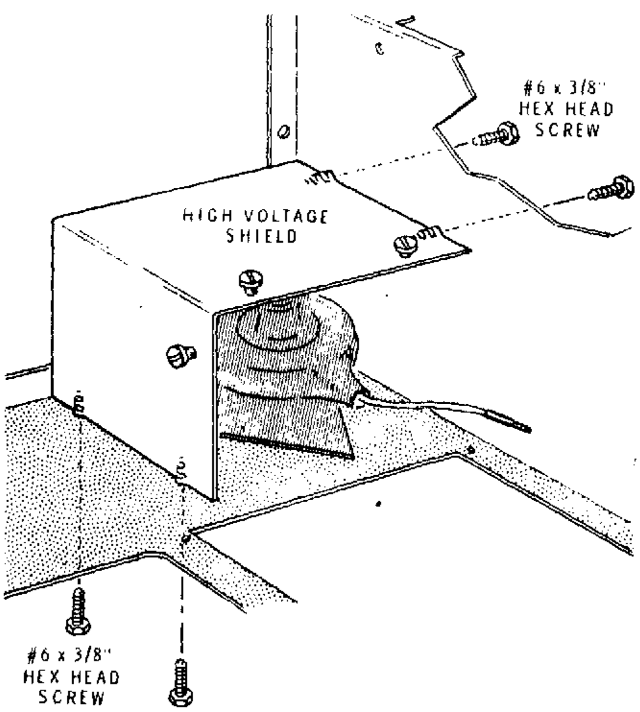
I

EXAMPLE TYPE "E" PROCEDURAL TEXT/GRAPHICS
(Usage of Type "B1" Data in Type E Format)

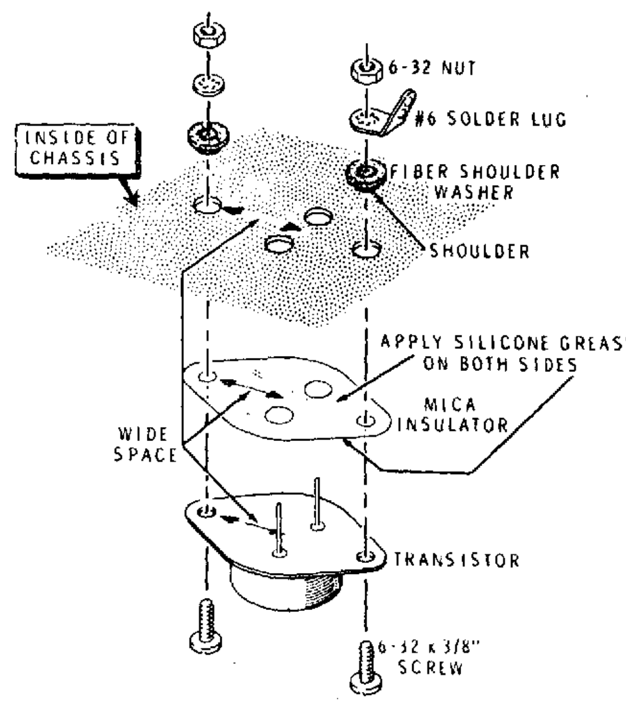
TYPICAL ASSEMBLY OR DISASSEMBLY DATA



1. Install three #6 x 1/4" sheet metal screws in the high voltage shield.



2. Mount the high voltage shield on the chassis
Use screws (4) (#6 x 3/8" hexhead)

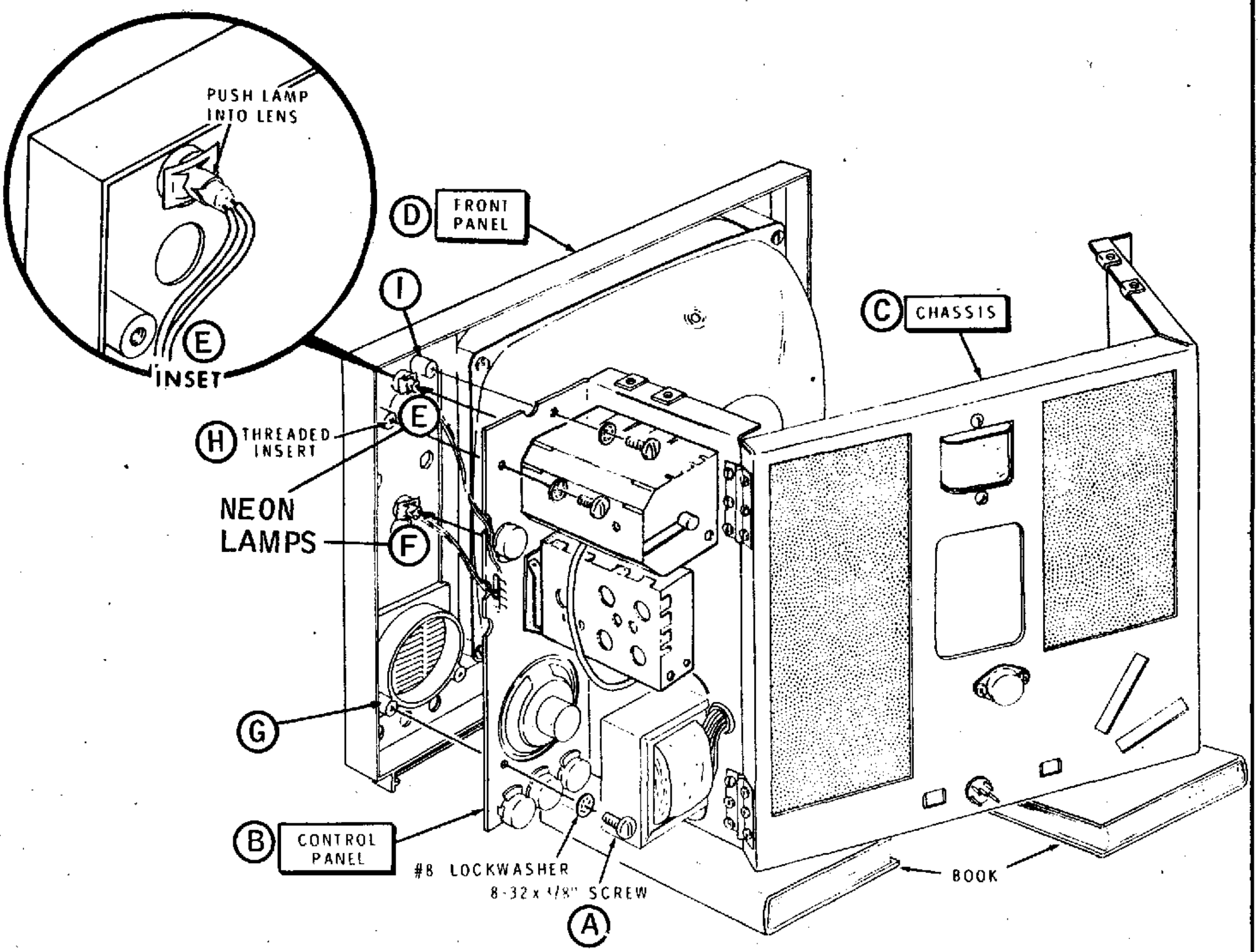


3. OBTAIN:
   - Transistor (# 417-90)
   - MICA Insulator
   - Fiber Shoulder Washer (2)
   - Screws (6-32 x 3/8" (2)
4. APPLY Layer of Silicone Grease on both sides of MICA Insulator
5. MOUNT Transistor and MICA Insulator as shown to chassis.

FIGURE 9 (Page 4 of 8)
EXAMPLE TYPE "E" PROCEDURAL TEXT/GRAPHICS
(Usage of Type "B2" Data in Type "E" Format)

I

TYPICAL ASSEMBLY AND DISASSEMBLY TYPE DATA



1) OBTAIN: (3) 8-32 x 3/8" Screws (A)
(3) #8 Lock Washers (A)

2) POSITION: Control Panel (B)
(As Shown) Chassis (C)
Front Panel (D)

3) CAREFULLY Push Neon Lamps (E,F) into Lamp Lenses (as per detail)

4) START Three Screws and Lockwashers (A) into the illustrated inserts (G, H, I)
CAUTION: Be sure that no wires are pinched between Chassis and Control Panel.

5) TIGHTEN Front Panel Mounting Screws (#) (A)

FIGURE 9 (Page 5 of 8)

J EXAMPLE OF TYPE "E" TROUBLESHOOTING DATA

(Usage of Type "C" Data Within Type "E" Format)

TESTING:

1. Activate Vacuum Tube Voltmeter Test Equipment as per Standard Operating Procedures (GM-2) for this equipment

2. Attach Probe Lead (Black) to equipment chassis

3. Touch designated test point, as required.

If Test Values Vary greater than 10% from nominal readings

- Replace Part (If spare available) utilizing

  General Process Procedures and Detailed Transistor Replacement Data (CM-6).

- If Replacement not available notify Mission Control.

CAUTION: Unless otherwise stated, all maintenance tasks should be in powered-down condition.

OSCILLOSCOPE TESTING:

1. Connect the oscilloscope test equipment as per Standard Operating Procedures (GM-3) for this equipment.

2. Attach probe leads to grounds and test points as required by (GM-3).

3. Compare test patterns at designated test points with standard patterns.

J

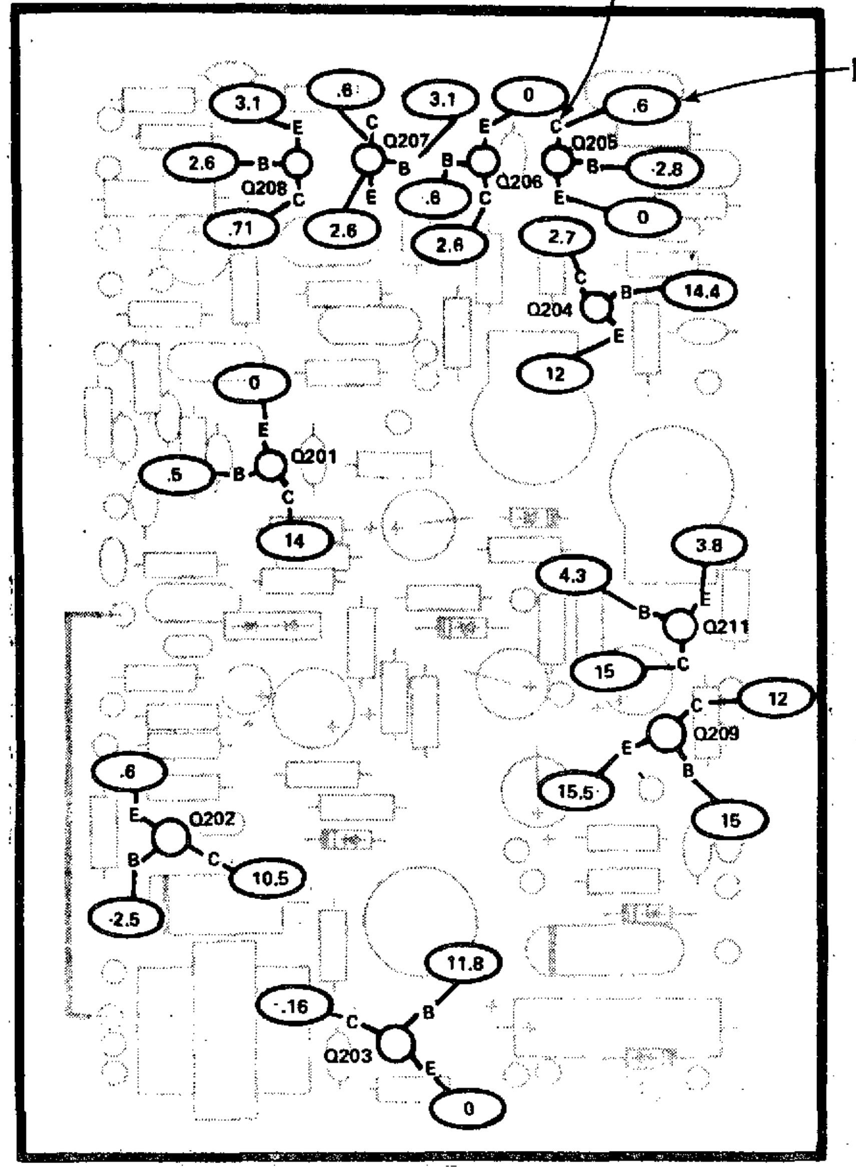
FIGURE 9 (Page 6 of 8)

EXAMPLE OF TYPE "E" TROUBLESHOOTING DATA

(Usage of Type "C" Data Within Type "E" Format

VOLTMETER TEST POINTS

TEST POINT LOCATION



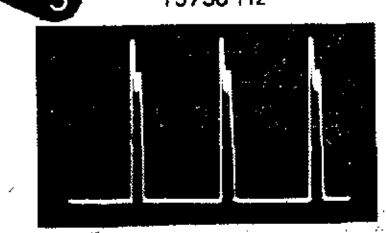
NOMINAL TEST VALUE

(SHOWN FROM COMPONENT SIDE)

USE CM -6 PROCEDURES FOR TRANSISTOR REPLACEMENT

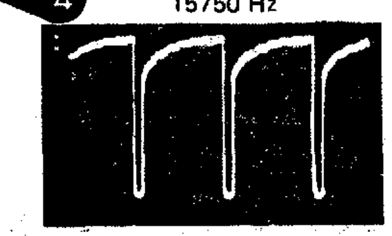
OSCILLOSCOPE TEST PATTERNS

3 15750 Hz



17V P to P

4 15750 Hz



.18V P to P

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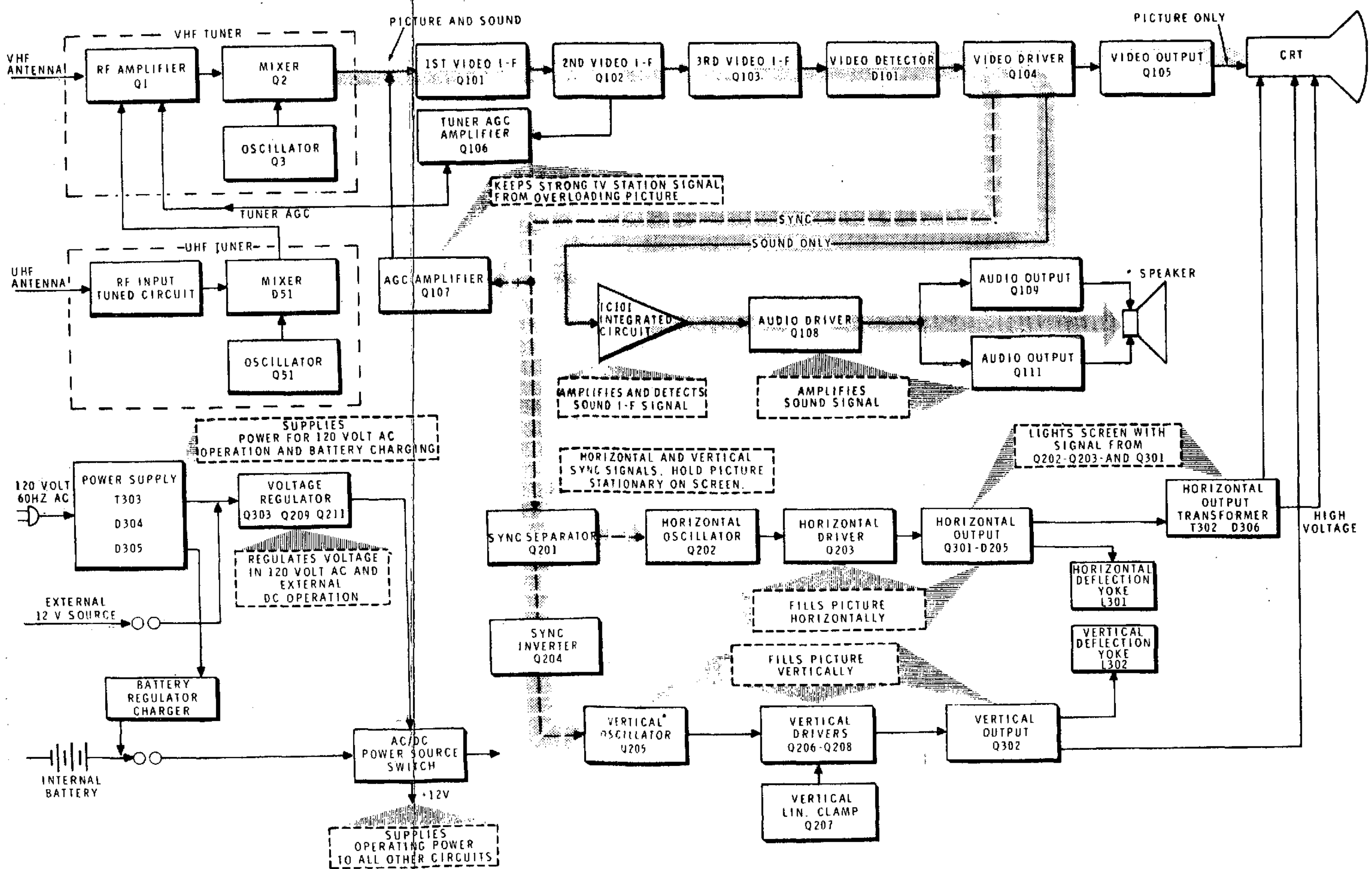
FIGURE 9 (Page 7 of 8)

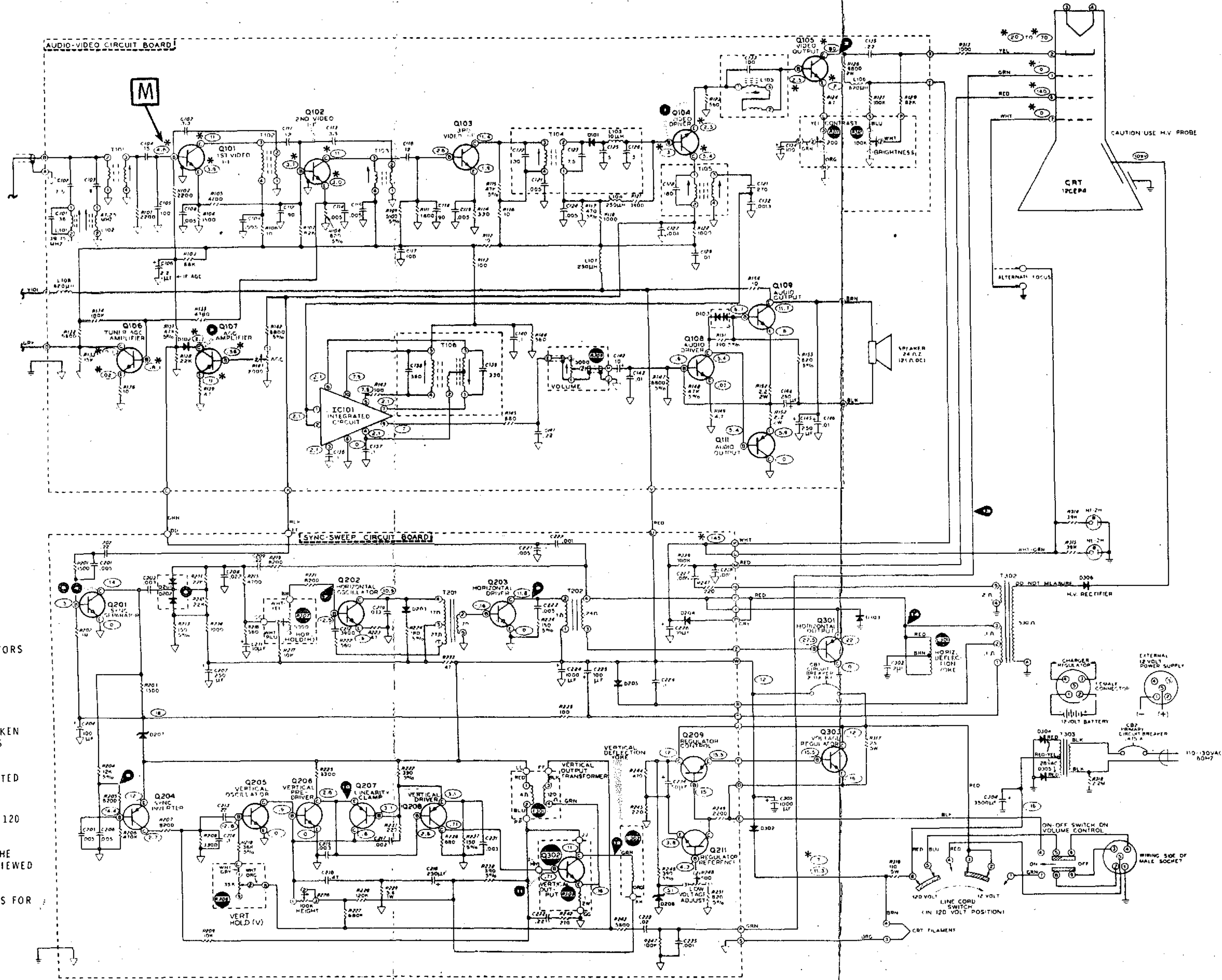
K EXAMPLE TYPE "E" FUNCTIONAL SCHEMATICS DATA



FOLDOUT FRAME FOLDOUT FRAME

L

FIGURE 9 (Page 8 of 8)
EXAMPLE TYPE "E" DETAILED SCHEMATICS DATA



N

SCHEMATIC NOTES

TYPICAL PARTS LOCATION DATA

1. RESISTOR AND CAPACITOR NUMBERS ARE IN THE FOLLOWING GROUPS:

0-49	PARTS IN THE VHF TUNER.
50-99	PARTS IN THE UHF TUNER.
100-199	PARTS ON THE AUDIO-VIDEO CIRCUIT BOARD.
200-299	PARTS ON THE SYNC-SWEEP CIRCUIT BOARD.
300-399	PARTS MOUNTED ON THE CHASSIS.
400-499	PARTS OF INTEGRATED CIRCUIT (IC101).

2. THIS SYMBOL AROUND A PART NUMBER MEANS THAT THIS PART IS MOUNTED ON THE CHASSIS, EVEN WHEN ITS POSITION ON THE SCHEMATIC SUGGESTS ANOTHER LOCATION.

3. ALL RESISTORS ARE 1/2 WATT UNLESS MARKED OTHERWISE. RESISTOR VALUES ARE IN OHMS (K=1000, M=1,000,000).

4. ALL CAPACITORS LESS THAN 1 (.01 ETC.) ARE IN µF. ALL OTHER CAPACITORS ARE IN pF UNLESS OTHERWISE MARKED.

5. Hz (HERTZ)=CYCLES PER SECOND.
kHz (KILOHERTZ)=KILOCYCLES PER SECOND.
MHz (MEGAHERTZ)=MEGACYCLES PER SECOND.

6. THIS SYMBOL INDICATES A POSITIVE DC VOLTAGE MEASUREMENT, TAKEN WITH AN 11 MEGOHM VTVM, FROM THE POINT INDICATED TO CHASSIS GROUND. VOLTAGES MAY VARY ±10%.

7. * THIS SYMBOL INDICATES A VOLTAGE THAT MAY VARY WITH ASSOCIATED CONTROL SETTING.

8. ALL VOLTAGES MEASURED WITH CONTROLS SET FOR NORMAL PICTURE ON 120 VOLT AC LINE VOLTAGE WITH NO SIGNAL INPUT.

9. ARROWS AT CONTROLS INDICATE CLOCKWISE ROTATION, VIEWED FROM THE SHAFT END OF THE CONTROL. CIRCUIT BOARD MOUNTED CONTROLS ARE VIEWED FROM FOIL SIDE.

10. REFER TO THE CHASSIS PHOTOGRAPHS AND CIRCUIT BOARD X-RAY VIEWS FOR THE PHYSICAL LOCATION OF PARTS.

FOLDOUT FRAME

FOLDOUT FRAME

4.0 GENERAL GUIDELINES FOR APPLICATION OF IFCM JPA DATA TYPES

As noted previously in this specification, the selection of the Job Performance Aid data type to support any specific crew inflight corrective maintenance task shall be as specified by the NASA organizational elements that are responsible for flight crew procedures development. Therefore, the following qualitative criteria data should be considered as guideline information only for both NASA and contractor personnel.

Figure 10 presents qualitative criteria for the selection of the IFCM JPA data types as a function of task criticality, task complexity, and training time/fidelity. This qualitative data plot illustrates that the more critical and important a task is for crew safety and mission success the more is there a need for detailed and definitive onboard task procedural data that can be used as "do-it-yourself" instructions for the flight crew. However, if significant training time can be devoted by the flight crew to learning the IFCM task on high fidelity mockups or simulators then simpler JPA's (Type A) can be utilized to support the IFCM activity.

In a similar manner, the more complex the IFCM task the more is the graphical type JPA's an appropriate selection. However, the amount of training time and the fidelity of the training can reduce and modify this need for the more comprehensive JPA data being onboard for crew usage. In Figure 11, additional qualitative selection criteria are presented that illustrates appropriate IFCM JPA data types with respect to the systems being repaired, the levels of indenturing into systems hardware required and the complexity of the task itself. In particular it can be noted that the more complex electrical/electronic tasks are more suited to the "E" Type of JPA data whereas the simpler mechanical and fluid tasks are better served with the "A" Type data

From these data plots it is apparent that any specific IFCM task data support question must be considered in view of task requirements (including systems involved and task levels) and training availability for the crew and mission in question. As a general rule, it is desirable to support IFCM tasks with Type A data, if possible. However, if task requirements dictate, selective usage of the more complex graphic data types should be considered.

FIGURE 10

QUALITATIVE GUIDELINE CRITERIA
FOR
SELECTION OF INFLIGHT CORRECTIVE MAINTENANCE (IFCM)
JOB PERFORMANCE AID (JPA), DATA TYPES

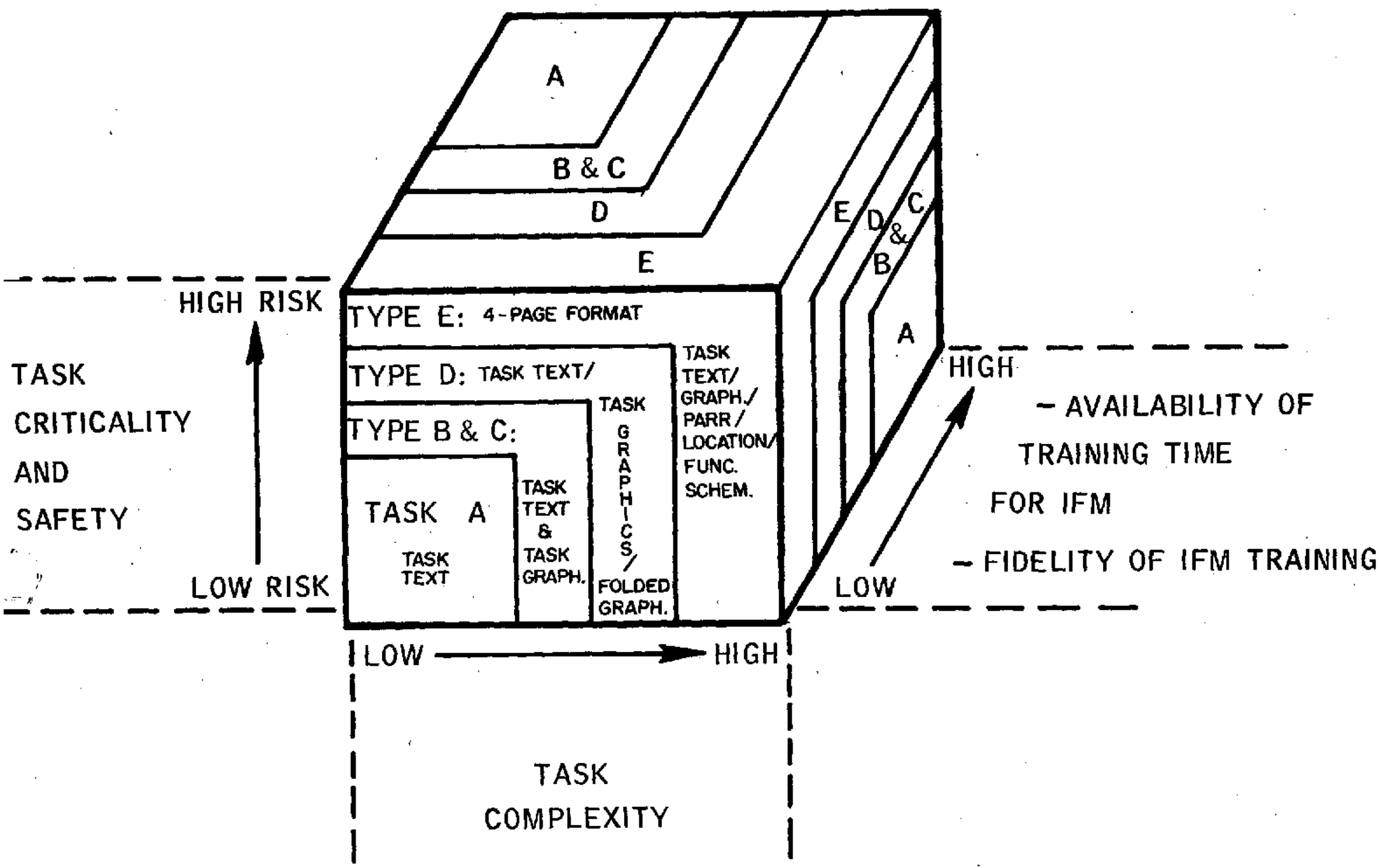


FIGURE 11

QUALITATIVE GUIDELINE CRITERIA
FOR
SELECTION OF IFCM JPA DATA AIDS
(LEVEL/SYSTEMS/COMPLEXITY)

IFCM LEVELS — TASK INDENTURING		"A"	"B"	"C"	"D"	"E"
	1. SUBASSY/ PART	NOT APPLICABLE	M 2 F 2	M 2 F 2	M 2 3 F 2 3	E 1 2 3
	2. ASSY.	E 1 1 F 1	M 1 2 F 1 2	E 1 2 M 2 F 2	E 2 M 2 3 F 2 3	E 1 2
	3. SYSTEM	M 1 F 1	M 1 2 F 1 2	M 2 F 2	M 2 3 F 2 3	NOT APPLICABLE
		JPA DATA TYPES				

MATRIX
ENTRY CODES

SYSTEMS TYPES	TASK COMPLEXITY
E ELECTRICAL/ ELECTRONIC	1 SIMPLE
M MECH./ ELECTRO & MECH.	2 MEDIUM COMPLEXITY
F FLUID-MECH	3 COMPLEX

APPENDIX C
DEFINITIONS

For the purposes of this study, the following definitions shall apply:

a. Accessibility - a measure of the relative ease of admission to the various areas of spacecraft equipment or items being repaired or refurbished.

b. Contingency Inflight Maintenance - those crew actions performed in response to failures occurring in flight for which no preplanned procedures and support equipment have been included on-board. Planning for this type of inflight maintenance must be done by the flight crew with assistance from the ground control support as is appropriate.

c. Failure - the inability of an item to perform within previously specified limits.

d. Failure Analysis - the logical, systematic examination of an item or its diagram(s) to identify and analyze the probability, causes, and consequences of potential and real failures.

e. Item - used to denote any level of hardware assembly; i.e., system, segment of a system, subsystem, equipment component, part, etc.

f. Inflight Replaceable Unit (IFRU) - an item which, when unserviceable, can be restored to an operational condition through replacement by the flight crew during flight or space operations.

g. Inflight Maintenance (IFM) - those crew actions required, during spaceflight for safety or mission reasons, to (a) retain the spacecraft or payload system in an operable condition (scheduled IFM), (b) troubleshoot and isolate failed equipment items (inflight diagnostics), and (c) restore failed items to an operable status (corrective maintenance). IFM shall include: Preplanned scheduled IFM tasks, Preplanned unscheduled IFM tasks, and Contingency IFM tasks for which planning must be done during the mission in real-time.

h. Inflight Corrective Maintenance (IFCM) - those crew actions performed to restore an item to a satisfactory operable condition after a malfunction has caused degradation of the item below the specified performance level. The major tasks associated with IFCM are:

- Preparation - gathering data, tools and spares, configuring systems for inflight maintenance tasks, and airlock operations.
- Translation - establishing a movement path throughout (IVA) or over (EVA) the space vehicle to and from the payload or spacecraft maintenance worksite.
- Worksite Preparation - establishing crew, tools, and equipment restraints at worksite to enable crew to perform maintenance tasks in zero-g environment.
- Restoring Actions:
- Disassembly - worksite "open-up" and equipment disassembly to the extent necessary to gain access to the item that is to be replaced.
- Localization and Isolation - determining the location of a failure with or without the use of accessory support equipment on the subsystem level of inflight maintenance.
- Alignment - performing any alignment, minimum tests, and/or adjustments made necessary by the repair action.
- Verification Checkout - performing the minimum checks or tests required to verify that the equipment has been restored to satisfactory performance.

i. Inflight Corrective Maintenance Levels - a division of inflight maintenance tasks based upon the level of indenturing into systems and equipment hardware required by the maintenance task. There are three levels of inflight maintenance.

(1) Subassembly Level - Tasks performed at a level that requires the crew to "open up" a normally sealed or totally enclosed unit, drawer or chassis, and replace or repair parts and/or subassemblies.

(2) Assembly Level - Tasks performed at this level require replacement of a modularized item, i.e., assembly, unit, drawer or chassis. Assembly level tasks are essentially interchange actions of removing a defective item and installing the replacement.

(3) System Level - Tasks performed at this level are addressing total systems problems and do not involve parts or module replacement, but are associated with such activities as leak detection and repairs, glycol replacement, etc., that are not normally scheduled activities.

j. Inflight Corrective Maintenance Modes - Inflight corrective maintenance tasks can be classified into different modes based upon the worksite environment ((1) IVA or (2) EVA) and upon the type of operations being performed (crew direct manual, etc.). These modes include:

Mode 1A: Intravehicular, Crew Direct Manual Operations
Mode 1B: Intravehicular, Remote Manipulator System ("aided") operations
Mode 2A: Extravehicular, Crew Direct Manual Operations
Mode 2B: Not applicable
Mode 2C: Extravehicular, Crew Direct Manual Operations from Remote Manipulator System ("aided" - Cherry Picker operations)
Mode 2D: Extravehciular, Crew Direct Manual from Astronaut Maneuvering Unit. ("aided" operations)

k. Inflight Scheduled or Preventive Maintenance - the actions performed on a time scheduled basis that attempts to retain a spacecraft or payload item in a specified condition by providing systematic refurbishment inspection, detection, and prevention of incipient failure. This also includes servicing operations.

l. Inflight Maintenance Concept - a narrative statement or illustration that defines the theoretical means of maintaining an equipment item or system during spaceflight. The statement relates the tasks that should be performed, the tools, spares, restraint and mobility equipment that should be used to perform the inflight maintenance, and the training requirements of flight personnel necessary for safe task performance.

m. Job Performance Aids - devices and/or data that facilitate task performance by man in the operation and/or maintenance of equipment systems. These aids may be data storage devices (microfilm, computer, film, etc.), display devices (movie projector, computer data terminal, etc.), audio tape and play back devices and printed copy storage (flight data procedures, schematics, etc.). These devices or data specify actions to be taken, equipment to be used or worked upon, and criteria for decision-making events. These aids may be used cooperatively, or concurrent with task performance or can be used as reference data for training and operations.

n. Job Performance Aid Data Types - data used in Job Performance Aids can be classified as (a) textual or verbal information or (b) graphics or pictorial information.

(a) Textual or Verbal Information: Data in word and numerical form that utilizes a style of "directively" identifying or specifying (1) the job or tasks and their proper sequence of performance, (2) the controls, equipment and tool elements that are involved in the tasks and (3) the responses anticipated from the tasks. Tabular data in chart form is also used in conjunction with the textual data for describing performance criteria, etc. Data in this textual checklist form has been the major Job Performance Aid used for on-the-job performance of operations and maintenance by flight or ground crew of aircraft and spacecraft. The extensive use of this JPA form has been due to its compactness, ease of producibility and ease of change.

(b) Graphic or Pictorial Information - data that conveys information through pictorial representation of three-dimensional forms. This type information is uniquely suited for the representation of equipment shape, form, fit, and location within other assemblies and equipments. It's usage within Job Performance Aids in the past has been limited due to the greater costs of preparing the material and the difficulty in making rapid changes to such data.

o. Onboard Loose Equipment - those equipment items that must be developed and/or procured and stowed onboard the spacecraft as additional equipment for (a) crew operations support (checklists, etc.), (b) crew life support (space suits, food, etc., and (c) crew inflight maintenance support (tools, spares, restraint devices).

p. Maintainability - a characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources.

q. Maintenance - all actions necessary for retaining an item in or restoring it to a specified condition.

r. Preplanned Inflight Maintenance - those crew actions required to retain, troubleshoot and restore items to an operable status. Support in the way of procedures, tools, spares, test equipment, etc. are defined prior to flight and are included as on-board stored loose equipment. Preplanned IFM includes tasks which are (a) Scheduled as a integral part of normal operations and (b) Unscheduled for normal operations but for which the support resources are included on-board. No preplanned designation of time for accomplishment of these type tasks are included in the flight plan. However, performance of unscheduled tasks shall be as required for the mission.

s. Redundancy - the existence of more than one means for accomplishing a given function. Each means of accomplishing the function need not necessarily be identical.

t. Reliability - the probability that an item will perform its intended function for a specified interval under stated conditions.

u. Servicing - the replenishment of consumables needed to keep an item in operating condition.

v. Systems Types of Job Performance Aids - the nature of information and the format required within JPA's for inflight corrective maintenance support will vary as per the type of spacecraft or payload system being repaired or fixed. The classification of systems based upon unique data requirements is as follows:

    E = Electrical/Electronic Data Types
    M = Mechanical/Electro-mechanical Data Types
    F = Fluid/Fluid Mechanical Data Types

w. Troubleshooting Types of Operations - Job Performance Aid support data requirements to support troubleshooting operations will vary dependent upon the configuration of controls/displays and the inclusion of onboard checkout and monitoring equipment. The types of troubleshooting operations include:

    Type 1 - using installed onboard automatic troubleshooting equipment such as the Performance Monitor System on the Shuttle Orbiter.

    Type 2 - using spacecraft controls/displays and crew diagnostic procedures.

    Type 3 - using special test equipment.

    Type 4 - visual inspection of failure site and/or failed equipment.

APPENDIX D

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