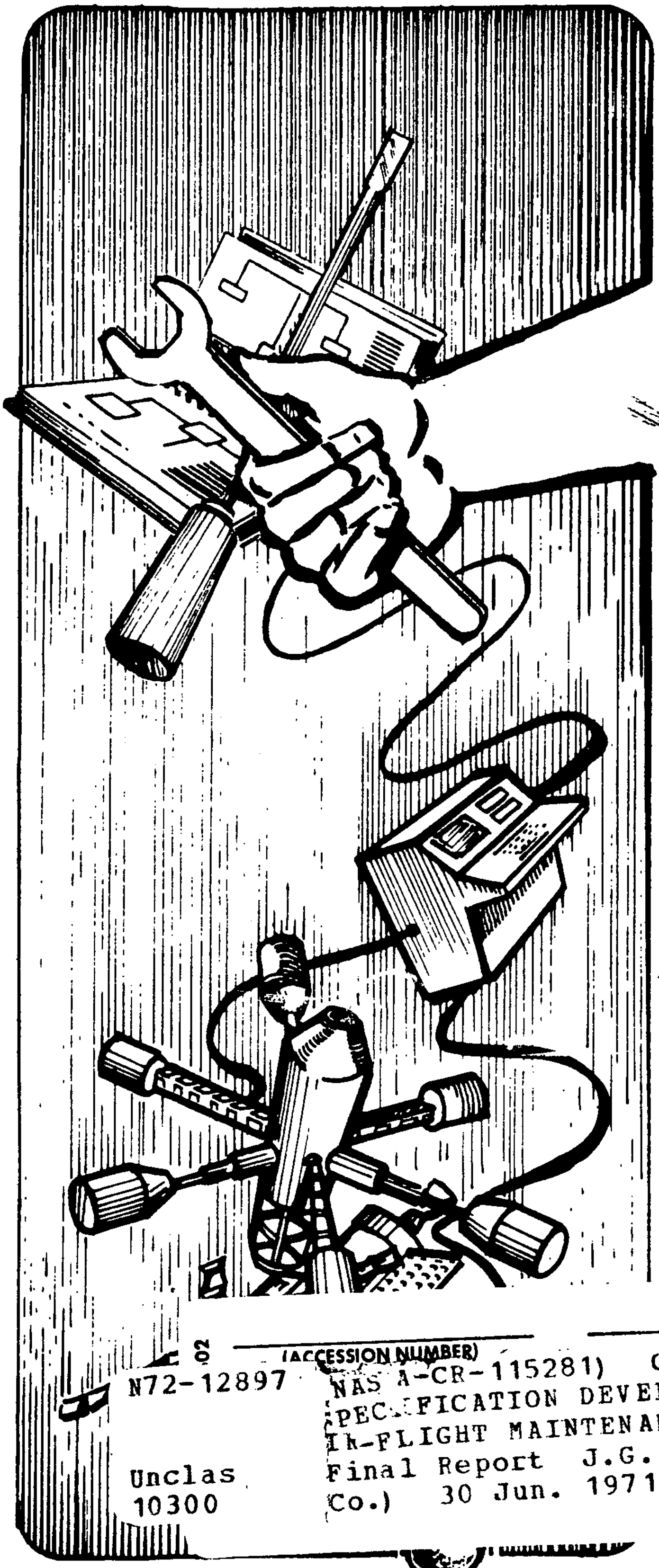

FINAL REPORT

FOR THE

CREW INTERFACE SPECIFICATION DEVELOPMENT STUDY

FOR CR115281

IN-FLIGHT MAINTENANCE AND STOWAGE FUNCTIONS

OPEN

OFFICE OF PRIME RESPONSIBILITY

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PREPARED BY

GENERAL ELECTRIC

APOLLO & GROUND SYSTEMS - HOUSTON PROGRAMS
HOUSTON, TEXAS

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N72-12892

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Appollo & Ground Systems
Houston, TX

Jun 71

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FOR THE
CREW INTERFACE SPECIFICATION DEVELOPMENT STUDY
FOR
IN-FLIGHT MAINTENANCE AND STOWAGE FUNCTIONS

Submitted in Accordance with Data Requirements List
(DRL Line Item #4) of Contract NAS 9-11336

JUNE 30, 1971

PREPARED BY

APOLLO & GROUND SYSTEMS
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ABSTRACT

This study addressed the need and potential solutions for an orderly systems engineering approach to the definition, management and documentation requirements for in-flight maintenance, assembly, servicing and stowage process activities of the flight crews of future spacecraft.

These processes were analyzed and described using a new technique (mass/function flow diagramming), developed during the study, to give visibility to crew functions and supporting requirements, including data products. This technique is usable by NASA for specification baselines and can assist the designer in identifying both upper and lower level requirements associated with these processes. These diagrams provide increased visibility into the relationships between functions and related equipments being utilized and managed and can serve as a common communicating vehicle between the designer, program management and the operational planner.

The information and data product requirements to support the above processes were identified along with optimum formats and contents of these products. The resulting data product concepts are presented to support these in-flight maintenance, (including assembly, servicing and inspection) and stowage processes.

A preliminary location coding system was developed that has multiple applications relative to stowage, procedures, maintenance and operations of future manned spacecraft.

Recommendations for future studies are presented.

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1.0 INTRODUCTION

This report summarizes the findings of the Phase I Crew Interface Specification Study for In-Flight Maintenance and Stowage functions in Future Manned Spaceflights. The study was performed by General Electric Apollo & Ground Systems - Houston Programs under contract with the NASA-Manned Spacecraft Center for the purpose of developing new concepts for specifiable data products that will directly support future manned spaceflight crew training and real-time mission operations in the new and expanded areas of In-Flight Maintenance and Stowage. This study was performed for the Flight Crew Operations Directorate of the NASA Manned Spacecraft Center under contract NAS 9-11336. The Technical Monitor of this study was Mr. E. W. Hoskins, Chief, Team Operations Section of the Flight Crew Integration Division.

The increased duration of future projected manned spaceflights will create significant new demands on crew preparation activities, crew training and real-time mission in-flight crew tasks to service, repair and maintain the space vehicles. These longer missions also will require vastly increased amounts of crew equipments, consumables, experiment equipments and wastes that must be utilized, disposed of, and managed by increased crew complements for these periods of time.

There is much historical and empirical data available on generally related topics of ground preparation and maintenance of aircraft and space vehicles. However, due to the nature of the weightless environment, little directly related experience has been gathered on the conduct of complex maintenance tasks and the related management of crew motions, tools, test equipment and spares in this environment. Since the obvious increased limitations of weight, volume, equipment and data that these missions impose, it becomes extremely important to plan thoroughly for these activities and to develop and utilize advanced concepts, where appropriate, to provide the crew with the best means available for crew operations and spacecraft safety. The present Crew Interface Study seeks to review present state-of-the-art maintenance management policies and supporting data concepts to establish a basis for data development studies and planning for these in-flight maintenance tasks.

Previous manned spaceflights have provided a wealth of empirical data on vehicle preparations and stowage activities. The major guidelines of these activities were to minimize the amount of in-flight stowage management required by flight crews. Even though this type of detailed planning will still be conducted, for vehicle launch as before, nevertheless as the missions become longer and crew complements increase, stowage management becomes increasingly an in-flight task which will require new planning and data products to support these crew activities.

The need for better methods of establishing these new mission requirements and of developing and implementing designs and data packages to support these new and expanded in-flight maintenance and stowage functions is the major purpose of this Phase I study effort.

2.0 STUDY RESULTS

The subsequent sections of this report contain the results of the General Electric - Apollo and Ground Systems/Houston Programs' Phase I Crew Interface Specification Study of In-flight Maintenance and Stowage functions. The study's purpose was to develop concepts for flight crew supporting data for future missions, where new and expanded in-flight maintenance and stowage functions are required.

The study has produced conceptual products, such as the mass/function flow process data, that have already proven to be of value for Skylab Program design, training, and Crew Compartment Stowage Reviews. In addition, study stowage data product concepts are serving as a basis for Skylab In-flight Stowage Configuration documentation. Applications have also been made of study stowage data concepts in the Apollo 15 Lunar Surface EVA Flight Crew training and mission preparation activities.

The concepts, as well as other study results, are described and presented for NASA's use along with recommendations for future related studies.

2.1 RESEARCH AND REVIEW TASK

2.1.1 In-Flight Maintenance

As long-term mission maintenance of manned spacecraft by flight crew personnel constitutes a new dimension in flight planning and preparation activities heretofore not considered, it was necessary to research areas of maintenance that are akin to the in-flight spacecraft functions. The first portion of this phase was dedicated to collecting state-of-the-art DOD and airline aircraft maintenance manuals and related specifications as well as studies evaluating the adequacies of present technical data concepts for training and operations support. A particular effort was made to obtain data pertinent to technical manuals and related specifications for recently developed aircraft such as the DC-10, L-1011, F-14 and C-5A. A significant amount of research material was obtained and is listed in the Bibliography of this final report (Appendix E).

The C-5A data was found to be most pertinent, inasmuch as the aircraft is equipped with an on-board malfunction detection/troubleshooting system. This system (MADARS - Malfunction Detection, Analysis, and Reporting) is the first operational computerized system wherein the flight crew interfaces with a sophisticated on-board maintenance analysis system.

Through the cooperation of the Grumman Aerospace Corporation and the Naval Air Systems Command, a new military specification for preparation of maintenance manuals along with portions of the F-14A Organizational Maintenance Manual (drafted in accordance with the new specification) was obtained. New methods of presenting maintenance data are used in this manual, as well as microform format and coding identification methods. It is the first departure from the old classical DOD maintenance manual in decades. The division of the manuals into work packages has considerable promise for similar application to NASA In-flight Data Support for maintenance tasks in future manned spacecraft.

The design of Data Management Systems (DMS) will not only influence the in-flight maintenance concepts of future manned vehicles, but the form and storage methods of supporting maintenance data as well. A review, therefore, was made of current NASA thinking regarding future data management systems and is discussed in detail in Paragraph 2.8 of this report. In addition, the new Navy system of storage of maintenance information on microfilm (MIARS - Maintenance Information and Retrieval System) was reviewed (56). It became obvious during the review of DMS concepts that the DMS will be a pacing factor in the design, maintenance, and interface data supplied to the crew of future spacecraft.

The Skylab flight crews will be the first to perform a limited number of planned in-flight maintenance tasks on spacecraft systems. It was therefore considered important for a study survey to be made of existing NASA program plans and data for in-flight crew maintenance. An analysis was made of all planned Skylab maintenance tasks, tools to be used, rationale for sparing, maintenance procedures, and other pertinent available data. However, existing operational handbook procedural data to date is considered inadequate, and malfunction/ troubleshooting procedures have not been developed for the Skylab Operations Handbook as of the completion of this Phase I Study. Due to the limited amount of Skylab tasks, maintenance training has only recently been given consideration as part of the training cycle by MSC; hence, in-flight maintenance has not yet been given the emphasis it probably will require for the Skylab Program.

Long-term mission spacecraft will demand an order of magnitude increase in in-flight maintenance considerations over that of Skylab. Numerous North American Rockwell and McDonnell-Douglas reports and presentations were reviewed wherein maintainability criteria and maintenance concepts were investigated for various Space Station designs. The on-board checkout design philosophy was particularly pertinent to this study and was reviewed where data was available.

Maintainability design criteria for shuttle was also reviewed, but it was basically ground maintenance oriented and provided little insight for this study.

The In-flight Maintenance Study performed by the Martin-Marietta Corporation for MSC in 1969 (15) contained a great deal of maintainability design criteria and could be helpful to the designer; but this study, like all other NASA studies reviewed, failed to address how, when and in what format maintenance data will be presented for crew training and on-board crew activities.

A thorough review was made of publications, studies, articles, etc., addressing the adequacy of basic maintenance manuals and what they should provide maintenance personnel. Booz Allen performed a study for the Naval Air Systems Command (60) in which adequacy of technical manuals was assessed. In general, technical manuals were not considered effective, were too costly, were not kept current, and were antiquated in conveying information to maintenance personnel. A complete revamping of the classical manual specifications was recommended. It is in reference to these problems that the present Crew Interface Specification Study is directing efforts to develop new ideas that will be useful in relieving this age old problem. Other studies conducted for the Air Force (PIMO), Navy (SIMS), and Army (HUMRO) all corroborate the need for new technical manual data concepts that can serve as proceduralized job-performance aids rather than as sterile background reference discussions as has been the case with technical manuals in the past.

2.1.2 In-Flight Stowage

In order to intelligently review in-flight stowage requirements, a complete review of the current NASA Apollo stowage process was necessary. The process was reviewed and described on a time-phased process flow chart (Appendix A, Figure 8).

This permitted the study team, as well as others, to have excellent visibility into the NASA stowage preparation and configuration management process. A detailed examination was made of Apollo field site stowage drawings now being used, Apollo and Skylab Stowage Lists and formats, Flight Data File stowage maps and the stowage related configuration management process of the Apollo Program. The result of this review and analysis of stowage requirements provided the visibility and background knowledge necessary to design the formats and define the requirements for the contents of the Skylab In-flight Stowage Configuration Document discussed in Paragraph 2.6.1. In addition, a detailed review was made of the Skylab food process in order to obtain actual planned program data for examination of new stowage data concepts. The results of this investigation is discussed in Paragraph 2.6.3 and indicates a need for an efficient method of consumables and loose equipment tracking, and this study addresses itself to that need with potential solutions.

2.2 DOD MAINTAINABILITY PROCESS REVIEW AND DESCRIPTION

From Apollo and previous manned spaceflight experience, it has become apparent that better methods and techniques for accurately defining crew interface requirements are needed. As a result, the research and review task of the present study was directed toward examining the latest state-of-the-art methods of defining maintenance requirements in the related military and commercial aircraft development programs. This led to the examination of the latest DOD methods of integrated maintenance management for complex weapon systems. DOD specifications and Standards of Maintainability were reviewed including MIL-M-26512, MIL-STD-470 and 471, MIL HDBK 472, the Navy WR-30 (Integrated Maintenance Management Program) and the AFSC Maintainability Design Handbook (DH 1-9).

In addition, a maintainability principles and practices text (88) was reviewed as well as the GE Integrated Logistics Support Management Study (78). From these reviews, it was observed that classically maintenance denotes an action to restore to or retain in operation a system or component while maintainability is a characteristic of design and installation that is related to the ease and economy of maintenance, maintenance task performance accuracy, availability of equipment and safety.

The present Crew Interface Specification Study is concerned mainly with in-flight maintenance and related supporting data concepts. However, due to the NASA policy of utilizing previous spacecraft and mission operations experience of the flight crews to assure compatibility of new designs and mission requirements, the need to relate in-flight maintenance crew functions to the overall maintainability process is emphasized. Therefore, the review of the DOD systems engineering approach to maintainability, used to develop complex hardware systems, was considered appropriate for large manned spacecraft programs as well. At present, no comparable focal point exists within the Manned Spacecraft Program to the DOD Integrated Maintenance Management Team concept. NASA maintainability presently is treated within the requirements for subsystems design and is not treated as an integrated discipline. However, requirements for maintainability still exist and must be efficiently addressed.

To obtain information concerning maintainability requirements, the DOD Maintainability Program was reviewed. Basically, this approach consists of six major program elements:

1. Maintainability Program Plan
2. Maintenance Concept
3. Maintainability Analysis
4. Maintenance Analysis
5. Support Requirements Definition
6. Maintainability Demonstration

For visibility, the complete process was described on a large flow chart and submitted with the mid-term report of this study. It provides an excellent overview of the elements, interfaces and the system development cycle related to the process of maintainability design in hardware procurement.

In addition, the Navy Department's Integrated Maintenance Management System (WR-30) was reviewed (57). This system is a detailed implementation plan for the DOD Maintainability Program noted above. Specifically, this system provides for:

1. The establishment of management controls and procedures by the Government and contractor to assure the achievement of maintainability and support planning.
2. The establishment of a maintainability program employing analytical techniques to identify factual maintenance requirements for progressive comparison with the imposed or predicted maintainability parameters in terms of maintenance man-hour per flight hour or operating hour.
3. The application of maintainability design and related procedures through which the established maintainability parameters can be realized.
4. A technique which will assure that quantitative requirements and qualitative maintainability characteristics are established during the analysis phase and incorporated into design.
5. An evaluation plan to test, evaluate, and demonstrate the degree to which maintainability requirements have been achieved, including the verification of the maintenance resources.
6. The preparation of Maintenance Engineering Analysis Records (MEAR's) which document maintenance concepts, requirements, and tasks; identify necessary maintenance resources; determine and report maintenance personnel and training requirements; provide the basis of content of appropriate technical manuals, determination of support equipment requirements, provisioning material support; and provide the basis for support requirements progress and status reporting.
7. The design, approval, selection, and ordering of end item of support equipment and related technical data required.
8. The selection and furnishing of spares and repair parts, including associated documentation, to be procured under the contract.
9. The development, updating, and submission of management progress reports, technical data, and summary reports.
10. The early establishment of an Integrated Maintenance Management Team, of which the contractor is a member, the function of which is to insure the accomplishment of the total logistic support program.

The various MEAR's forms were reviewed and summarized in Figure 1. These forms give detailed guidelines as to the analyses and documentation required to identify and justify the planned maintenance concept proposed by prime contractors. Maintenance predictions, support equipments, technical data requirements, etc., are also included in this documentation. In general, this data supports

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In addition, the Navy Department's Integrated Maintenance Management System (WR-30) was reviewed (57). This system is a detailed implementation plan for the DOD Maintainability Program noted above. Specifically, this system provides for:

1. The establishment of management controls and procedures by the Government and contractor to assure the achievement of maintainability and support planning.
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3. The application of maintainability design and related procedures through which the established maintainability parameters can be realized.
4. A technique which will assure that quantitative requirements and qualitative maintainability characteristics are established during the analysis phase and incorporated into design.
5. An evaluation plan to test, evaluate, and demonstrate the degree to which maintainability requirements have been achieved, including the verification of the maintenance resources.
6. The preparation of Maintenance Engineering Analysis Records (MEAR's) which document maintenance concepts, requirements, and tasks; identify necessary maintenance resources; determine and report maintenance personnel and training requirements; provide the basis of content of appropriate technical manuals, determination of support equipment requirements, provisioning material support; and provide the basis for support requirements progress and status reporting.
7. The design, approval, selection, and ordering of end item of support equipment and related technical data required.
8. The selection and furnishing of spares and repair parts, including associated documentation, to be procured under the contract.
9. The development, updating, and submission of management progress reports, technical data, and summary reports.
10. The early establishment of an Integrated Maintenance Management Team, of which the contractor is a member, the function of which is to insure the accomplishment of the total logistic support program.

The various MEAR's forms were reviewed and summarized in Figure 1. These forms give detailed guidelines as to the analyses and documentation required to identify and justify the planned maintenance concept proposed by prime contractors. Maintenance predictions, support equipments, technical data requirements, etc., are also included in this documentation. In general, this data supports

FIGURE 1

MAINTENANCE ENGINEERING ANALYSIS RECORDS (M.E.A.R.S.)

FOR

- AERONAUTICAL WEAPONS
- WEAPON SYSTEMS
- RELATED EQUIPMENT

WR-30

E = END ARTICLE
S = SYSTEM
A = ASSEMBLY

E

I. END ARTICLE SUMMARY

NOMENCLATURE
DESIGNATION/PART NO
MEAR CONTROL NO
CONTRACTOR
MODEL

PROVIDES SUMMARY INFORMATION OF END ARTICLE

SIGN OFF ON CONCEPT, DESIGN, REQUIREMENTS, TASKS, RESOURCES, FACILITY

GIVES % AVAILABILITY, REWORK - OVERHAUL INTERVAL, DESIGNATED REWORK ACTIVITY, INSPECTION INTERVAL, DAILY MAINTENANCE TIME, OUT-OF-COMMISSION RATE AND MAINTENANCE MAN MINUTES/FLIGHT HOUR.

RECORDS MEAR CHANGES WITH GOVERNMENT APPROVAL AND DATES ALONG WITH SUBORDINATE SYSTEM MEARS AND THEIR PARAMETERS

- FORCED REMOVAL INFORMATION IS GIVEN FOR THE MORE DIFFICULT ITEMS TO MAINTAIN.

S

IA. SYSTEM MEAR SUMMARY

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO
CONTRACTOR
MODEL

- SUMMARY OF SYSTEM MAINTENANCE FACTORS
  - SIGN OFF ON RELIABILITY SPECIFICATIONS BY NUMBER, CONCEPT, DESIGN FEATURES, REQUIREMENTS AND TASKS, IDENTIFIED RESOURCES.
- LISTS CLASS I DESIGN CHANGES
- GIVES SYSTEM MEAR CHANGE RECORD AND GOVERNMENT APPROVAL
- INDICATES CFE VS. GFE
- ESTIMATES UNIT COST
- RECOMMENDS MAINTENANCE FACTOR
- SEQUENTIALLLY GIVES ALLOWANCE SPARES ALLOCATION LIST

A

IB ASSEMBLY MEAR SUMMARY

NOMENCLATURE
DESIGNATION/PART NO
MEAR CONTROL NO.
CONTRACTOR
MODEL

- SUMMARY AT ASSEMBLY LEVEL FOR PROCUREMENT ACTIONS
  - SIGN OFF ON RELIABILITY SPECIFICATION BY NUMBER, CONCEPT, MAINTENANCE REQUIREMENTS, DESIGN FEATURES, TASKS AND RESOURCES
  - P/N OF NEXT HIGHER ASSEMBLY; APPLICABLE PROCESS SPECIFICATION; DESIGN SPECIFICATION; EXTENT OF MAINTENANCE; LEVEL OF TRAINING REQUIRED
  - MEAR CHANGE NUMBER, REASON, DATE, GOVERNMENT APPROVAL
- MAINTENANCE AND OVERHAUL FACTOR FOR SPARES, REPAIR PARTS AND ASSOCIATED EQUIPMENT
  - ALLOWED OFF-TIME
  - ESTIMATED TURN-AROUND TIME
  - REWORK REMOVAL RATE
- STATUS OF SUPPORT DOCUMENTATION

E,S,A

II. MAINTENANCE CONCEPT

NOMENCLATURE
DESIGNATION/PART NO
MEAR CONTROL NO.
CONTRACTOR
MODEL

- GIVES MAINTENANCE CONCEPT WITH FUNCTION
  - COMPLETED AFTER ANALYSIS OF FAILURE MODES OF SUB-UNITS
  - SYSTEM FUNCTION DEFINITION
- MAINTENANCE CONCEPTS:
  - NATURE AND FREQUENCY OF SCHEDULED AND UNSCHEDULED MAINTENANCE REQUIREMENTS
  - CAPABILITY OF PERSONNEL TO PERFORM TASKS AND COST OF CONSTRAINTS
  - REASON FOR MAINTENANCE CONCEPT

E,S

III MAINTENANCE TIME DISTRIBUTION CHART

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

GRAPHICAL MANAGEMENT TOOL FOR VERIFYING MAINTENANCE:

CHART SHOWS DAILY, PERIODIC INSPECTION AND PREVENTATIVE MAINTENANCE DURING LOOK PHASE.

CHART SHOWS REMOVAL AND REPLACEMENT SCHEDULED AND UNSCHEDULED TIME FOR PHASE AFTER FAULT ISOLATION.

TOTAL MAINTENANCE MAN MINUTES/FLIGHT HOUR

E,S,A

IV. MAINTAINABILITY EVALUATION

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO
CONTRACTOR
MODEL

- CHECK-OFF LIST OF CONSIDERATIONS VERSUS MANNER OF ACCOMPLISHMENT EACH BLOCK IS CHECKED IF CONSIDERATION USED.
- MAINTAINABILITY PREDICTION AND RELIABILITY PREDICTION FIGURES ARE LISTED AS OUTLINED IN INTEGRATED MAINTENANCE MANAGEMENT PLAN.

S,A

V. RELIABILITY AND DESIGN DATA

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

OVERALL CONFIDENCE IN DESIGN REQUIREMENTS IS SHOWN BY LISTING:

PROBABLE MODES OF FAILURE
FAIL-SAFE CHARACTERISTICS
REDUNDANT CIRCUITS
SAME PARTS IN SIMILAR INSTALLATIONS
TOTAL DESIGN LIFE, TIME BETWEEN OVERHAUL, MEAN TIME BETWEEN FAILURE
PROBABLE RESULTS OF FAILURE
CURRENT FAILURE HISTORY

E,S,A

VI. MAINTENANCE REQUIREMENTS

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

MAINTENANCE REQUIREMENTS ARE GIVEN ALONG WITH TECHNICAL JUSTIFICATIONS, MAINTENANCE TYPE CODE, INTERVAL, MAINTENANCE LEVEL AND REFERENCE DOCUMENTS.

E,S,A

VII MAINTENANCE TASKS

NOMENCLATURE
DESIGNATION/PART NO
MEAR CONTROL NO.
CONTRACTOR
MODEL

TASK NUMBERS ARE LISTED RELATED TO REQUIREMENT NUMBERS. TASKS ARE SPECIFIED WITH WORK AREA AND TASK TIME

A

VIII. PERSONNEL PLANNING DATA

NOMENCLATURE
DESIGNATION/PART NO
MEAR CONTROL NO.
CONTRACTOR
MODEL

EACH REQUIREMENT CORRESPONDS TO MAINTENANCE LEVEL, MAINTENANCE CODE, SERVICE RATING AND PERSONNEL BY SKILL LEVEL. A BREAKDOWN OF MAN MINUTES SHOWS TIME FOR EACH SKILL AND TOTAL TIME WITH FREQUENCY AND MAINTENANCE MAN MINUTE/FLIGHT HOUR.

E,S

VIIIA. PERSONNEL PLANNING DATA SUMMARY

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

SCHEDULED AND UNSCHEDULED MAINTENANCE MAN MINUTES/FLIGHT HOUR IS GIVEN WITH MAINTENANCE LEVEL AND NAVY RATING. TOTAL TIMES ARE BROKEN OUT.

E,S,A

IX. TECHNICAL SUPPORT DATA SUMMARY

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

REQUIREMENT NUMBER IS LISTED VERSUS DRAWINGS, REPLACEMENT SCHEDULE AND OTHER RELATED TECHNICAL DATA THAT THE CONTRACTOR RECOMMENDS AS NECESSARY.

E,S,A

X. SUPPORT EQUIPMENT

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

SPECIAL TOOLS AND SUPPORT EQUIPMENT ARE CALLED-OUT AS NEEDED TO PERFORM THE MAINTENANCE REQUIREMENTS. THE MEAR CONTROL NUMBER IS GIVEN FOR EACH SUPPORT ITEM

E

XI. SUPPORT EQUIPMENT REQUIREMENTS SHEET

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

THIS EXHIBIT PROVIDES TECHNICAL AND PROCUREMENT DATA REQUIRED FOR THE ACQUISITION OF SUPPORT EQUIPMENT. MORE DETAIL IS PUT ON THIS MEAR FOR SUPPORT TASK, ACTION VERB, PARAMETER MEASURED AND TYPE OF OUTPUTS. QUANTITIES, ESTIMATED PRICES, RESEARCH AND DEVELOPMENT REQUIRED, AND SKETCH REFERENCES, STATUS THE SUPPORT EQUIPMENT.

E,S,A

XII MATERIAL LIST

NOMENCLATURE
DESIGNATION
MEAR CONTROL NO.
CONTRACTOR
MODEL

MATERIAL INFORMATION IS AS FOLLOWS:

ITEM NAME, PART NUMBER, SUBORDINATE MEAR RECORD, STOCK NUMBER, ITEM AND LOT NUMBER, MANUFACTURER'S PART NUMBER, SPARES ALLOCATIONS, UNIT PRICE, QUANTITY PER END ITEM, AND SHELF LIFE.

E,S,A

XIII. ADDENDUM SHEET

NOMENCLATURE
DESIGNATION/PART NO.
MEAR CONTROL NO.
CONTRACTOR
MODEL

THIS ADDENDUM SHEET MAY BE UTILIZED WHEN ADDITIONAL SPACE IS REQUIRED TO PROVIDE INFORMATION THE CONTRACTOR BELIEVES TO BE PERTINENT.

the maintainability activities but is not usable directly for operations supporting technical data requirements. Classical technical manual data is still used to support the training and operations for maintenance. No new concepts for technical data are specified by WR-30.

2.3 DEVELOPMENT OF THE MASS/FUNCTION FLOW PROCESS DESCRIPTION METHOD

As noted earlier in this report, one of the major problems in developmental programs is the difficulty in early identification of crew interface requirements and the related loose equipment provisioning. In experimental and flight test type programs, many changes are anticipated. However, in reviewing Apollo Program experience it appears that a significant portion of the experiments and loose equipment changes stemmed from a lack of understanding of interfaces and in "system lag" associated with sluggish implementation of changes due to ambiguous directions.

Historically, the development of the systems engineering discipline stemmed from the need for better and more orderly definition of mission requirements and related systems and hardware performance requirements and interfaces to satisfy both requirements. This discipline has been used in designing hardware, but relatively little application of the technique has occurred in the "operations" areas.

The need for defining new requirements in the in-flight maintenance, assembly, servicing and stowage areas, centers in not only defining functions that must be accomplished by the crew, but in designating related loose equipment, tools, test equipment, and spares to be used and where these items are located within the spacecraft. The enormity of the details that must be planned and designed for, as well as managed by the flight crew, suggests that new data techniques giving quick overall visibility to these requirements are essential.

As part of the GE Phase I study activity, developmental work was conducted on applying systems engineering type flow-diagramming techniques to the description of these operational requirements related to maintenance and stowage. By equating man or equipment requirements and locations to mission requirements, systems engineering flow designing techniques become applicable. Therefore, by the usage of function boxes to describe crew functions, decisions and stowage locations, and flow lines to track equipment movement in a sequential order throughout the spacecraft, a new graphic technique for "crew operations" process description was developed.

In the Phase II study, specification data should be developed that will provide descriptions of this analytical technique and detailed examples that will serve as preparation guidelines to contractors of this type of supporting data for in-flight maintenance and stowage functions. In addition, program related milestones should be prepared to illustrate a timely manner in which these diagrams may support the design, training, and real-time mission support data functions of a complex manned spacecraft program.

2.4 NASA CREW INTERFACE PROCESS DESCRIPTIONS

The mass/function flow technique provides the analytical tool that can be used by spacecraft system designers in program development Phase A, B, and C studies to define crew interface requirements in a manner that assists in providing detailed definitions of loose equipment and spares, stowage requirements, equipment movements, etc. As part of the Phase I study effort, process diagrams were prepared to demonstrate the techniques and to analyze, describe and identify requirements associated with the future mission crew processes for in-flight maintenance, assembly, servicing and stowage functions. Appendix A (Figures 1-4) contains these mass/function flow diagrams. This data served as a basis for further study of the associated technical data requirements for these crew interface functions. In addition, data was available from the Skylab Program that enabled an in-depth study to be conducted of the on-board food preparation and food management process requirements. Appendix A (Figures 5-6) contains the resulting food process diagrams. These data were utilized by astronaut and MSC Skylab Program personnel during Skylab crew station reviews conducted at Huntsville, Alabama, in April 1971.

The orderly description and overall visibility to crew station stowage and food preparation provided by these process diagrams were considered extremely helpful in reviewing the adequacy of the Skylab spacecraft design from a "crew operations" orientation. Such practical examples of the program utilization of this preliminary process data demonstrates the value of this GE-developed application of the systems engineering approach for configuration management and crew interface planning and preparations.

2.5 NASA CREW INTERFACE MANAGEMENT PROCESS DESCRIPTIONS

The GE mass/function flow technique was also applied to the analysis and description of those presently utilized NASA interface management processes thru which Apollo crew procedures are developed and stowage preparations are coordinated to support mission functions. These are shown in Appendix A, Figures 7 and 8 respectively. The purpose of this activity was to acquaint study team members with those requirements such that where possible, newly developed processes for future programs would be in consonance with these NASA management practices. Particularly, these diagrams provide visibility as to program related time phasings wherein various data products are required to support program and crew interface support activities.

2.6 IN-FLIGHT STOWAGE PROCESS AND DATA PRODUCT STUDY

The purpose of the stowage process/data product Phase I study task was to identify future crew interface in-flight stowage functions through review of future spacecraft and mission requirements and subsequent description of the supporting crew interface processes. Analysis of the related technical information requirements to support these crew stowage processes provided the basis for the subsequent stowage data product concept studies. The study included:

1. Development of a generic in-flight stowage process definition using the mass/function flow technique (Appendix A, Figure 4).
2. Verification of this process description through reviews of Skylab and Space Station design and mission data.
3. Identification of the basic implications of the in-flight stowage process for crew interface functions and supporting data requirements.

From review of mission data, spacecraft designs and stowage provision concepts, the following general inferences concerning stowage requirements and related data concepts are appropriate:

1. Figure 2* is a comparative chart of spacecraft stowage characteristics for U.S. Manned Spacecraft. This chart focuses attention on the increased magnitude of the stowage inventory problem that occurs as a function of increased crew size, larger spacecraft free volume and longer missions. It is readily apparent from this data that a closer tracking of loose equipments, consumables and their location will be required of the flight crew in future missions as compared to similar functions in the Apollo, Mercury and Gemini Programs. Short mission turn-arounds make it imperative to inform configuration management and procurement organizations of the needs resulting from unpredictable usage or equipment failures that create unplanned stowage requirements.
2. Support data and procedures for in-flight stowage management must assist the flight crew by minimizing the clerical burden associated with stowage tracking for logistics as well as for mass properties control. Usage of on-board data management systems may assist in this type of bookkeeping control, but the basic supporting data must still be generated by supporting personnel, and it should be in a form useful for training, yet still suitable for usage as in-flight job-performance aids.

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*From "Crew Functions in Manned Spaceflight," J. P. Loftus, MSC Paper presently in preparation for publication (1971).

FIGURE 2
SPACECRAFT STOWAGE CHARACTERISTICS

Spacecraft Class of Equipment	Mercury	Gemini	Apollo			Skylab 2/			
			Command Module	Lunar Module		Command Module 3/	Orbital Assembly Module		
				Ascent Stage	Descent Stage		Multiple Docking Adapter	Airlock Module	Orbital Workshop
Food & Hygiene 1/	10	46	200	40	-	45	-	-	743
Equipment	16	7	12	4	33	22	192	6	330
Television & Photographic	7	52	40	18	7	35	-	-	254
Extravehicular Activity	-	21	30	62	5	35	1	2	14
Operational	15	70	230	89	8	285	44	417	455
Total number of Items	48	196	512	213	53	422	237	425	1796
Number of Stowage Compartments	-	13	32	22	8	32	14	8	186
Nominal Mission Duration - Days	1/3-1 1/2	3-14	8-14	1-3		5	140		
Number of Crewmen	1	2	3	2		3	3		

1/ One unit of food is 3 meals for one man.

2/ Planned

3/ For each of three spacecraft

NOTE : All numbers are typical and vary for specific missions.

3. Improved inventory-keeping methods should be devised that eliminate the need of the crew being overburdened with a mass of clerical details. The tracking method should be effective in identifying stowage quantities and locations, yet requires a minimum of crew time to record. Some method of attaching identification data cards as tags to stowed items is required. This data could then be read into on-board data management equipment, if available, and tracked for instantaneous stowage management. These in-flight inventory methods also relate to the reporting of logistics requirements that can initiate procurements, define supplies needed, request data packages and otherwise help to insure effective use of crew time while in orbit.

2.6.1 Skylab In-Flight Stowage Configuration Documentation

As a result of experience gained in these in-flight stowage process investigations and since no adequate in-flight stowage documentation had been developed for Skylab, GE was requested by the Technical Monitor to conduct an in-depth study of Skylab in-flight stowage data product requirements.

At the time of this request, meetings were being conducted with contractor, MSFC and MSC Skylab Program personnel to determine the requirements for an In-flight Stowage Configuration Document. GE personnel participated in these meetings, and the resulting preliminary recommendations for this document were examined with respect to the adequacy of these concepts. A preliminary GE investigation revealed that these preliminary NASA-suggested data formats and contents would require a document size of from 1,000 to 1,500 pages. A document of this size would have questionable value for in-flight operations. As a result, study effort was directed to the development of a data concept that would significantly reduce the document size and be suitable for "practical" uses by the flight crew of this data.

The results of this GE study resulted in recommended formats and content definitions for this Skylab In-flight Stowage Configuration Document that are shown in Appendix B. Data in this configuration would result in a complete document of only 350 to 500 pages and would provide Room Stowage Maps that could be used by flight crew for efficient inventory assessment and stowage management at critical stages of the Skylab missions. The total GE recommended document data includes:

1. Suggested Book Configuration
2. Alphabetical Stowage Item/Location Data
3. Transfer List
4. Locker Launch Configuration Graphics
5. Locker Address Stowage History
6. Room Stowage Map

Appendix B also includes content illustrations for these formats. These in-flight stowage data concepts have been developed to satisfy particular crew in-flight stowage management problems. As a result, these data concepts are presently being considered for implementation on the Skylab Program. These recommended In-flight Stowage Configuration Document formats are designed for the particularly unique requirements of the Skylab Program at its present stage of development. Prior to the development of a NASA Stowage Management specification, additional study should be directed toward examining the possibility of integration of Field-Site Stowage Drawing requirements with the In-flight Stowage document for better utilization of stowage graphics.

2.6.2 Future Stowage Process Requirements

Using the mass/function flow technique, a generic in-flight stowage process was defined in which crew and experiments loose equipment and consumables were utilized and managed. This process, shown in Appendix A (Figure 4), considers the dynamics of in-flight resupply; bulk stowage changes; operational aspects of consumption of food, water, spares, personal hygiene equipment and medical supplies; type of disposal; logistics support; inventory requirements; and data management interfaces. As in the other mass/function flow diagrams, this in-flight stowage process diagram provides rapid visibility to the designer, operator and program manager allowing them to analyze design, operational and program requirements for compatibility and reasonableness during the early phases of the development cycle. Such a stowage process definition should be a requirement for all future manned spacecraft, and it should be submitted by the prime contractor at the Preliminary Design Review, formalized at the Critical Design Review, and updated when functions involving major stowage changes are implemented.

2.6.3 Detailed Food Process Study

One aspect of the Skylab in-flight stowage process was investigated to evaluate the usefulness of the mass/function flow diagramming technique for in-depth analysis of crew housekeeping and stowage functions. The function selected was that of the Skylab in-flight food management process. This process was analyzed, and a mass/function flow diagram was prepared. This diagram is included as the Skylab Food Process Chart (Figure 5 of Appendix A). This data is an overview of the food stowage, consumption and disposal functions necessary to be performed by the flight crew.

The major portion of the Skylab food supply will be loaded and launched on Skylab 1. This includes food stowable at ambient temperatures and frozen foods contained in frozen food lockers. These lockers will be stowed and activated for cooling 30 days prior to launch. Food will also be loaded aboard the Command Modules which will be used by the crew during rendezvous and reentries. Additional food will be carried by the CM's for transfer to the Orbital Workshop. This food is of the ambient stowage type only.

Food packages will be transferred from forward stowage compartments and from the CM to the pantry area for subsequent usage. Package materials will then be temporarily stowed in biologically clean stowage lockers. As individual food cans and waste materials collect, they are placed in overcans that are stowed in the waste overcan lockers for subsequent transfer to the waste tank. This temporary stowage of wastes is necessary due to the limited cycling of the trash airlock in transferring wastes to the permanent stowage in the waste tank.

The Food Preparation Chart (Appendix A, Figure 6) is a mass/function flow diagram which presents an identification and ordered flow of all types of food and menus planned for the Skylab Program. Larger overcans contain cans of several sizes, each labeled for individual crew members. Can lids are removed and discarded to the waste overcan area. Thereafter, diaphragms are slit as required, and water, hot or cold, can be added and the food cans can be heated or chilled for consumption. Prior to eating, a dye pill is swallowed to color the feces as a means of obtaining nutritional data. This food preparation process chart can serve in its present format as a basic training device for in-flight food preparation.

Both of these food process mass/function flow diagrams demonstrate that this technique is appropriate for analysis and documentation of detailed aspects of crew housekeeping and stowage function. They have been used by Skylab Program personnel in the Crew Station Reviews held at MSFC in Huntsville, Alabama, in April 1971. These data proved useful for design review activities and are felt to be extremely valuable devices for training of flight crews in these processes.

2.7 OPERATIONAL LOCATION CODING SYSTEM STUDY AND DEVELOPMENT

Both the in-flight maintenance and the in-flight stowage process studies revealed an urgent need for a standard, specifiable location coding system for future manned spacecraft. Particularly, the Skylab stowage investigation exposed the inadequacies of its location coding system for stowage, in-flight maintenance and operations applications. In order to identify and satisfy location coding system requirements, the Technical Monitor requested that GE initiate a location coding system study as part of the Phase I effort.

This study utilized the following guidelines:

1. The system should be designed to provide a standard method of location coding of crew interface items such as panels, lockers, system components and stowage areas.
2. The location code alone should provide data on where an item can be found, within acceptable accuracy, within an identified module or room.

3. The system must have generic applications for major spacecraft configurations under consideration.
4. The system should be brief, simply understood and useful for location identification on schematic data; stowage list location data; In-flight crew procedures data; Test and Checkout procedures data; and have application to manufacturing and ground preparations.

A preliminary location coding system was developed as a result of this study effort and is recommended for consideration in the design of future manned spacecraft. This location coding system and basic supporting rationale is discussed in the detailed presentation sheets of Appendix C of this final report.

2.8 ON-BOARD DATA MANAGEMENT SYSTEM STUDY

The Data Management System (DMS), in conjunction with the Display and Control System (D&C), of a space vehicle is the crew to vehicle interface for all operations on-board the spacecraft. Current concepts and prototype hardware for these systems were examined during Phase I of this study. Capabilities and limitations of these systems in presenting data to and in accepting commands from the crew were identified.

Of particular concern was in-flight maintenance and stowage activities. A further result of the study was the identification of some functional requirements that these activities impose on the DMS and D&C Systems.

2.8.1 In-Flight Maintenance

The In-flight Maintenance Process Chart (Appendix A, Figure 1) shows the process by which the spacecraft is maintained in an operational condition. The Data Management System must store the technical information shown under "maintenance support resources" and must provide for crew access to pertinent portions of this data through the Display and Control System, either automatically or upon crew interrogation.

2.8.1.1 Automatic Displays

The actual format and content of automatically displayed data and related hardware design has not as yet been specified for future space programs. Significant additional developmental work remains to be completed and will be a function of the developed hardware and software capabilities. The displayed data forms will be dependent upon hardware design and upon requirements for automatic fault detection, isolation, malfunction status display and correction through automatic switching to redundant systems and alternate modes of operation. In addition, when a malfunctioning or defective In-flight Replaceable Unit is identified, the associated crew displays will also be provided in standard acceptable formats. The extent to which the above displays will be automated by the DMS is yet to be determined. Automatic display of the need for scheduled servicing and maintenance activities by the crew and related procedures may also be required and can influence the forms of displayed data.

Historical data is presently available on hardware and software implementation of automatic data displays analogous to those required for future spacecraft. These have been developed for industrial process control, Apollo Spacecraft Acceptance Checkout Equipment, and are currently being utilized in DMS prototypes being built by the MSC Information Systems Division. However, the major difficulties exist in defining subsystems and experiments requirements and the DMS interfaces. An early and continuing integration effort is required to assure compatibility between crew interface operations and maintenance requirements, the DMS, and spacecraft and experiments subsystem functions. Early definition of crew in-flight maintenance supporting data requirements is essential for specifying the format parameters and contents which must be presented by the DMS.

2.8.1.2 Interrogable Displays

Technical information must be available for crew interrogation when insufficient automatic fault isolation and correction techniques are available or when manual procedures are required. Crew interface data must support manual fault isolation procedures with functional system data, accurate logic tree and sequential crew procedures and with data on the physical location of systems equipments, tools and spares.

The problem of integrating this type of crew interface data with the DMS is not as critical as for the system-interactive type of automatic displays previously discussed. Namely, the data format and content can remain similar to hard copy technical support data, but a system for coding this data for automatic handling and retrieval by the DMS must be developed. The Navy F-14 Technical Manual Specification has addressed a similar problem.

2.8.2 In-Flight Stowage Management

The Data Management System can serve as a major inventory management tool to assist the flight crew in stowage and logistics activities. Ideally, it would be desirable to have the Data Management System perform all inventory and mass properties management activities with the flight crew required only to input data as to consumption and changes in location of equipments. However, near term programs will probably require that the crew or ground control perform a major portion of these tracking activities. Review of any computerized data management concepts for stowage configuration tracking should be considered in the development of specifications for stowage management data products.

2.8.3 NASA/MSC Data Management Systems Hardware Concept Review

Figure 3 contains a summary of "Data Management Hardware Concepts" reviewed during the Phase I study effort. The operational procedures and related data formats associated with these hardware concepts are also included in Figure 4. These charts provide a general indication of the types of crew interfaces anticipated with the Data Management Systems now under consideration. Continuing surveys of these design efforts should be maintained and considerations of their implications for crew interface data formats and content should be included in the specifications for these crew interface data products.

2.8.4 Navy Technical Manual Microform Coding System

As part of the Phase I study effort, a review was conducted of recent Navy specifications for technical aircraft maintenance manual data that includes detailed instructions for coding of all this data for microform retrieval packages. Figure 5 contains a brief summary of the Navy Technical Manual Specification Microform Coding System. Each frame of technical data is coded in accordance with this system for usage in organizational, intermediate and depot level maintenance manuals for future naval aircraft.

A system, similar to that discussed above, for interrogable on-board crew interface data will be required for future space program Data Management System retrieval. Namely, all on-board interrogable crew interface data should be coded as an integral part of the format of that data for microform reproduction and retrieval by the Data Management System. A specification of the coding system to be used should be included as part of any specification for future program crew interface data.

2.8.5 Computer Assisted Flight Planning

The Phase I study also included a review of possible impacts of the Computer Assisted Flight Planning System on crew interface data and DMS requirements. To date, thru the Skylab Program, no active consideration has been given to in-flight crew interactions with this computer assisted ground system for flight planning. However, since such a flight planning system will generate crew procedures to accomplish automatically planned flight activities, it is necessary that there should be reasonable compatibility between the content and formats of in-flight crew operations and maintenance data, and that data which is generated and edited by the Computer Assisted Flight Planning System. Periodic surveillance of the outputs of this computerized system should be made to determine

FOLDOUT FRAME 1

FOLDOUT FRAME 2

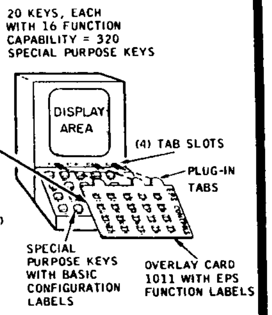
FIGURE 3

DATA MANAGEMENT SYSTEM HARDWARE CONCEPTS

CONTROLS

FIXED FUNCTION CONTROLS
- ALPHA-NUMERIC KEYBOARD (AN)
- SPECIAL PURPOSE KEYS (SK)

RECONFIGURABLE FUNCTION CONTROLS
- OVERLAYS WITH PLUG-IN TABS FOR REPROGRAMMING OF COMPUTER INTERPRETATION OF SPECIAL PURPOSE KEYS
- COMPUTER DRIVEN CHANGES (IN FUNCTIONS AND LABELS OF SPECIAL PURPOSE KEYS)
  - + RECONFIGURABLE CONTROL PANEL (RCP) (SEE BELOW)
  - + RECONFIGURABLE KEYS SIMILAR TO RCP EXCEPT THAT (UP TO 24) DIFFERENT LABELS APPEAR DIRECTLY ON EACH KEY.
  - + LIGHT PEN OR OTHER PROBE ACTIVATES "KEY" AREAS ON CRT OR PLASMA OPPOSITE COMPUTER DRIVEN LABELS DISPLAYED ON SCREEN.



COMPUTER

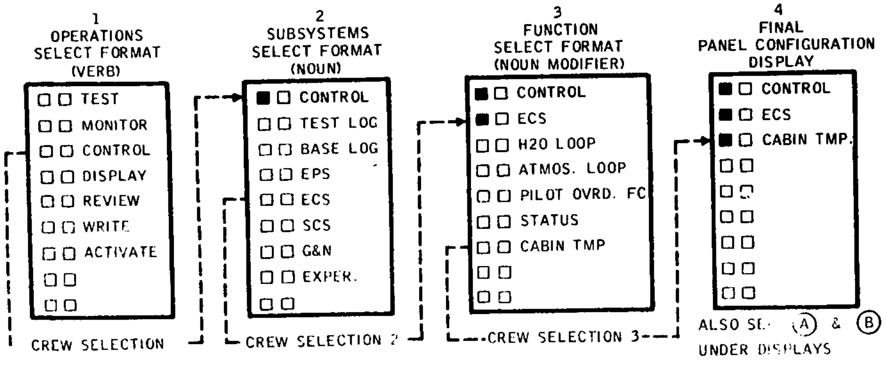
STORED PROCEDURES	STORED DATA
• MAINTENANCE • ASSEMBLY • SERVICING • STOWAGE • OPERATIONS	• EXPENDABLES • SPARES • SYSTEMS • EXPERIMENT • FAILURE HISTORY • SCHEMATICS • LAYOUTS • BIOMEDICAL • BASE LOG • TEST LOG • FLIGHT PLANS • CONTINGENCY PLANS • STATUS • LIBRARY • OPERATIONS
STORED PROGRAMS	
• TESTS • FAULT DETECTION • FAULT ISOLATION • MONITORS • OPERATIONS • TEST LANGUAGE • TEST LOGS	

RECONFIGURABLE CONTROL PANEL (RCP)

☐ ON ☐ OFF RECONFIGURABLE CONTROL FUNCTION NAME

CREW SELECTABLE CONTROL PUSH BUTTONS

■ = "ON" ☐ = "OFF"



1 OPERATIONS SELECT FORMAT (VERB)
- ☐ ☐ TEST
- ☐ ☐ MONITOR
- ☐ ☐ CONTROL
- ☐ ☐ DISPLAY
- ☐ ☐ REVIEW
- ☐ ☐ WRITE
- ☐ ☐ ACTIVATE
- ☐ ☐
- ☐ ☐

CREW SELECTION

2 SUBSYSTEMS SELECT FORMAT (NOUN)
- ■ ☐ CONTROL
- ☐ ☐ TEST LOG
- ☐ ☐ BASE LOG
- ☐ ☐ EPS
- ☐ ☐ ECS
- ☐ ☐ SCS
- ☐ ☐ G&N
- ☐ ☐ EXPER.
- ☐ ☐

CREW SELECTION 2

3 FUNCTION SELECT FORMAT (NOUN MODIFIER)
- ■ ☐ CONTROL
- ■ ☐ ECS
- ☐ ☐ H20 LOOP
- ☐ ☐ ATMOS. LOOP
- ☐ ☐ PILOT OVRD. FC
- ☐ ☐ STATUS
- ☐ ☐ CABIN TMP
- ☐ ☐
- ☐ ☐

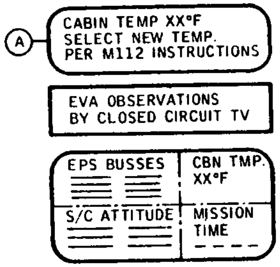
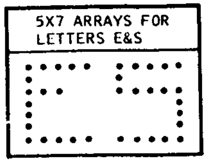
CREW SELECTION 3

4 FINAL PANEL CONFIGURATION DISPLAY
- ■ ☐ CONTROL
- ■ ☐ ECS
- ■ ☐ CABIN TMP.
- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐

ALSO SE. Ⓐ & Ⓑ UNDER DISPLAYS

NOTE. SELECTIONS REMAIN "ON" AND MOVE TO HEAD OF SUBSEQUENT FORMATS.

DISPLAYS

TYPE	TYPICAL DISPLAYS	PREDICTED FLIGHT QUAL. STATUS - 1975
CRT • REAL TIME DATA - SYSTEMS STATUS - SYSTEMS DATA - REMOTE MONITORING • FIXED DATA - CREW PROCEDURES - INSTRUCTIONS • INTERACTIVE CONTROL THRU COMPUTER	 Ⓐ CABIN TEMP XX°F SELECT NEW TEMP. PER M112 INSTRUCTIONS EVA OBSERVATIONS BY CLOSED CIRCUIT TV EPS BUSSES CBN TMP. XX°F S/C ATTITUDE MISSION TIME	• 6" X 8" • BLACK AND WHITE • 1500 AN CHARACTERS OR 500 GRAPHICS WITH 300 AN CHARACTERS • LIGHT PEN OR SIMILAR PROBING FOR RECONFIGURABLE CONTROLS (SEE CONTROLS)
MICROFILM PROJECTOR • FIXED DATA - OPERATIONS - SCHEMATICS - LAYOUTS - TABLES - INSTRUCTIONS - LISTS • INTERACTIVE CONTROL THRU COMPUTER	Ⓑ M112 - CABIN TEMP SELECT	• 8" X 8" • 3000 PAGES/CASSETTE RANDOM ACCESS 5 SECOND AV. 10 SECOND MAX. • PROJECTABLE ON CRT OR PLASMA
PLASMA • REAL TIME DATA - SYSTEMS STATUS - SYSTEMS DATA • FIXED DATA - CREW PROCEDURES - INSTRUCTIONS • INTERACTIVE CONTROL THRU COMPUTER	SAME AS CRT (EXCEPTING CCTV)	• LIGHT PEN TYPE INTERACTION • 8" X 8" • RESOLUTION OF 60 POINTS/INCH • FULL RANGE CURSOR • FULL PAGE WRITING 500 MSEC. • AN CHARACTERS • GRAPHICS • 4000 CHARACTERS (.066" X 0.1")
LIGHT EMITTING DIODE • RECONFIGURABLE LABELS. (SEE RCP)	5X7 ARRAYS FOR LETTERS E&S 	• SEE CONTROLS • NO FURTHER DATA AVAILABLE
COMPOSITE MICROFILM PROJECTED ON CRT OR PLASMA • OPTICAL PROJECTION • VIDEO MIXING	• SCHEMATICS WITH REAL TIME DATA VALUES SHOWN AT APPROPRIATE LOCATIONS.	• RFP (MSC) IS OUT (JAN. 1971) FOR COMBINATION OF PLASA & MICROFILM AS SHOWN ABOVE.

Ⓑ M112 - CABIN TEMP SELECT

TMP.	CODE	TMP.	CODE	TMP.	CODE
60	2600	67	2607	74	2616
61	2601	68	2610	75	2617
62	2602	69	2611	76	2620
63	2603	70	2612	77	2621
64	2604	71	2613	78	2622
65	2605	72	2614	79	2623
66	2606	73	2615	80	2624

TO CHANGE CABIN TEMP:

• AN - ML2	TYPE IN
• SK - ENTER DATA	PRESS
• AN - CODE	TYPE IN
• SK - ENTER DATA	PRESS

FIGURE 4

DATA MANAGEMENT SYSTEM - GENERIC OPERATIONAL PROCEDURES

I. GENERAL PROCEDURES (USING ALPHA-NUMERIC (AN) KEYBOARD)

- SK - MICROFILM SELECT PRESS
- AN - 1 PRESS
- SK - ENTER DATA PRESS
- M - M1 IS NOW DISPLAYED SHOWING ALL DMS OPTIONAL OPERATIONS KEYED TO FRAME NUMBERS.
- OPERATOR - CHOOSE APPROPRIATE OPTION AND FRAME NUMBER
- SK - MICROFILM SELECT PRESS
- AN - FRAME NUMBER PRESS
- SK - ENTER DATA PRESS
- M - SELECTED FRAME IS PRESENTED
- OPERATOR - FOLLOW INSTRUCTIONS ON MICROFILM FRAME SELECTED, ENTERING DATA OR OPTIONS AS REQUIRED. AT EACH ENTRY, "ENTER DATA" KEY MUST BE PRESSED. THE MICROFILM DISPLAY THEN AUTOMATICALLY ADVANCES TO THE NEXT SET OF INSTRUCTIONS OR OPTIONS. THIS PROCESS IS CONTINUED UNTIL THE SEQUENCE IS COMPLETED.

  OPERATOR INPUTS MAY BE CHECKED AS THEY APPEAR ON THE CRT OR PLASMA DISPLAY READOUT AREAS.

  OPERATOR ERRORS ARE ALSO AUTOMATICALLY DISPLAYED ON THE CRT, PLASMA OR MICROFILM DISPLAYS.

NOTES:
(1) + OR - A NUMBER INDICATES THAT THE PROGRAM AUTOMATICALLY JUMPS BACK (-) OR FORWARD (+) THAT NUMBER OF ELEMENTS.
(2) IF OUT = IF OUT OF LIMITS
(3) IF IN = IF WITHIN LIMITS
(4) UL = UPPER LIMIT
(5) LL = LOWER LIMIT

II. CREW TEST PROGRAMMING (USING ALPHA-NUMERIC (AN) KEYBOARD)

- SEE "GENERAL PROCEDURES" COLUMN I FOR ALL AN TEST SEQUENCES. THESE PROCEDURES WILL LEAD TO THE FOLLOWING WHICH CAN ALSO BE DIRECTLY INITIATED:
- SK - SELECT SEQUENCE PRESS
- M - M10 DISPLAY FOLLOWS:

> TO WRITE NEW TEST: PRESS "TEST LOG," "W" AND "ENTER DATA." TYPE IN NEW NAME AND FUNCTION ON "AN" AND PRESS "ENTER DATA."
> FOR OTHER SEQUENCES: PRESS "MICROFILM SELECT," TYPE IN "11" AND PRESS "ENTER DATA."

A NEW TEST, "CBN TMP," IS TO BE WRITTEN.

- SK - TEST LOG PRESS
- AN - W PRESS
- SK - ENTER DATA PRESS
- AN - CBN TEMP - PERIODICALLY CHECKS AND DISPLAYS OUT OF LIMIT CABIN TEMP TYPE IN
- SK - ENTER DATA PRESS
- M - A DISPLAY IS NOW PRESENTED WHICH GIVES THE OPERATOR INSTRUCTIONS ON OPTIONS NEEDED TO START WRITING A TEST. EACH ENTRY IS CALLED A TEST ELEMENT.

NOTE: IT IS RECOMMENDED THAT A FLOW CHART AND THE CORRESPONDING SEQUENCE OF TEST ELEMENTS BE MADE UP BEFORE CONTINUING

(SEE LAST THREE PARAGRAPHS OF COLUMN I.)

THE ELEMENTS OF THE NEW TEST FOLLOW:

```
BEGIN CBN TMP
SWITCH 1234 ON
MEASURE 1234 (STORE VALUE IN) ML1
COMPARE ML1 70°F, 60°F (IF IN LIMITS) + 8
DISPLAY P LINE 1:  CABIN TEMP ML1 °F
DISPLAY P LINE 2:  UL 75°F, LL 60°F
DELAY 0.5 SEC.
DISPLAY P LINE 1:  BLANK
DISPLAY P LINE 2:  BLANK
DELAY 0.1 SEC.
GO TO:  -8
DELAY 300 SECS.
GO TO·  -10
END
```

III. TEST ACTIVATION PROCEDURES

A. THRU ALPHA-NUMERIC (AN) KEYBOARD (FOR CREW PROGRAMMED TESTS)

- SK - SELECT SEQUENCE PRESS
- M - M10 IS DISPLAYED:

> SEE COLUMN II

- SK - MICROFILM SELECT PRESS
- AN - 11 TYPE IN
- SK - ENTER DATA PRESS
- M - M11 DISPLAY FOLLOWS:

> TO REVIEW TEST LOG: IF EXACT NAME IS NOT REMEMBERED, PRESS "TEST LOG," "R" AND "ENTER DATA."
> TO REVIEW/MODIFY A TEST: TYPE IN EXACT TEST NAME, PRESS "ENTER DATA," PRESS "R" AND "ENTER DATA."
> TO ACTIVATE A TEST: TYPE IN EXACT TEST NAME, PRESS "ENTER DATA," PRESS "A" AND "ENTER DATA."
> TO STOP A TEST: TYPE IN EXACT TEST NAME, PRESS "ENTER DATA," PRESS "S" AND "ENTER DATA."

TEST WRITTEN IN COLUMN II IS ACTIVATED:

- AN - CBN TMP TYPE IN
- SK - ENTER DATA PRESS
- AN - A PRESS
- SK - ENTER DATA PRESS
- P - DISPLAY FOLLOWS:

> CBN TMP IN PROGRESS

NOTE: IF TEMP IS IN LIMITS, THIS DISPLAY (WHICH IS GENERATED BY THE EXECUTIVE ROUTINE AND NEED NOT BE WRITTEN BY CREW) STAYS ON UNTIL TEST IS STOPPED.

IF TEMP IS NOT IN LIMITS, ABOVE IS TRUE PLUS:

- P - FOLLOWING DISPLAY BLINKS ON 0.5 SEC. AND OFF 0.1 SEC., REPEATING CONTINUOUSLY:

> CABIN TEMP XX °F
> UL 75°F, LL 60°F

IF TEMP GOES BACK INTO LIMITS, ONLY FIRST (IN PROGRESS) DISPLAY REMAINS UNTIL TEST IS STOPPED.

B. THRU RECONFIGURABLE CONTROL PANEL (RCP) (FOR PRE-PROGRAMMED TESTS)

- RCP - ON PRESS
- RCP - WILL NOW SHOW PRE-PROGRAMMED OPTIONS

> SEE RCP 1 DISPLAY

- RCP - CONTROL ON PRESS
- RCP - WILL NOW SHOW ALL S/C SYSTEMS THAT ARE PRE-PROGRAMMED FOR RCP CONTROL

> SEE RCP 2 DISPLAY

- RCP - ECS ON PRESS
- RCP - WILL NOW SHOW ALL ECS SUBSYSTEMS THAT ARE PRE-PROGRAMMED FOR RCP CONTROL

> SEE RCP 3 DISPLAY

- RCP - CABIN TEMP ON PRESS
- RCP - IS NOW IN FINAL CONFIGURATION

> SEE RCP 4 DISPLAY

- CRT - THE FOLLOWING IS DISPLAYED:

> CABIN TEMP XX °F
> SELECT TEMP PER
> M112 AND ENTER
> CODE INTO ML2

- M - M112 IS ALSO DISPLAYED:

> SEE M112 IN DISPLAY AREA

- AN - ML2 TYPE IN
- SK - ENTER DATA PRESS
- AN - CODE TYPE IN
- SK - ENTER DATA PRESS

LEGENDS:

SK = SPECIAL PURPOSE KEYS
AN = ALPHA-NUMERIC KEYBOARD
RCP = RECONFIGURABLE CONTROL PANEL
CRT = CATHODE RAY TUBE DISPLAY
M = MICROFILM PROJECTOR DISPLAY/FRAME NUMBER
P = PLASMA DISPLAY
ML = MEMORY LOCATION/NUMBER

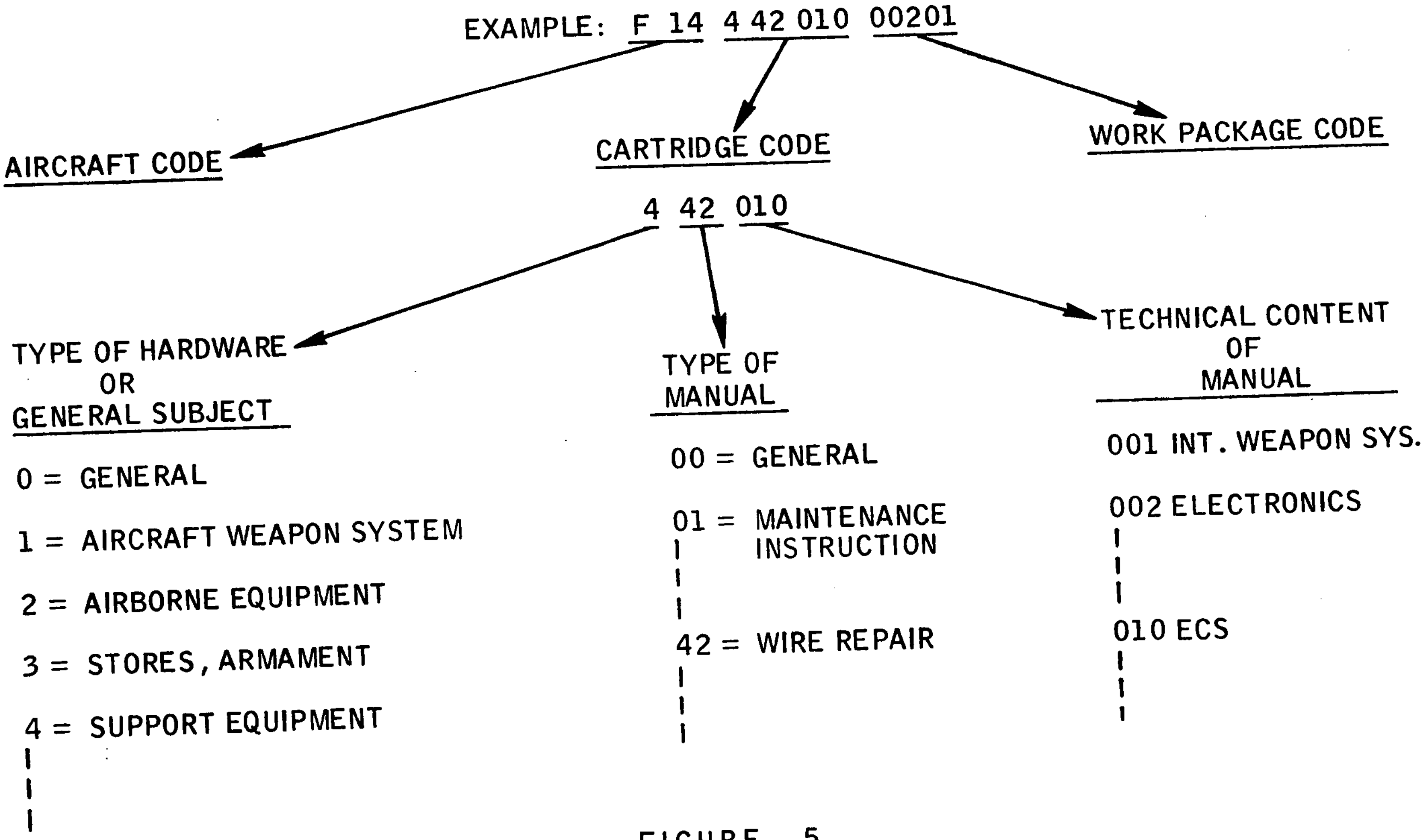


FIGURE 5

NAVY MICROFORM CODING SYSTEM

if specifications of in-flight crew interface data formats should be in consonance with automatic ground generated procedural formats.

2.8.6 Lockheed C-5A Systems

As part of the Phase I examination of the state-of-the-art on-board Data Management Systems for in-flight maintenance and stowage, the Lockheed C-5A systems depicted in Figure 6 were studied.

The C-5A Malfunction Detection Analysis and Recording Subsystem (MADAR) described in Figure 6 contains CRT and microfilm displays, manual controls, and a hard copy recorder integrated into an on-board Checkout and Malfunction Management System. This system is used for in-flight monitoring and fault detection thru observations in real-time of electrical characteristics and vibrational waveforms of operating equipment. This MADAR's CRT equipment is also used for ground maintenance diagnostics, and, in conjunction with the microfilm display system, can retrieve any technical data concerning the aircraft, systems and maintenance. As such, there are systems analogies with future spacecraft on-board data management systems that should be examined in depth in any subsequent studies.

The Integral Weight and Balance System (IWBS) can be used to determine and predict the center-of-gravity of the aircraft as items are off-loaded and on-loaded during ground loading and in-flight operations. It may be noted that this system uses only longitudinal fuselage station data for computing center-of-gravity information and does not consider transverse or vertical placement data of stowed items. At present, it appears that future manned spacecraft will require mass properties management in three dimensions. However, the required fidelity and accuracy of this data is yet to be determined. Nevertheless, it appears that the C-5A IWBS does give general guidelines for a system for preparation of the Shuttle type vehicles for launch and may have in-flight applications through the ability to insert estimates of weights and positions resulting from large scale stowage operations and related shifting of weights in flight. Figure 6 is indicative of the current state-of-the-art of Data Management Systems of the type required to perform limited on-board maintenance and stowage operations for aircraft.

2.9 IN-FLIGHT MAINTENANCE PROCESS AND DATA PRODUCT STUDY

The purposes of the In-flight Maintenance Process/Data Product Phase I study task were to:

1. Examine future manned spacecraft concepts and mission plans and develop a generic definition of the in-flight maintenance process using the mass/function flow diagramming technique (Appendix A, Figure 1).

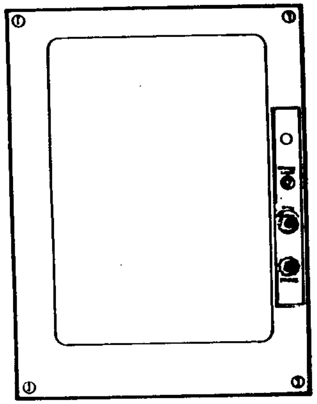
FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 6

C-5A MADARS & IWBS SYSTEMS

C5A MALFUNCTION DETECTION, ANALYSIS AND RECORDING (MADAR) SUBSYSTEM

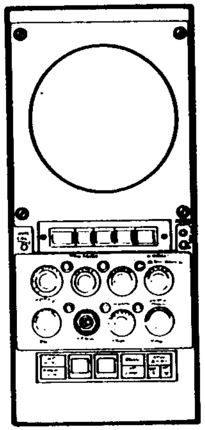


A

DATA RETRIEVAL UNIT

STORED DISPLAYS - MICROFILM

- DIGITAL CONTROL DATA
- TEST INSTRUCTIONS
- MALFUNCTION STATEMENTS
- CORRECTION INSTRUCTIONS
- PAGE NUMBERS OF TECH ORDERS
- WAVE FORM COMPARISONS

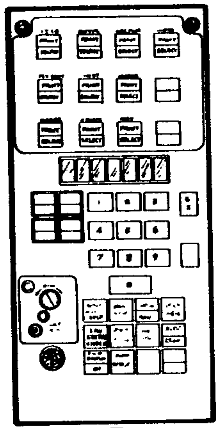


B

OSCILLOSCOPE AND DIGITAL READOUT UNIT

REAL TIME DISPLAYS

- WAVE FORMS
- AC VOLTAGES
- DC VOLTAGES

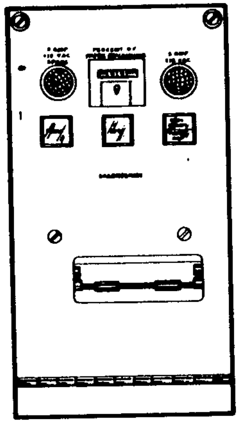


C

CONTROL AND SEQUENCER UNIT

MANUAL CONTROL

- OPERATING COMMANDS
- DATA INSERTION
- DATA CONTROL
- SUBSYSTEM SELECT
- SUBSYSTEM STATUS

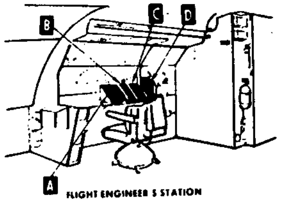


D

PRINTOUT UNIT

HARD COPY PRINTER

- MALFUNCTION RECORDS
- STORED MESSAGES
- LRU FAILURE RECORD:
  - AIRCRAFT ID
  - DATE
  - TIME
  - SUBSYSTEM ID
  - LRU NUMBER
  - LRU EQUATION

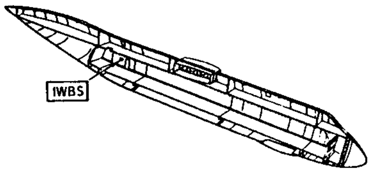


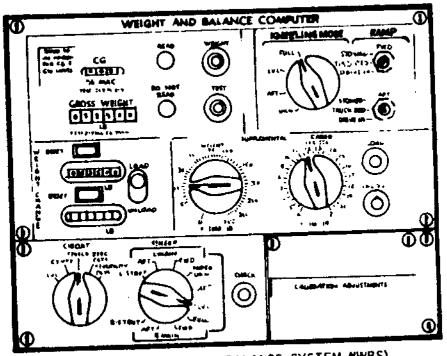
FLIGHT ENGINEER'S STATION

MAINTENANCE DATA RECORDER
BAY 3 AVIONICS RACK

DIGITAL DATA RECORDER	
TREND DATA	LRU FAILURE DATA
• LEAKAGES • POWER CONSUMPTION • PARAMETER DRIFT	• AIRCRAFT ID • DATE • TIME • SUBSYSTEM ID • LRU NUMBER • LRU EQUATION

C5A INTEGRAL WEIGHT AND BALANCE SYSTEM (IWBS)





INTEGRAL WEIGHT AND BALANCE SYSTEM (IWBS)

CONSISTS OF
- WEIGHT SENSING TRANSDUCERS ON LANDING GEAR
- ELECTRONIC COMPUTER UNIT - POWERS SENSORS
  - RECEIVES SENSOR SIGNALS AND COMPUTES GROSS WEIGHT AND C.G.

WEIGHT AND BALANCE COMPUTER

- VERIFIES WEIGHT & BALANCE CALCULATIONS
- WEIGHS INDIVIDUAL CARGO ITEMS
- PREDICTS A/C GROSS WEIGHT AND C.G. AFTER + OR - Δ CARGO OR FUEL

2. Verify the in-flight maintenance process descriptions through studies of Skylab and Space Station subsystems design concepts, maintainability plans and mission data.
3. Utilize this process description to identify the information requirements of the in-flight crew maintenance functions to determine the basic data categories and contents that would support their activities.
4. Utilize results of the research and review activities of military and commercial aircraft and current vehicle NASA subsystem crew operational data to determine candidate data product concepts that appear to satisfy most effectively the information requirements for crew in-flight maintenance.

The scope and magnitude of the in-flight maintenance problem in future manned spacecraft can be inferred from the comparative data presented in Figures 7* and 8* in Crew Controls and Displays. These charts provide a tabulation of the numbers and types of controls and displays used in the U.S. Manned Spaceflight Program to date and in the planned Skylab Program. Even though the design planning trends appear to be in the direction of more integrated display concepts with fewer control/display elements for operations interfaces, future spacecraft concepts will be of greater complexity; and with longer minimum duty cycles for their vehicles, in-flight maintenance activities will become a major aspect of future manned spacecraft operations.

The Phase I study activities have addressed the in-flight process of assembly and servicing as distinct from the in-flight maintenance process. In real-time mission activities, these processes do not exist as separate functional entities but are dealt with within the framework of:

1. OPERATIONS - Those crew activities wherein control and management of the vehicle systems and experiments are accomplished in flight to satisfy planned mission requirements. This includes normal assembly operations of equipment and spacecraft and systems operational verification checks that are conducted with normal operations procedures. Routine housekeeping tasks are also included.
2. MAINTENANCE - Those crew activities necessary for retaining an item in or restoring it to a serviceable condition. This includes:
    - Scheduled maintenance (servicing and inspection functions)
    - Fault Detection - Isolation/Troubleshooting/Diagnostic functions
    - Disassembly/Remove/Repair/Replace/Reassembly (Both EVA and IVA)
    - Calibration/Alignment/Adjust/Test and Checkout for return to operations.

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*From "Crew Functions in Manned Spaceflight," J. P. Loftus, MSC Paper presently in publication (1971).

FIGURE 7

CREW CONTROLS AND DISPLAYS

Spacecraft / Device Characteristic	MERCURY	GEMINI	APOLLO		SKYLAB			
						Orbital Assembly Module		
	Mercury	Gemini	Command Module	Lunar Module	Command Module	Multiple Docking Adaptor	Air Lock	Orbital Workshop
Panels	3	7	28	12	26	31	58	74
Work Stations	1	2	5	2	5	3	4	8
Control Elements Total 4/	98	286	721	378	760	350	694	363
Circuit Breakers	(20)1/	107	264	160	256	19	307	214
Toggle Switches	56	123	326	144	372	239	326	88
Push Button Switches	8	20	13	7	15	12	0	0
Multiposition Rotary Switches	6	19	21	16	19	50	22	32
Continuous Rotary Switches	3	-	35	21	36	17	3	9
Mechanical Devices	3	13	57	26	57	7	35	18
Unique Devices 2/	2	4	5	4	5	6	1	2

1/ Fuses not circuit breakers in Mercury.

2/ Three axis controllers, computer keyboards, etc.

3/ Flight Director Attitude Indicator, computer displays, entry monitor, cross points.

4/ Numbers for each program vary depending upon particular spacecraft.

FIGURE 8

CREW CONTROLS AND DISPLAYS - Cont'd

Spacecraft Device Characteristic	MERCURY	GEMINI	APOLLO		SKYLAB			
						Orbital Assembly Module		
	Mercury	Gemini	Command Module	Lunar Module	Command Module	Multiple Docking Adaptor	Air Lock	Orbital Workshop
Display Elements Total 4/	45	68	131	144	152	222	323	116
Circular Meters	16	7	24	6	23	1	-	2
Linear Meters	-	25	33	25	33	14	64	42
Digital Readouts	3	14	18	13	19	20	1	18
Event Indicators	19	16	47	96	68	182	258	50
Unique Displays 3/	7	6	9	4	9	5	-	4
Inflight Measurement Points 4/	100	225	475	473	521	918	521	281
Telemetered	85	202	336	279	365	918	521	230
Displayed Onboard	53	75	280	214	289	167	129	30
Caution and Warning	9	10	64	145	61	97	91	8
Input								
Analog Signal	9	10	42	45	33	2	87	2
Discrete Signal	-	-	22	100	28	95	4	6
Output	9	10	35	34	35	13	38	8

This Phase I study in accordance with the Statement-of-Work, has addressed assembly and servicing activities as entities apart from maintenance. However, any subsequent study activities will address in-flight maintenance process and data elements utilizing the categorization delineated above.

2.9.1 Future Mission In-Flight Maintenance Requirements

The Research and Review task discussed earlier produced a significant amount of near-term future program design study documentation (Skylab, Shuttle, and Space Station), numerous reports of specialized maintenance studies, and detailed data on preliminary plans for Skylab Program in-flight maintenance tasks, tools and spares.* These data provided the baseline documentation for development of generic descriptions of the crew processes associated with in-flight maintenance. Using the mass/function flow technique for process analysis and description that was developed in this study, diagrams of the In-Flight Maintenance, Assembly, and Servicing Processes were developed and are included in Appendix A, Figures 1, 2, and 3 respectively.

2.9.1.1 In-Flight Maintenance Process

The In-Flight Maintenance Process Diagram includes the crew functions required of the crew, and the basic logic of these operations. Namely the in-flight maintenance process is an integral part of in-flight operations. Contrary to comparable aircraft operations, the same crew, and for early future missions the same individuals, must perform the in-flight maintenance tasks as well as operate the spacecraft. In addition, due to the limited logistics operations, the same crew must be closely involved in resupply operations and spares management. As future spacecraft crews increase in size and mission duration is extended, these tasks will become more specialized with specific crew members being responsible for well defined aspects of these functions as is done in maritime and naval operations.

Since logistics functions will remain within the confines of the space program's project management, with no external reliance on other supply "ports" (as is usually possible with aircraft and naval vessels), the nature of the In-flight maintenance process will be much more closely related to routine spacecraft operations than is the case in other military or commercial programs. The significance of this close tie-in with operations is that the logic of operations must be considered in the preparation of maintenance procedures. Namely, when a fault is detected, safety-of-flight considerations if applicable, must always be examined prior to accomplishing the repairs or replacement of the failed items. However, this safety-of-flight examination for spacecraft is much different from aircraft or submarine operations inasmuch as the "sparing" exercise in space is a much more limited one than in submarines and the ability to "land at the nearest airport" does not exist as a relatively safe and inexpensive solution to the problem. As a result each failure

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*Specific references of the data sources are included within the NASA portion of the study Bibliography in Appendix E pages E-1 thru E-3.

corrective procedure must be analyzed in relation to the availability of on-board spares, tools, test equipment, maintenance aids and data as well as the relationship to shuttle flight logistics capabilities. All of these factors tend to force a more detailed and accurate planning and preparation for maintenance than has been the case in past space flights, military aircraft and naval operations. However, the "flight-test program" nature of space operations, as well as recent austere economic policies, has tended to delay emphasis on the maintainability and maintenance functions in the design and training phases of the recent programs. Experience is providing evidence that an increased effort will be required to provide sufficient support of these areas.

The In-Flight Process diagrams also document the results of the analysis of the basic categories of support resources needed for each of the process functions. The purpose in including this data was to provide a basis for identifying those supporting elements that are associated with each of the in-flight maintenance process functions. The need to relate technical information requirements to these processes was of particular concern and will be discussed in detail later in this report.

As the "spares" function of in-flight maintenance is examined, one notes that the limitations in space dump capabilities results in the requirement for a more formal and rigid consideration of maintenance related stowage management and disposal functions. This interface is also examined in the In-Flight Stowage Management Process (Appendix A, Figure 4).

In the Phase I study requirements, in-flight Maintenance, Assembly, Servicing and Stowage functions were identified as areas wherein new or significantly expanded crew participation could be anticipated. Each of these in-flight processes was examined separately during the Phase I study for purposes of obtaining visibility into the associated requirements. After conducting analyses of the processes, it appears that the manner in which these processes will be organized for real-time operations will be to include Servicing activities as a segment of Scheduled Maintenance activities, with the exception of those servicing functions that will be controlled and monitored entirely from operational consoles and within operational time-lines. In addition assembly operations appear to fall more in the domain of routine operations with operational time-line checklists used to support these functions. In special cases assembly functions will be an integral part of preparations and close-out of remove/replace or repair maintenance functions. In view of the above, the structure of these functions in any subsequent studies will be in accordance with the task organization in "Operations" and "Maintenance" as outlined in Paragraph 2.9.

Figures 2 and 3 of Appendix A contain respectively the resulting diagrams of the Phase I analyses wherein Assembly and Servicing functions were studied.

2.9.1.2 Assembly Process

The In-Flight Assembly Process consists of two basic types (EVA and IVA) of assembly tasks with significantly different support requirements associated with each type. In addition, there will probably be significantly different sizes and masses of components associated with these tasks. Namely, EVA assembly activities generally will consist of orbital docking and mating of large scale modules. From observed spacecraft design concepts to date, it would appear that these activities will be an integral part of the relatively routine operations tasks and task timelines and as such will be a part of the normal flight planning activities, hence, fall outside the scope of this study contract. However, when contingencies exist wherein normal assembly is not possible, then contingency assembly EVA tasks are required. The supporting data products for their activities, such as cuff-checklists similar to those used in lunar surface operations involving pressurized suit operations will be required. Environmental conditions will define different "Preparation for Maintenance" activities and equipments as is noted on the In-Flight Maintenance Process Diagram (Figure 1, Appendix A).

The IVA Assembly functions may be more numerous if resupply cargo volume is restricted and resupply items must be delivered in a disassembled condition for more efficient volume utilization. In which case, "Do It Yourself" assembly instructions will be included with the equipment and treated as an integral part of operations.

In view of the above, any subsequent studies of assembly functions within this contract activity will be only of those that are an integral part of maintenance operations.

2.9.1.3 Servicing Process

Figure 3, Appendix A, contains the analytical results of the investigation of the future In-flight Servicing Process requirements. Characteristically in military and commercial aircraft and ship operations, Servicing functions have been considered as an integral part of the maintenance activities. This convention will also be followed in future manned spaceflight programs and for this reason, as previously noted, any subsequent study activities will consider servicing as a part of scheduled maintenance activities. As can be noted on the In-Flight Servicing mass/function flow diagram (Appendix A, Figure 3) this process consists of three major resupply functions. First, discretely packaged items to support housekeeping, crew, systems and experiment maintenance will be transferred mainly by manual crew operations. This function obviously is closely related to the stowage process and generally this function will be managed as an integral part of the Stowage Process (Appendix A, Figure 4). The second type of servicing will be the resupply of servicing fluids such as fuel, O_2, N_2 water, etc. The nature of these resupply materials tends to require supportive tankage design and as such tends to require specialized attention within the design and operations areas. Most of the crew functions associated with this type of servicing will be an integral part of operations and will be included in routine operational timelines and checklists. The third type of servicing is associated with the scheduled maintenance functions of spacecraft systems and experiments equipments. It is with this third type of servicing that the present study is most concerned. Servicing tasks result from mission related time, are functions of equipment and consumables usage, and are identified in mission plans and thru scheduled maintenance inspections wherein the following specific activities are performed:

1. Systems and spacecraft integrity checks.
2. Spacecraft care and cleaning.
3. Verification of integrity of safety devices and interlocks.
4. Scheduled calibrations and alignments due to equipment performance variance as a function of mission time.
5. Checking for mechanical deterioration due to equipment age, cycles of use or environmental conditions (meteroid, thermal, vacuum, etc.)

Detailed discussion of information requirements and data products necessary to support the servicing functions will be discussed subsequently in the following paragraphs as an aspect of the In-flight Maintenance Process.

2.9.2 In-Flight Maintenance Process Verification Utilizing Skylab and Space Station Design Concepts

2.9.2.1 Skylab In-Flight Maintenance Process Analysis

As Skylab is the first NASA spacecraft with an established requirement for in-flight maintenance tasks, a process analysis of these planned tasks was made. Basically, in order to perform a specific task, procedural data, tools, spares and support equipment must be identified and/or supplied to the crewman or crewmen performing the task. Figure 1 in Appendix D shows the results of this analysis. The tasks are identified by module, system and type (remove, replace, repair and clean); the number of spares carried on board for each task is specified; the tools required for each task are identified; and a complete list of tools is included and cross-referenced to the relevant tasks. Procedures are not related to tasks, as those handbook procedures that were available at the time of this analysis were extremely limited in scope and number. However, the Skylab In-Flight Maintenance chart presents an excellent overview of the planned maintenance tasks and the logistics involved in these tasks, thus demonstrating the advantages and applicability of process description analysis to planned mission maintenance tasks. The integration of task/tools/spares is in itself most enlightening.

2.9.2.2 Investigation of Orbital Workshop Heat Exchanger Fans Control Functions

In order to determine if operational schematics of a functional control loop could be used for maintenance troubleshooting supportive data at a low level (component/wiring) analysis was made of the heat exchanger fans, located in the airlock module, that supply cooling air to the orbital workshop. These four fans have controls in both the airlock module and the orbital workshop, so the fans provide interesting subjects for analysis.

It was necessary that the fan control system be studied in detail prior to describing their functional control loops (Figures 2 and 3, Appendix D). The two descriptions of the same control function are shown using two different techniques, one of which has the capability of relating three distinct control loops of one function on an uncomplicated and simplified schematic. This technique is most useful in the event troubleshooting of the function is required. It permits the crew to mode the function (to any of the three functional loops) in order to assist in isolating the malfunctioning component or circuit.

2.9.3 Information Requirements of In-Flight Maintenance Activities

Prior to the review of present state-of-the-art documentation used in analogous military and commercial programs, the Phase I study approach was to examine in-depth the future in-flight maintenance process requirements and to identify the kinds of information that the crew requires for training in and performance of this activity. For the convenience of the reader the In-Flight Maintenance Process Diagram has also been included in Figure 4 of Appendix D. To this basic diagram has been added groupings of functional processes into categories that require similar informational support or, more specifically, can utilize common data formats to support crew training and real-time mission activities. The identified categories of crew in-flight maintenance functions are:

A. Scheduled Maintenance (Servicing and Inspection)

B. Fault Detection-Isolation/Troubleshooting/Diagnostics

C. Corrective Maintenance (Disassembly/Remove/Replace/Repair/ Reassembly)

D. Calibration/Alignment/Adjust/Test and Checkout

The data to support these categories of crew functions are described and amplified in Figure 5 of Appendix D. This chart specifies the basic supporting data that are required in each of these functional informational categories and identifies the type (decision or non-decision) data formats that is appropriate for each of the four functional categories. The basic purpose in developing this Information Requirements Chart was to establish some categorical guidelines for the data product investigations of present state-of-the-art concepts for technical manuals and job-performance aids being used in other military and commercial program areas.

The technical data needed to support in-flight maintenance activities consist of information that:

1. Defines crew actions to be followed in accomplishing a particular function. (Procedural Data)

2. Supplements the procedural text (1) above in providing graphics that relate the textual words to the three-dimensional shapes, forms and locations of components being manipulated in the specific access areas and environments of the spacecraft. (Supporting Data)

3. Provides reference information concerning the configuration of spacecraft systems and related performance characteristics. (Systems Data)

Items (1) and (2) above have been of the most immediate concern during the Phase I study with the optimization of systems data being considered by the Technical Monitor to be more a subject for subsequent study efforts. More detailed discussion of data products for each of these functional categories is included in Paragraph 2.9.4. The nature of the information requirements of the four categories of crew in-flight maintenance functions is such that in some cases sequential ordering alone of tasks is sufficient whereas in others decisions based on system responses are necessary in order to branch into appropriate subsequent sequences of tasks.

Non-decision (sequential) type of data format or sequential step-by-step procedural information is provided to insure that proper operating actions and sequences are accomplished and no operations are omitted. An example of this type of format is included in Figure 6, Appendix D and specifies the Controlled Object and the required Position or Response to be accomplished. For in-flight maintenance functions these formats may contain the Action to be accomplished on the Controlled Object (Control/Display or Equipment) and the anticipated System Response. This type of data may be just a schedule of tasks to be done (assuming the crew knows how to perform the task) with little or no step-by-step data or, depending on the amount of training activities, may include detailed step-by-step procedures.

The Decision (branching) type of data format is used with those type of crew operations wherein detailed system diagnostics are being accomplished. Namely, depending on the type or value of the System Response a branching decision must be made to alternate subsequent sequences of diagnostic steps. Examples of this type of data are the Apollo Crew-Malfunction Procedures, and the Navy specified Logic-tree and Logic-text formats which are included respectively, in Figures 7 thru 9 of Appendix D. These formats will be discussed further in subsequent paragraphs of this report.

The basic in-flight maintenance information requirements resulted from analyses of the In-Flight Maintenance Processes and were used as study guidelines in research reviews to select and develop appropriate documentation concepts for future manned spacecraft operations.

2.9.4 Maintenance Data Product Reviews

The information requirements to support in-flight tasks for training historically have differed significantly from that data used to support real-time mission operations. However, results of DOD studies (References 52, 53, 54) have indicated that proceduralized job-performance aids can provide both a significant increase in operational efficiency and a reduction of training time thru usage of these types of supporting data products. As a result a major purpose in the data products review for in-flight maintenance is to examine and develop concepts for integrated textual/graphics data that can be used in a job performance aid fashion for both training and real-time mission operations. This should provide significant reduction in unique supporting documentation for in-flight maintenance.

During the Research Phase of this study, an effort was also made to determine the "effectiveness" of today's technical manuals. One specific study performed by Booz-Allen Applied Research, Inc., for the Naval Air Systems Command (60) indicated numerous documentation shortcomings. Among those delineated were:

- Documentation is unsuited to the intended user's educational level.
- Documentation is ineffective in communicating information.
- Non-standard methods of data acquisition, selection, and presentation are used.
- Retrieval procedures render the delivered document inaccessible.
- Documents are produced independently within functional areas with minimal interfunctional coordination.
- Information is out-of-date, inaccurate and incomplete.
- Design is not conducted with its impact on documentation considered.
- Existing document specifications fail to give meaningful guidance to the preparation of technical documents.
- There is no systematic procedure through which the documentation shortcomings can be identified into language that a document producer can understand.

A paper presented at the NSIA Sumposium on Equipment Manuals (68) addressed the importance of information format and illustrations relevance. Three specific comments were:

- Every aspect for format should be designed for greater utility in the field.

- Manuals should provide the essential information in the most useful format. When illustrations contribute to that end, they belong in the manual. When they cannot be justified on that singular basis, the reduction in manual bulk is the more desirable objective.

- Format does affect utility and therefore should not be ignored. Some deliberate effort in this direction might just produce very worthwhile improvements.

2.9.4.1 Scheduled Maintenance Data Review

The Maintenance Concept for future Manned Spaceflight programs has not as yet been defined. However, from a review of future programs and mission data it appears that most near-term missions will consider in-flight maintenance functions as analogous to the military aircraft organizational maintenance activities. As a result data reviews for scheduled maintenance have included examination of Operational Handbooks and organizational type manuals for related servicing and inspection data concepts.

One of the examples of recent Operational Handbooks reviewed during the Research task of the Phase I study was the NATOPS Flight Manual for the TA-4F Aircraft (Ref. No. 94). This manual provides classical inspection supporting data that combines the Pre-flight Checklist with the graphical illustrations of the Exterior Inspection [Figure 10, Appendix D]. In addition the manual contains a major section on aircraft servicing which includes a servicing diagram [Figure 11, Appendix D] that is an overview of items to be serviced with data as to the refurbishing fluids types and capacities of containers. In addition detailed procedures and supporting graphics are provided for the servicing tasks [Figure 12, Appendix D]. These data are representative of servicing and inspection data provisions that have generally been provided in aircraft technical manuals. Only general references are made to servicing equipment, tools and related procedures since these are covered more specifically in manuals supporting the individual equipment.

In-flight maintenance data for servicing and inspection in future manned spacecraft can probably provide the crew with a much more integrated data package due to the closer relationship of operations and maintenance functions. It is anticipated that graphical depictions of the routes and major points of inspection tasks can be depicted in a similar fashion to that provided in the military manuals. However, the detailed procedural data and supporting graphics can be optimized for more efficient cross-indexing of text and graphics such as was done in the Air Force Pimo Maintenance Instructions (Figure 13, Appendix D) or in the G.E. developed Modular Equipment Operators Familiarization Handbook (Figure 14, Appendix D). In addition more data on support equipment and access panel and servicing point location can be included within the servicing and inspection procedures. The Operational Location Coding System, discussed previously, can be of significant value for locating tools, test equipment and servicing areas in the scheduled maintenance data packages.

As part of the Phase I study, a preliminary concept for the scheduled maintenance supporting data format for future manned spaceflight was developed and is summarily documented in Figure 15, Appendix D. Data in this form should be provided for each spacecraft subsystem with subsequent integration occuring as the inspection and servicing tasks are organized for flight planning purposes. Further detailing of this basic concept recommendation for specification purposes should be addressed in subsequent study activities.

2.9.4.2 Fault Detection-Isolation/Troubleshooting/Diagnostics

The major time consuming portion of maintenance tasks is in detecting and isolating equipment failures. The capability to rapidly assess the status of degraded or inoperative systems and to rapidly initiate correction action can save a mission and spacecraft. Well prepared and readily usable and retrievable troubleshooting procedures can be among the more significant maintenance tools that the flight crew has to attack the problem of fault isolation and failure identification.

During the research task much effort was spent in examining both military and commercial concepts for troubleshooting job performance aids. During the annual FAA sponsored Conference on Maintenance held in Oklakoma City in November, 1970 aircraft manufacturers of the DC-10 and L1011 aircraft indicated that fault detection through use of Built-In Test Equipment (BITE) and well planned fault isolation and failure identification could be among the major areas where significant operating cost reductions could be realized in future commercial aircraft operations. The U.S. Navy has recently issued specifications for new types of technical manual data including troubleshooting procedures. These include the "Logic-Tree" and "Logic-Text" type formats (Figures 8 and 9 of Appendix D). For the F-14 Naval aircraft program only these types of troubleshooting procedures will be included within the technical manuals for Maintenance. This does indicate a new realization of the importance of the decision or branching type of data to support troubleshooting functions. This data format forces the contractor into an orderly and systematic analysis of the systems performance characteristics and reliability data in arriving at a rational estimate of anticipated effects of failed components and in providing criteria and standards for branching to alternate paths for subsequent system malfunction analysis.

Various formats were examined for appropriateness for future space mission in-flight troubleshooting requirements. These included the "Logic-Tree" for the F-14 aircraft, the L-1011 logic diagrams and the NASA Apollo Crew Malfunction Procedures. All of these formats appear to be improvements over sequential type of data. However, for general efficiency of data space utilization and for clarity of presentation, it appears that the Apollo Crew Malfunction Procedures format (Figure 7, Appendix D) is the more acceptable for future manned spaceflight mission. This format, as presently used, does not necessarily identify down to the failed component (In-Flight Replaceable or In-Flight Repairable Unit - IFRU). Figure 16, Appendix D contains the recommended modifications to the logic rules and symbology developed by G.E. that appear necessary for the present Apollo Crew Malfunction Procedural format to serve as the basic troubleshooting supporting data format for future mission crew interface data. These recommendations assume that the procedural instructions for remove, repair and replacement actions for corrective maintenance will be conatined in separate work packages within each of the spacecraft subsystems discussions of the In-Flight Maintenance Handbook. These work packages, discussed in detail in the next paragraph, will be cross referenced from the three types of failure identifications in the troubleshooting procedures as noted in Figure 16, Appendix D.

It should be noted that these troubleshooting procedures will be organized by spacecraft subsystems and will be entered through the symptom being encountered in a similar manner as is presently done with the Apollo Crew Malfunction procedures.

2.9.4.3 Corrective Maintenance (Disassembly/Remove/Repair/Replace/Reassembly)

These types of data will provide the basic sequential instructions for crew tasks necessary to accomplish the in-flight corrective actions required to return the equipment to or maintain it in an "operational" condition. As noted in the previous discussion, these data will be contained in work packages that will be organized in a separate section of each of the subsystems of the In-flight Maintenance Handbook. As may be noted on the Information Requirements Chart (Figure 5, Appendix D) a significant amount of detailed supporting information is necessary to support these types of tasks, namely detailed component identification, location, size and orientation information is required to support the training and in-flight operations for these corrective maintenance tasks. In addition, tools, test equipment and spares should be identified and located to support the detailed procedures and procedural graphics. These data elements have been conceptually organized into a preliminary recommended format during the Phase I Study. Figure 17, Appendix D contains a summary description of this data format for Corrective Maintenance. The major function that is being addressed with this format concept is to provide within each Work Package all data necessary for corrective maintenance with the exception of the basic schematic and systems data which will be packaged separately.

2.9.4.4 Calibration/Alignment/Adjust/Test and Checkout

The crew in-flight maintenance activities include functions wherein special procedures are required, with relating supporting data, for the usage of specialized test equipment to align, calibrate, adjust, test and checkout systems and equipment. These functions will require additional information related to test point locations, anticipated data patterns and values at these locations, hook-up procedures as well as the associated extensions of the Type III troubleshooting procedures to accomplish fault isolation to the IFRU. The formats for these supporting data types will be a combination of previously identified troubleshooting decision-type formats in conjunction with the non-decision type procedural data formats for corrective maintenance with additional calibration data.

2.9.4.5 In-Flight Maintenance Data Products Review and Format Recommendations

Figure 18, Appendix D contains a brief summary of the preliminary concepts for the organization of In-Flight Supporting Data for Operations and Maintenance. These recommendations illustrate the manner in which the data formats previously recommended in this section can be integrated with present training and flight data file information for an integrated package of operations and maintenance supporting data. Further definition for specification purposes of the organization of the in-flight supporting data for maintenance should be conducted in subsequent studies.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The Phase I Crew Interface Specifications Study has included analyses of information requirements for present and projected NASA crew interface processes and subsequent data product development studies. From this effort it appears that a number of conclusions and recommendations can be made and are appropriate in view of the study results. These conclusion and recommendations have been summarily presented in the pages of Table 1.

Program difficulties encountered in Skylab and other developmental programs emphasize an immediate need for a means of providing contractors with guidelines for assignment of location codes and for the development of new in-flight stowage data products to support reviews, training and real-time mission operations. As a result, emphasis should be placed in subsequent study efforts to initially develop the recommended specifications for a genine location coding system and in-flight stowage data products. Effort should also continue in the in-flight maintenance data products study areas as well.

TABLE I

PHASE I CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS	RECOMMENDATIONS
● SPACE PROGRAM NEEDS EXIST FOR BETTER METHODS OF DEFINING IN-FLIGHT CREW REQUIREMENTS (PARTICULARLY IN THE MAINTENANCE AND STOWAGE AREAS) SUCH THAT "OPERATIONAL VISIBILITY" CAN BE MADE AVAILABLE TO SPACECRAFT/SYSTEMS DESIGNERS AND PROGRAM MANAGEMENT.	● NASA/MSC SHOULD INCLUDE WITHIN CONTRACT SPECIFICATIONS THE REQUIREMENT TO CONDUCT EARLY ANALYSES OF IN-FLIGHT MAINTENANCE AND STOWAGE ACTIVITIES AND DOCUMENT THE RESULTS IN "MASS/FUNCTION FLOW" TYPE DIAGRAMS FOR BOTH UPPER AND LOWER (MORE DETAILED) LEVEL PROCESS DESCRIPTIONS IN ORDER TO PROVIDE "OPERATIONAL VISIBILITY" TO DESIGNERS, PROGRAM MANAGEMENT, TRAINING AND OPERATIONAL PLANNING PERSONNEL.
● SUFFICIENT REDUNDANCIES WERE INCORPORATED INTO MERCURY, GEMINI, AND APOLLO SPACECRAFT SYSTEMS DESIGNS SUCH THAT "IN-FLIGHT MAINTENANCE" WAS NOT CONSIDERED NECESSARY FOR MISSION SUCCESS. HOWEVER, FUTURE LONG-DURATION MISSIONS WILL FORCE INCORPORATION OF "IN-FLIGHT MAINTENANCE" CONCEPTS AS A MEANS OF INSURING SPACECRAFT INTEGRITY, CREW SAFETY AND MISSION SUCCESS. ● NO COMPARABLE CENTRALIZED RESPONSIBILITY EXISTS WITHIN NASA/MSC PROGRAM OR LINE ORGANIZATIONS FOR MAINTAINABILITY MONITORING AS IS NOTED WITHIN THE MILITARY/DOD AND COMMERCIAL AIRCRAFT DEVELOPMENTAL ACTIVITIES. AS A RESULT, EARLY SKYLAB PROGRAM CONSIDERATIONS OF IN-FLIGHT MAINTENANCE REQUIREMENTS HAVE BEEN INSUFFICIENT.	● IN FUTURE MANNED SPACE MISSION PROGRAMS, GREATER EMPHASIS AND USAGE OF THE MAINTAINABILITY DISCIPLINE, AS USED IN DOD, BY BOTH NASA AND NASA CONTRACTORS SHOULD BE CONSIDERED WITH MODIFICATIONS WHEREIN OUTPUTS OF THE MAINTAINABILITY PROCESS ARE DIRECTLY SUPPORTIVE TO TRAINING AND REAL-TIME MISSION OPERATIONS. A "NASA-MODIFIED MAINTAINABILITY MANAGEMENT SYSTEM" SHOULD BE IMPLEMENTED IN ORDER TO REDUCE COSTS OF DEVELOPMENTAL CHANGES AND TO PROVIDE AN OPERATIONALLY MAINTAINABLE VEHICLE.
● THE FORM AND CONTENT OF PRESENT NASA/CONTRACTOR FLIGHT DATA FILE PRODUCTS ARE INADEQUATE TO SUPPORT THE NEW TRAINING AND REAL-TIME MISSION SUPPORT REQUIREMENTS OF IN-FLIGHT MAINTENANCE ON FUTURE LONG DURATION SPACE MISSIONS.	● NEW DATA PRODUCTS TO SUPPORT IN-FLIGHT MAINTENANCE TRAINING AND REAL-TIME MISSION OPERATIONS SHOULD BE DEVELOPED. SPECIFICALLY, THESE REQUIREMENTS INVOLVE: - MODIFICATION OF PRESENT APOLLO CREW MALFUNCTIONS DATA TO EXTEND THE TROUBLESHOOTING ANALYSES DOWN TO THE IN-FLIGHT REPLACEABLE UNIT LEVEL AND TO THEN CROSS REFERENCE TO THE CORRECTIVE MAINTENANCE WORK PACKAGES. - DEVELOPMENT OF A SEPARATE VOLUME OF OPERATIONS HANDBOOK DATA FOR IN-FLIGHT MAINTENANCE THAT WILL INCLUDE: ● INTEGRATED SERVICING PROCEDURES (WITH INTEGRAL GRAPHICS) ● INTEGRATED INSPECTION PROCEDURES (WITH INTEGRAL GRAPHICS) ● LISTS OF TOOLS AND LOCATIONS ● LISTS OF SPARES OR IN-FLIGHT REPLACEABLE UNITS (IFRU'S) BY SUBSYS. ● CORRECTIVE MAINTENANCE PROCEDURES (BY SUBSYSTEM) ● SPECIAL TEST & CHECKOUT PROCEDURES (BY SUBSYSTEM)
● THE TYPES, FIDELITY AND AMOUNT OF CREW TRAINING THAT CAN BE COMMITTED FOR IN-FLIGHT MAINTENANCE AND STOWAGE MANAGEMENT ACTIVITIES WILL DICTATE THE VOLUME AND DEPTH OF DOCUMENTATION REQUIRED FOR ON-BOARD OPERATIONS.	● TRADE-OFF STUDIES SHOULD BE CONDUCTED TO DETERMINE THE COST-EFFECTIVENESS OF INTENSIVE GROUND TRAINING PROGRAMS WITH HIGH FIDELITY MOCK-UPS VERSUS THE PROVISIONING OF WELL-DEFINED ON-BOARD PROCEDURALIZED DATA WITH SUPPORTING GRAPHICS.

TABLE I
PHASE I CONCLUSIONS AND RECOMMENDATIONS
(CONTINUED)

CONCLUSIONS	RECOMMENDATIONS
● THE FORM AND CONTENT OF PRESENT NASA/CONTRACTOR STOWAGE DATA PRODUCTS (i.e., STOWAGE LISTS, FIELD SITE INSTALLATION DRAWINGS, IN-FLIGHT STOWAGE MAPS) ARE INADEQUATE TO SUPPORT THE EXPANDED REQUIREMENTS FOR IN-FLIGHT STOWAGE MANAGEMENT ON FUTURE LONG-DURATION SPACE MISSIONS.	● NEW STOWAGE DATA PRODUCTS TO SUPPORT IN-FLIGHT STOWAGE MANAGEMENT BY FLIGHT CREWS SHOULD BE DEVELOPED: - FOR EFFICIENCY, THE FORMAT AND CONTENTS OF THE DATA TO SATISFY NASA REQUIREMENTS SHOULD BE SPECIFIED IN DETAIL. - THE FORMAT OF THIS ON-BOARD STOWAGE DATA SHOULD BE COMPATIBLE WITH ON-BOARD DATA MANAGEMENT SYSTEMS MICROFORM DATA CONCEPTS. - THE INTERFACES OF THIS ON-BOARD STOWAGE DATA WITH OTHER IN-PLACE STOWAGE MANAGEMENT AND PREPARATIONS DATA SHOULD BE WELL-DEFINED FOR REAL-TIME MISSION OPERATIONS. - PREPARATION OF ALL STOWAGE SUPPORT DOCUMENTS SHOULD BE OPTIMIZED, AND WHERE PRACTICAL, MULTIPLE USAGE OF SUPPORTING GRAPHICS DATA SHOULD BE UTILIZED. - IN-FLIGHT STOWAGE MANAGEMENT DATA SHOULD BE INTEGRATED WITHIN ONE VOLUME OF THE ON-BOARD FLIGHT DATA FILE.
● PRESENT METHODS USED IN NASA TEST AND OPERATIONS SUPPORTING DATA OF DESIGNATING LOCATIONS OF CONTROLS/DISPLAYS, LOOSE EQUIPMENT, STOWAGE COMPARTMENTS AND LOCKERS, EXPERIMENTS EQUIPMENTS, ETC., ARE INEFFICIENT, IN SOME CASES INACCURATE, AND IN ALL CASES INCONSISTENT BETWEEN DIFFERENT PROJECTS, SPACECRAFT AND MODULES.	● A STANDARD METHOD FOR LOCATION CODING FOR OPERATIONS AND MAINTENANCE OF SPACECRAFT SYSTEMS COMPONENTS, LOOSE EQUIPMENT, STOWAGE LOCKERS, CONTROLS/DISPLAYS, ETC., SHOULD BE DEVELOPED AND A SPECIFICATION WRITTEN THAT MAY THEN BE INCLUDED AS AN APPLICABLE DOCUMENT WITHIN APPROPRIATE NASA CONTRACTOR END-ITEM SPECIFICATIONS. THIS OPERATIONS LOCATION CODING SPECIFICATION WILL CONTAIN DETAILED GUIDELINES FOR APPLICATION OF SUCH A NASA STANDARD LOCATION CODING SYSTEM.

TABLE I
PHASE I CONCLUSIONS AND RECOMMENDATIONS
(CONTINUED)

CONCLUSIONS

- THE ON-BOARD DATA MANAGEMENT SYSTEM (DMS) CONCEPTS FOR FUTURE MANNED SPACEFLIGHT PROGRAMS, REVIEWED DURING THIS STUDY, INDICATE A SIGNIFICANT MODIFICATION OF THE PAST CLASSICAL CREW/CONTROL-DISPLAY/SPACECRAFT SYSTEMS INTERFACES AND RELATED ON-BOARD SUPPORTIVE DATA. THESE CONCEPTS INDICATE CONSIDERATIONS OF THE FOLLOWING TYPES OF REQUIREMENTS:
    - SYSTEM/DMS INTERACTIVE (AUTOMATIC) DATA RETRIEVAL MODE
    - CREW/DMS INTERROGABLE/INTERACTIVE DATA (SEMI-AUTOMATIC) RETRIEVAL MODE
    - EXTENSIVE DATA STORAGE CAPACITY:
        - LARGE VOLUME DATA STOWAGE ON MICROFORM (TEXT, GRAPHICS, PROCEDURES, ETC.)
        - RAPID ACCESS STORAGE IN COMPUTER MEMORY (CONTINGENCY PROCEDURES, INTERACTIVE PROGRAMS, SYSTEMS INTERACTIVE LOGIC AND TIME DEPENDENT DATA, CALIBRATION DATA, ETC.)
    - DMS SYSTEM PERFORMANCE CHARACTERISTICS
        - MICROFORM RETRIEVAL (10 SECONDS MAX.)
        - FULL PAGE (CRT WRITE-UP) (1/2 SECOND MAX. FOR 8"X8" DISPLAY)
    - NEW TYPES OF DMS RELATED DISPLAYS/CONTROLS
        - CRT TYPE DISPLAYS
        - PORTABLE/MULTIPLE USER LOCATIONS
        - RECONFIGURABLE CONTROLS

  THE ABOVE REQUIREMENT WILL HAVE IMPACTS ON CREW SUPPORTING DATA:
    - FORMATS
    - CONTENTS AVAILABLE ON ANY ONE PAGE

  FLIGHT CREWS WILL BE REQUIRED TO LEARN DMS OPERATOR LANGUAGE.

- IMPORTANCE OF DMS ON SPACECRAFT OPERATIONS AND CREW SAFETY DICTATES A SIGNIFICANTLY HIGH LEVEL OF DMS RELIABILITY AND TRADE-OFFS BETWEEN ALTERNATE MEANS OF DATA STOWAGE AND THIS RELIABILITY.

RECOMMENDATIONS

- FUTURE MANNED SPACECRAFT DESIGN WILL REQUIRED AN EARLIER DEFINITION OF CREW IN-FLIGHT DATA REQUIREMENTS (INCLUDING IN-FLIGHT MAINTENANCE AND STOWAGE MANAGEMENT DATA) THAN WAS NECESSARY FOR PREVIOUS MANNED MISSIONS. IN-FLIGHT CREW INTERFACE DATA CONCEPTS MUST CONTINUE TO FACTOR IN THE CONSTRAINTS OF DMS DESIGN CONCEPTS.

APPENDIX A

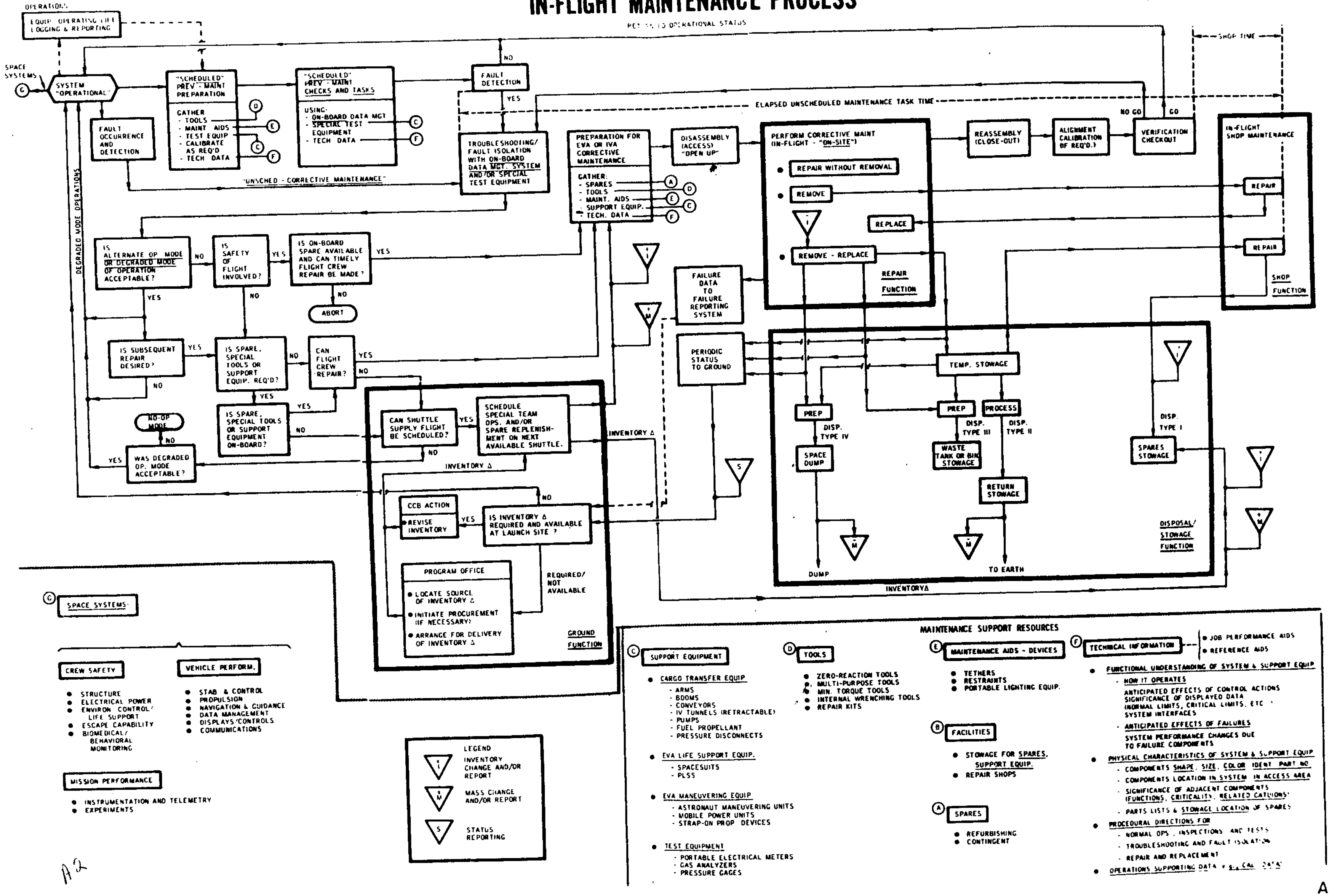
IN-FLIGHT MASS/FUNCTION FLOW PROCESS DEFINITIONS AND NASA MANAGEMENT PROCESS DESCRIPTION CHARTS

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 1

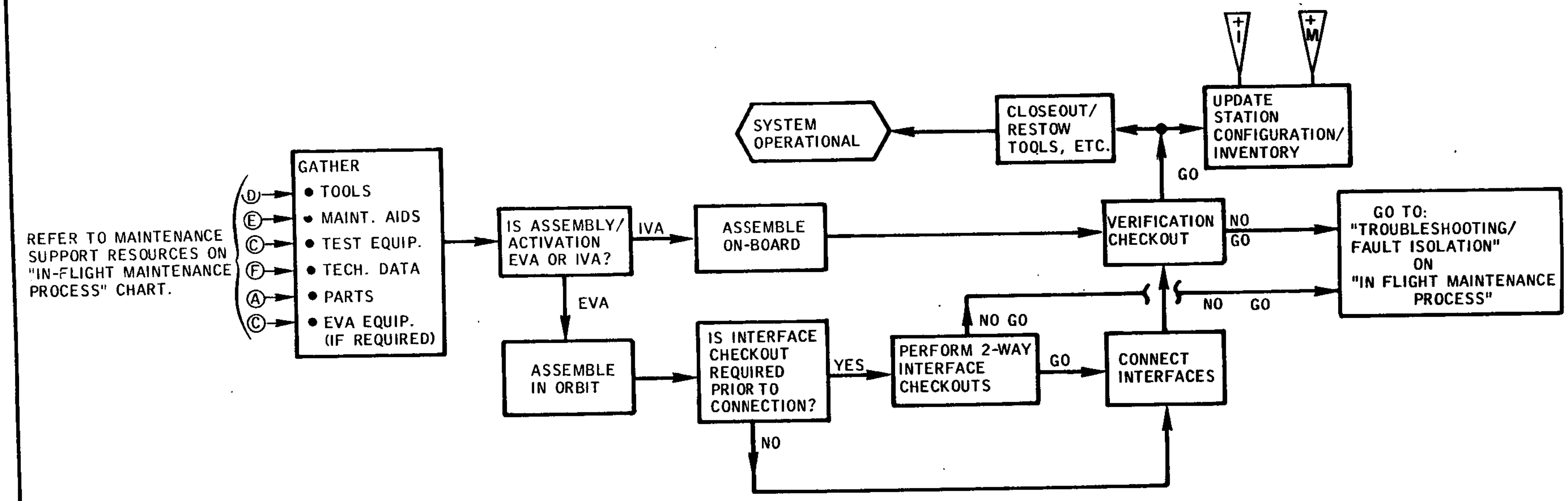
IN-FLIGHT MAINTENANCE PROCESS



A2

FIGURE 2

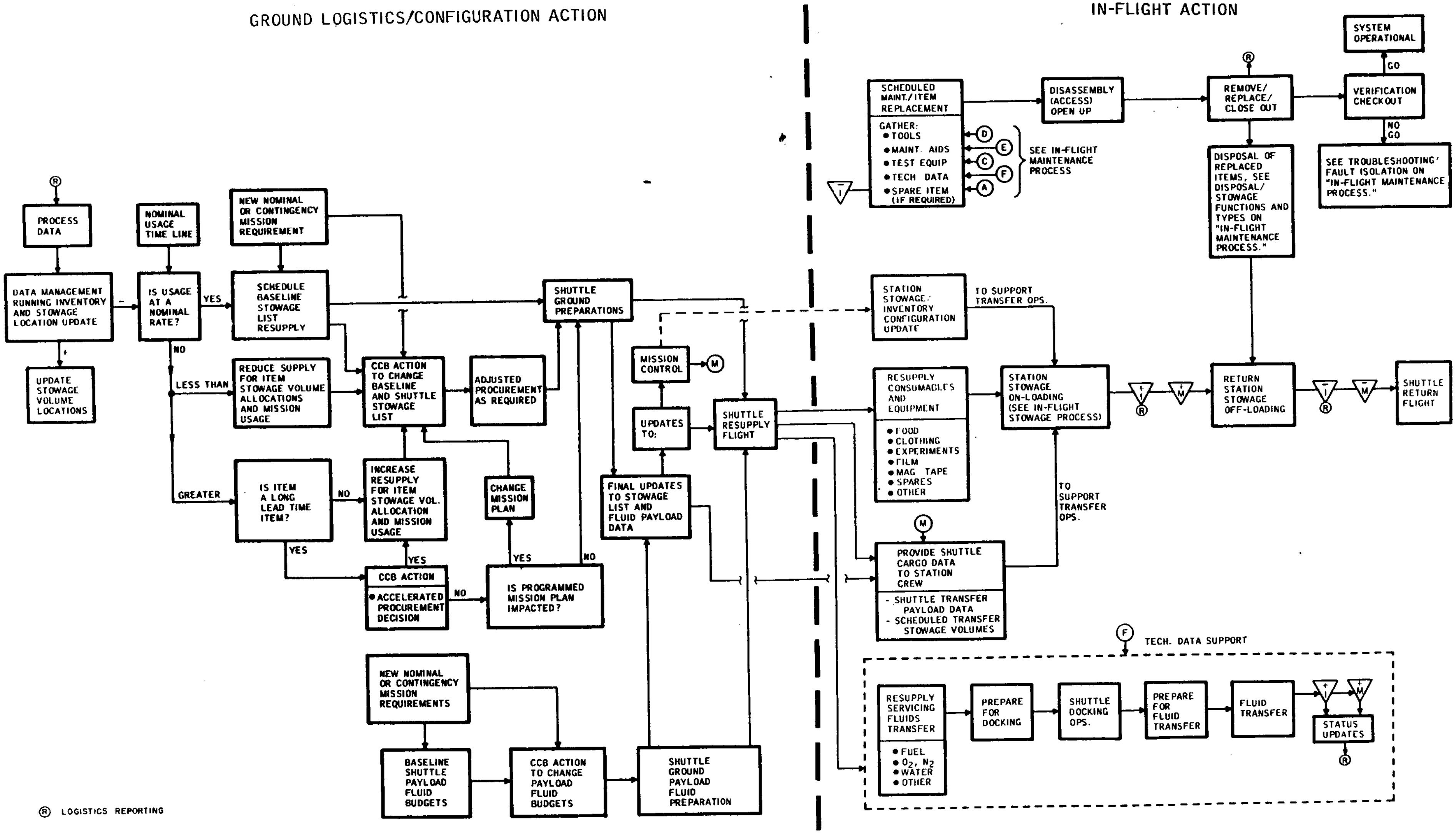
IN-FLIGHT ASSEMBLY PROCESS



A3

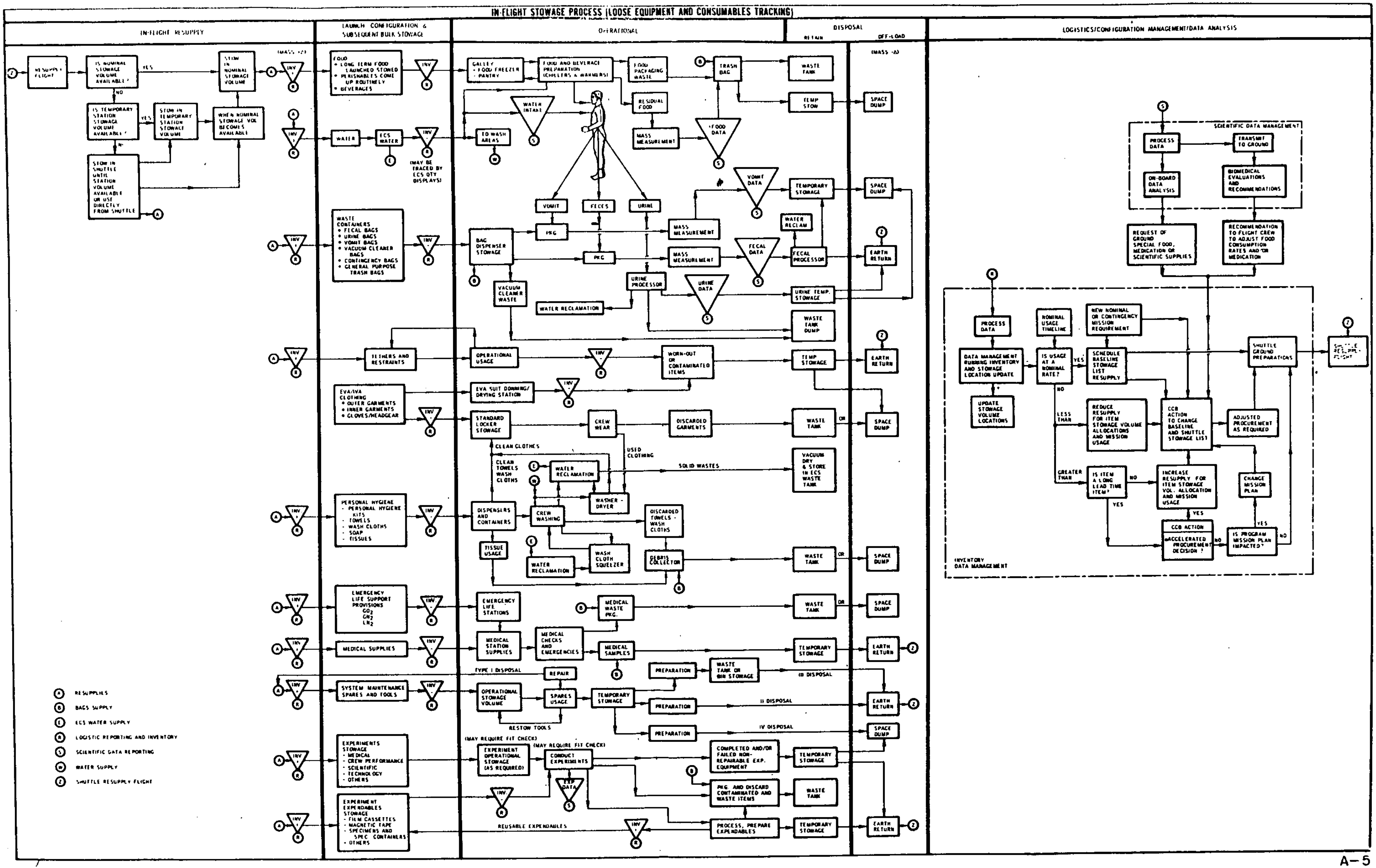
FIGURE 3

IN-FLIGHT SERVICING PROCESS



A4

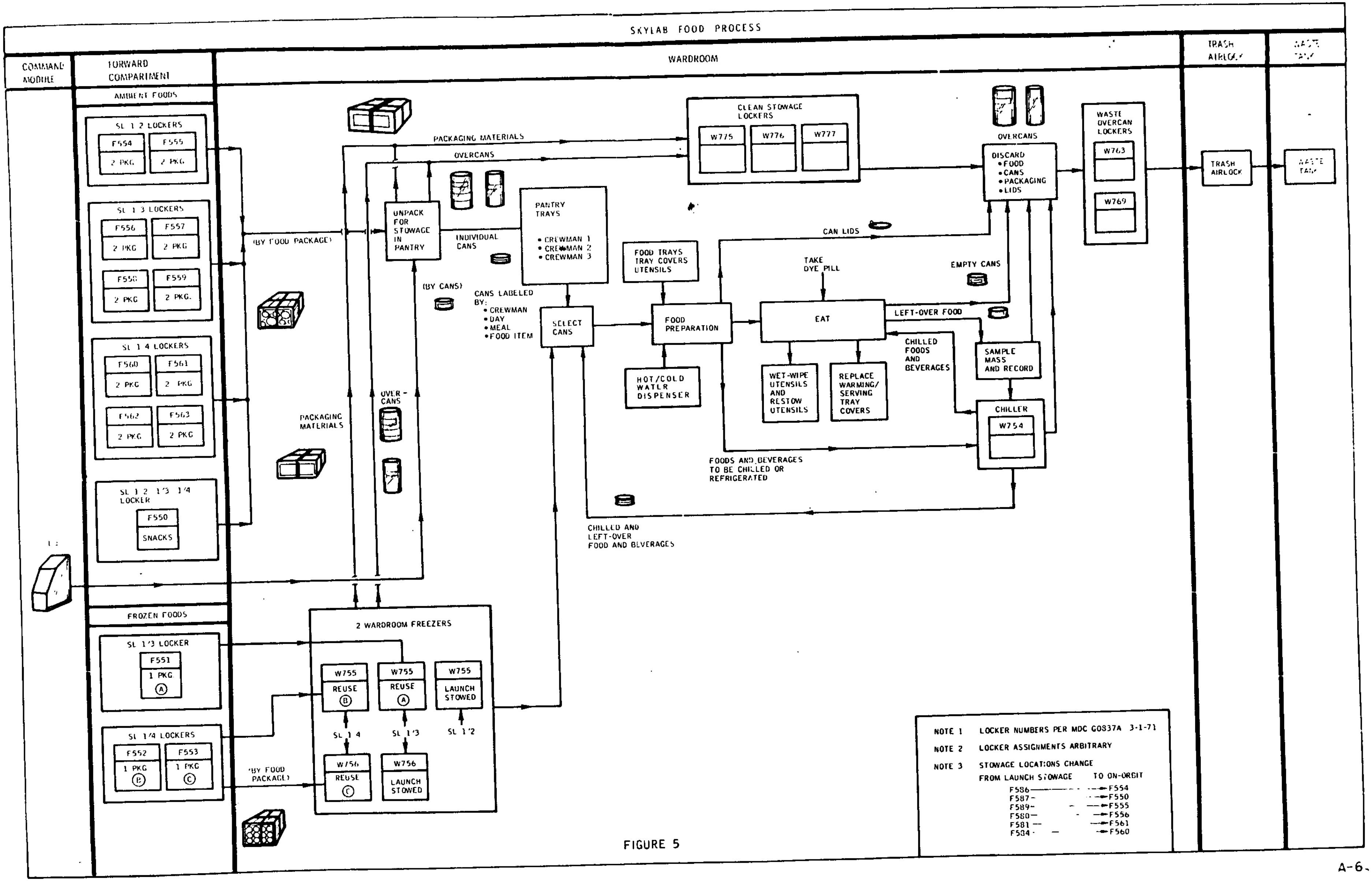
FIGURE 4



IN-FLIGHT STOWAGE PROCESS (LOOSE EQUIPMENT AND CONSUMABLES TRACKING)

FOLDOUT FRAME 1

FOLDOUT FRAME 2



NOTE 1 LOCKER NUMBERS PER MDC G0837A 3-1-71

NOTE 2 LOCKER ASSIGNMENTS ARBITRARY

NOTE 3 STOWAGE LOCATIONS CHANGE

FROM LAUNCH STOWAGE	TO ON-ORBIT
F586	F554
F587	F550
F589	F555
F580	F556
F581	F561
F584	F560

FIGURE 5

A4

SKYLAB FOOD PREPARATION PROCESS

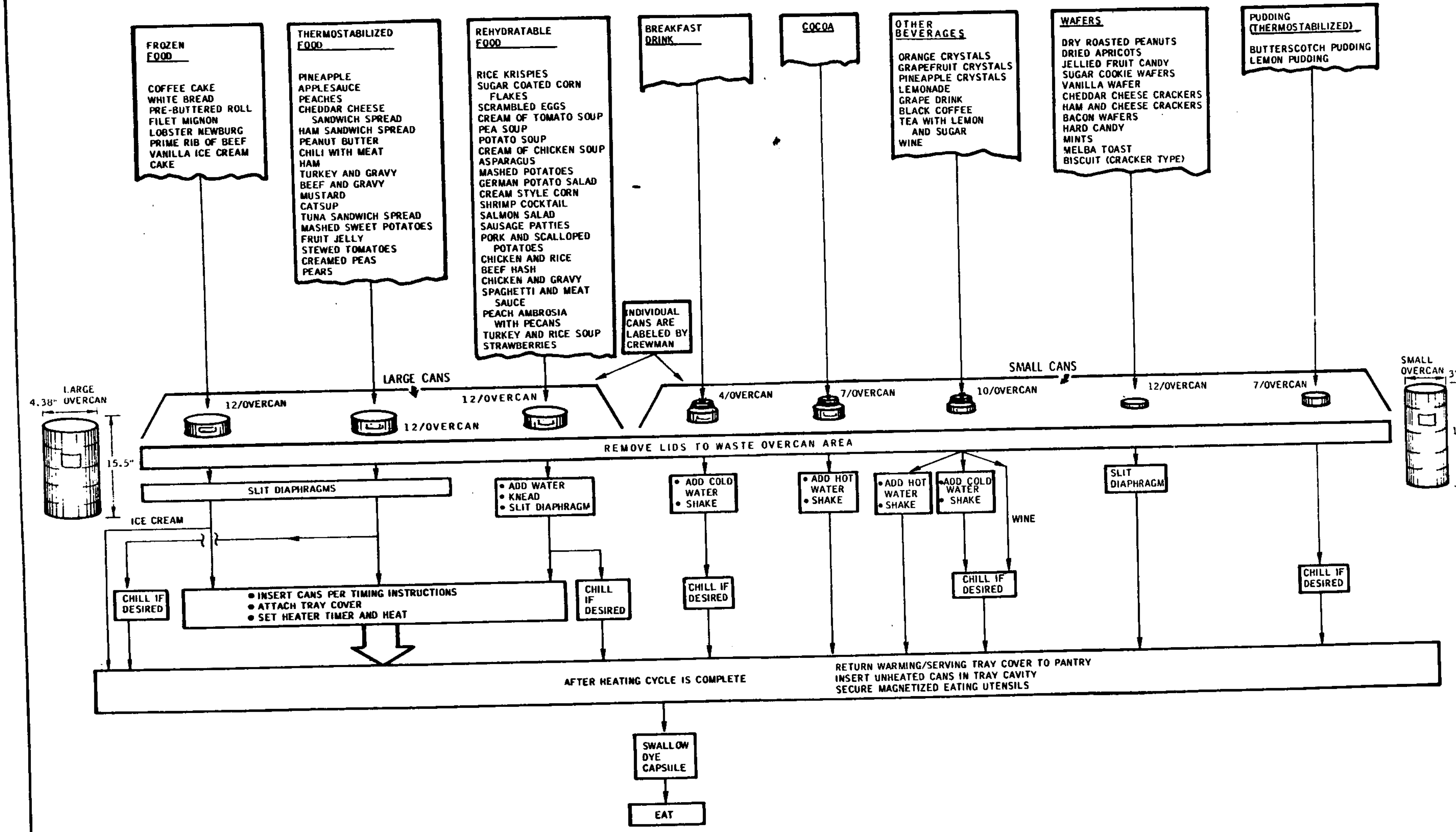
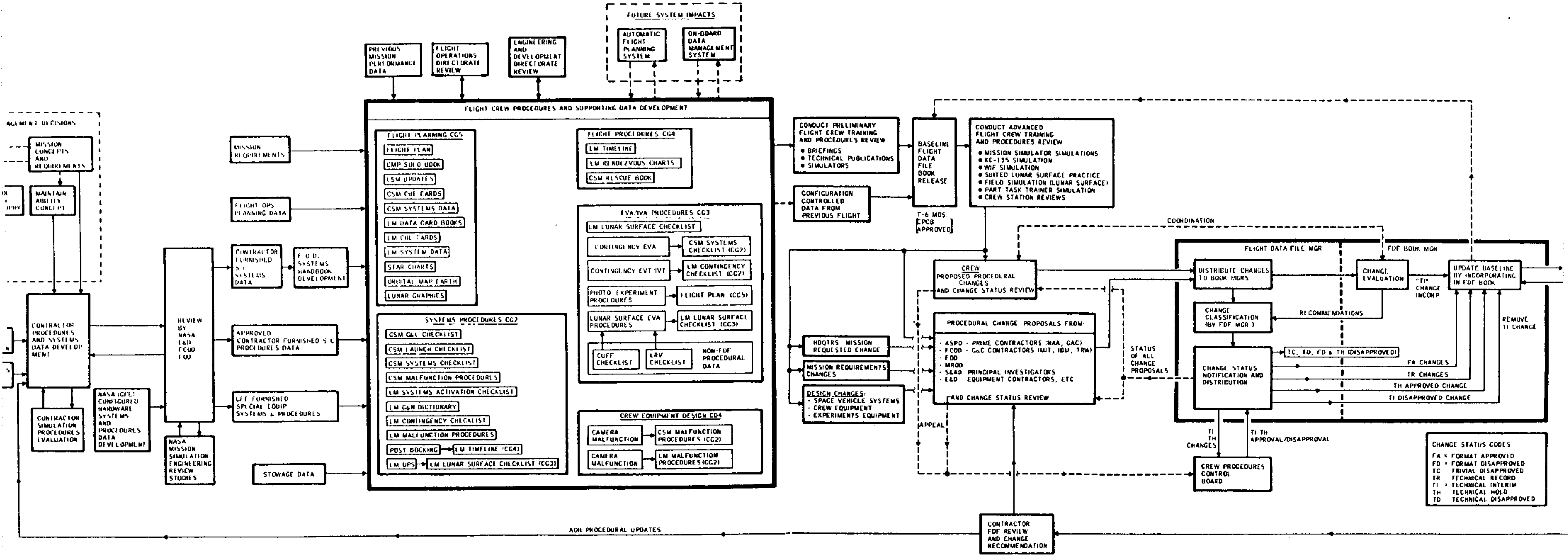


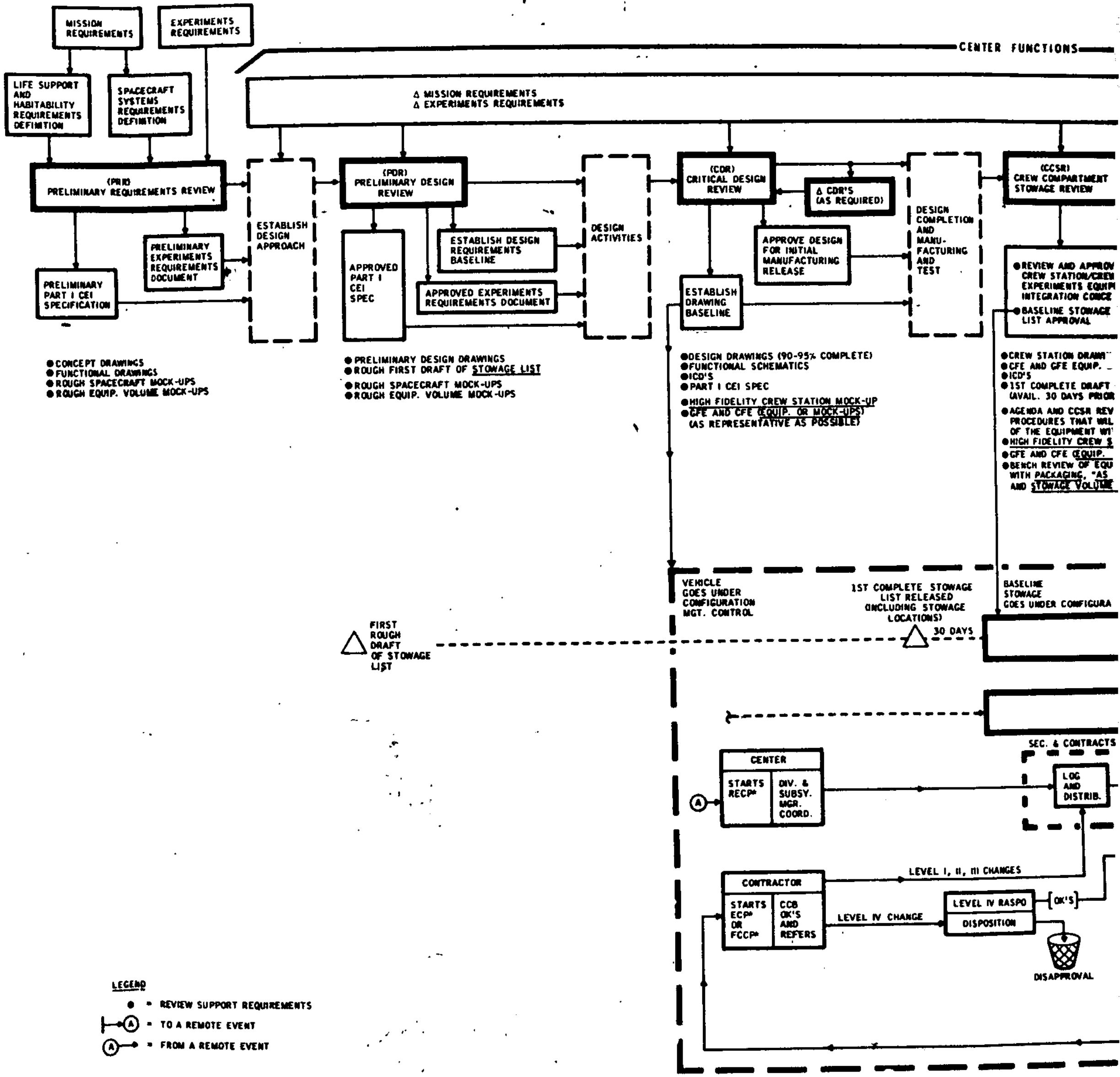
FIGURE 6

FIGURE 7

NASA CREW PROCEDURES/FLIGHT DATA FILE DEVELOPMENT PROCESS



FOLDOUT FRAME /

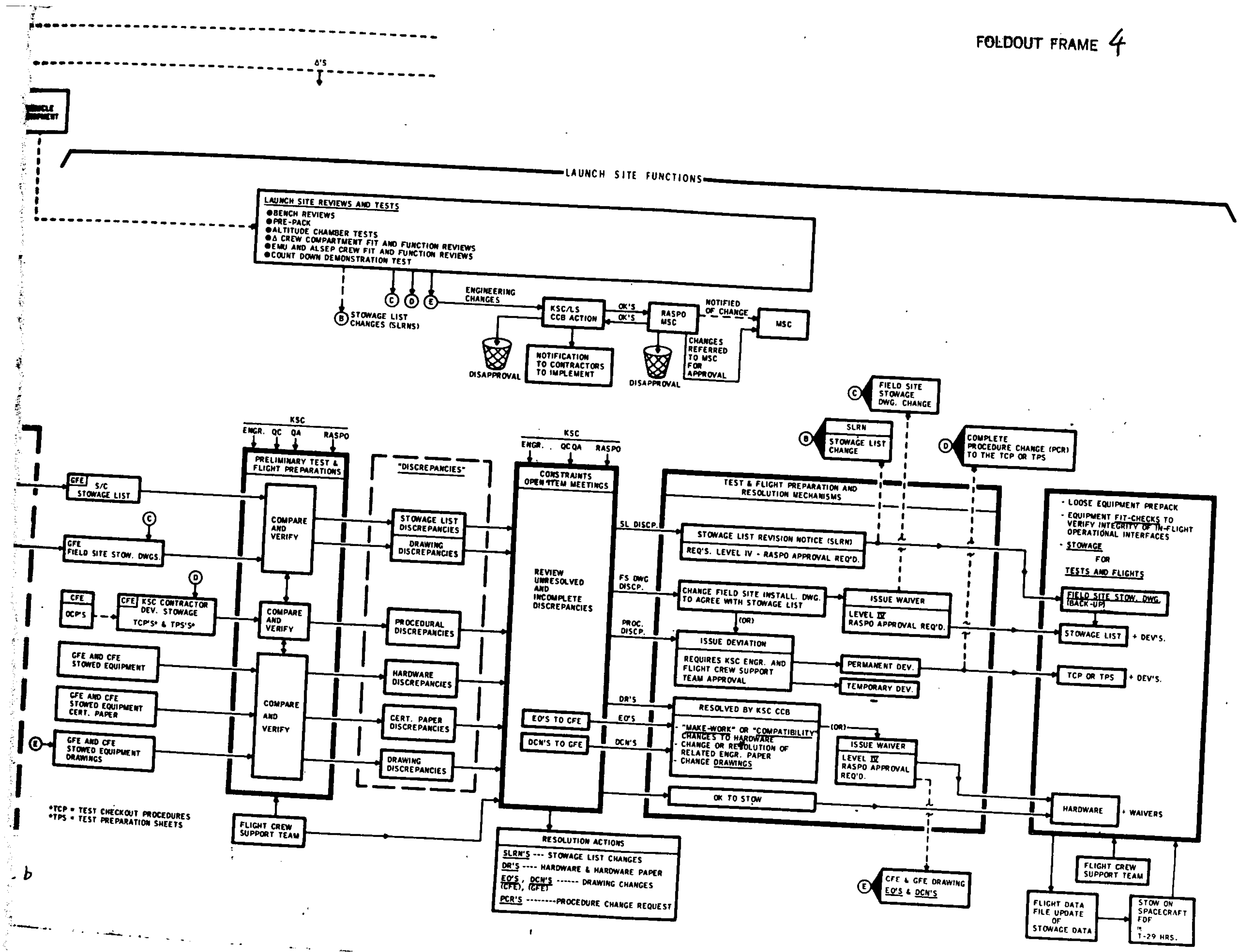


*RECP = REQUEST ENGINEERING CHANGE PROPOSAL
*ECP = ENGINEERING CHANGE PROPOSAL
*FCCP = FIRM CONTRACT CHANGE PROPOSAL

A9

A9-a

FOLDOUT FRAME 4

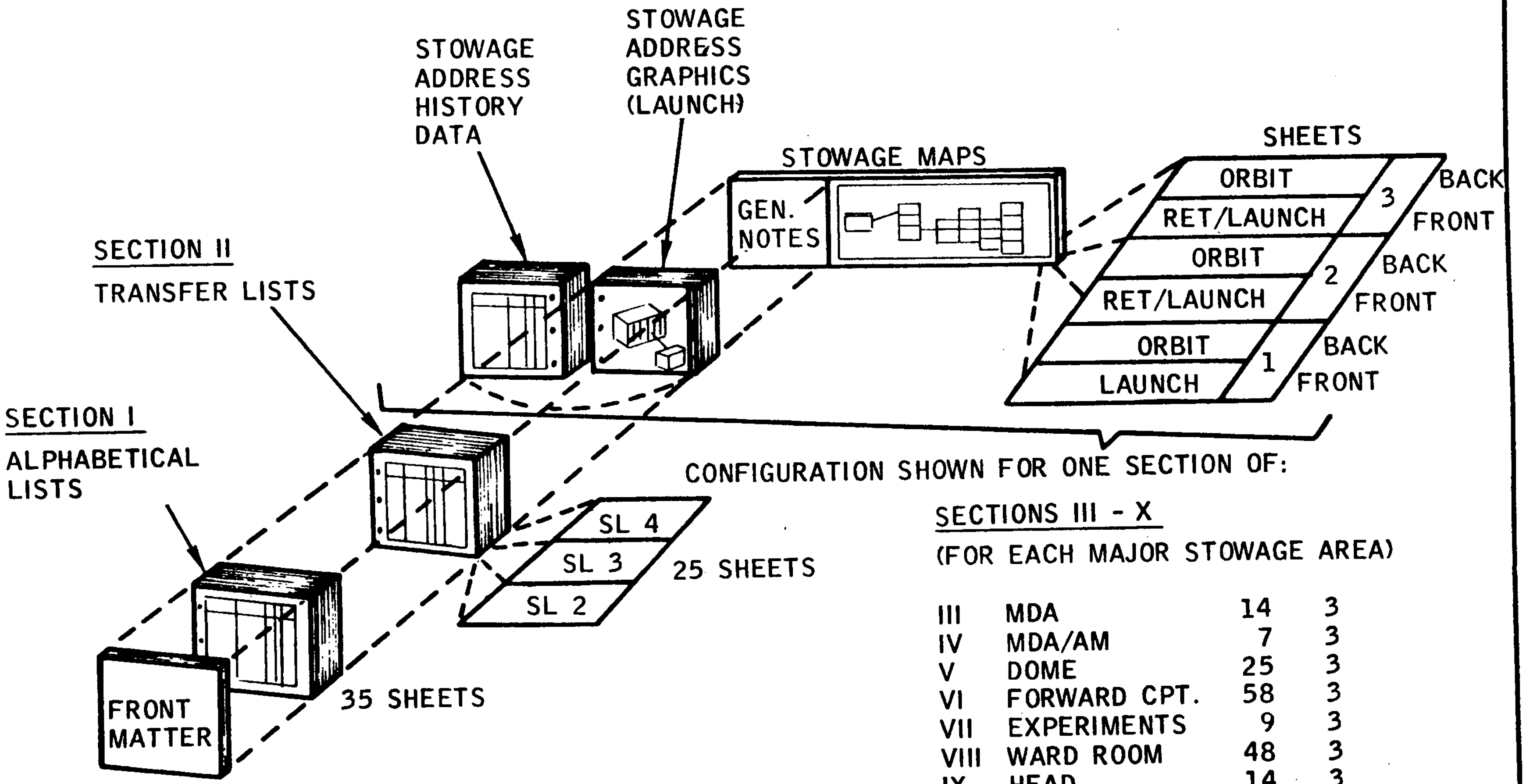


*TCP = TEST CHECKOUT PROCEDURES
*TPS = TEST PREPARATION SHEETS

APPENDIX B

RECOMMENDED DATA FORMATS AND CONTENT DEFINITION FOR THE SKYLAB IN-FLIGHT STOWAGE CONFIGURATION DOCUMENT

FIGURE 1
SUGGESTED IN-FLIGHT STOWAGE CONFIGURATION DOCUMENT



CONFIGURATION SHOWN FOR ONE SECTION OF:

SECTIONS III - X
(FOR EACH MAJOR STOWAGE AREA)

III	MDA	14	3
IV	MDA/AM	7	3
V	DOME	25	3
VI	FORWARD CPT.	58	3
VII	EXPERIMENTS	9	3
VIII	WARD ROOM	48	3
IX	HEAD	14	3
X	SLEEP	22	3
		197	24
		SHEETS	

TOTAL SHEETS = 281 (562 PAGES)

FIGURE 2
ALPHABETICAL STOWAGE ITEM/LOCATION DATA

PAGE _____

S/L ITEM NO.	NOMENCLATURE	LAUNCH CONFIGURATION STOWAGE ADDRESS (QUANTITY)		
		SL 1/2	SL 3	SL 4
1057.00.00	ABSORBERS, CO_2	M125(10) A4(4) A6(4) ECU(2)	M125(10) A4(4) A6(4) ECU(2)	M125(10) A4(4) A6(4) ECU(2)
0610.30.00	BAG, LAUNCH PINS	F527(1)	---	---
0610.31.00	BUNGEE RESTRAINT, GENERAL PURPOSE	W736(20)	W736(20)	W736(20)
1025.00.00	FIRE EXTINGUISHER	M180(1) D498(1) E670(1) E632(1)	M180(1) D498(1) E670(1) E632(1)	M180(1) D498(1) E670(1) E632(1)
0600.71.09	O-RING EXTRACTOR	F520(1)	F520(1)	F520(1)
0600.72.00	REPAIR KIT (WS)	F520(1)	F520(1)	F520(1)
0612.09.01	RESTRAINT ASSEMBLY, GEN. PURPOSE (LONG)	W736(20)	W736(20)	W736(20)
1151.00.00	VALVE, O_2, CRYOVENT ATMOSPHERE CONTROL	A9(1)	D400(1)	D400(1)

PAGE ___ OF ___

FIGURE 3
STOWAGE TRANSFER LIST

STOWAGE LIST ITEM NO.	ITEM NOMENCLATURE	FROM	TRANS. DEVICE	QTY.	TO	REMARKS
CM → SL 2 ORBIT TRANSFER (GET 028:00)						
0001.00.00	GARMENT, CONSTANT WEAR	A7	ISA BAG (A3)	10	W701	(5) NOTE: ISA BAG TEMP. STOWED IN W700
					W702	(3)
					M102	(2)
0002.00.00	HELMET BAG	A3		5	F502	
0003.00.00	CLAMP, UCTA	B6		3	F506	
↓ BY S/L ITEM NO.	" , "	B5		2		
SL 2 → CM RETURN TRANSFER (GET 620:00)						
0007.00.00	O-RING EXTRACTOR	W703	---	5	A7	
0009.00.00	REPAIR KIT	F501	ISA BAG (W700)	10	A8	NOTE: ISA BAG STOWED IN (A3)
0010.00.00	BUNGEE RESTRAINT	F502		5	A7	

NOTE: EXAMPLES ABOVE FOR ILLUSTRATION ONLY.

FIGURE 4
LOCKER LAUNCH CONFIGURATION GRAPHICS

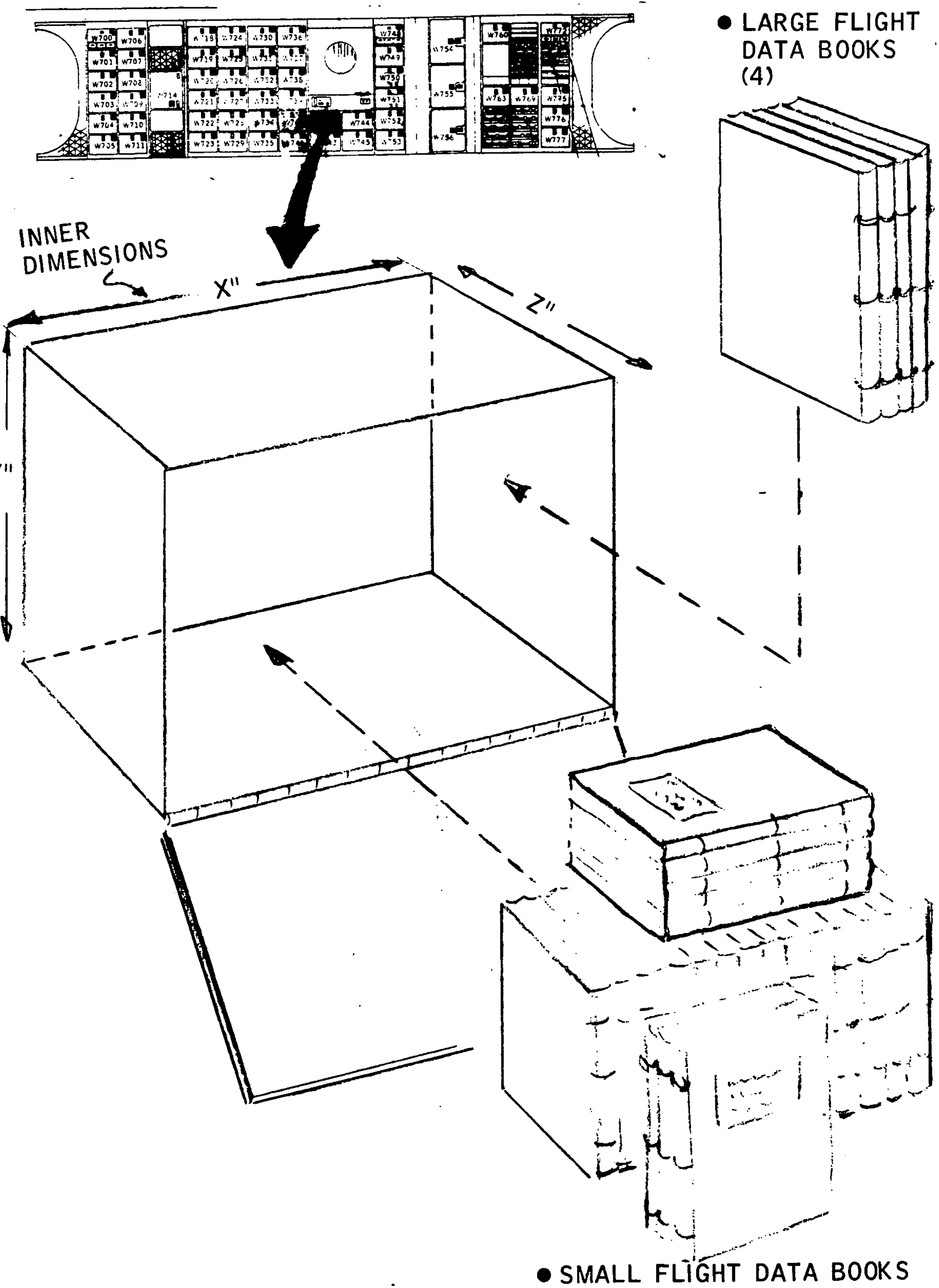


FIGURE 5
LOCKER ADDRESS STOWAGE HISTORY

PAGE ____

LOCKER NO. W755

		QUANTITY					
		SKYLAB					
		1	2		3		4
NOMENCLATURE	S/L ITEM NO.	L	O	R-L	O	R-L	O
FOOD, FROZEN	0209.01.03						
● OVERCANS	---	10	10	0	10	0	10
● CANS	---	120	120	0	120	0	120
● BALING	---	1	1	0	1	0	1

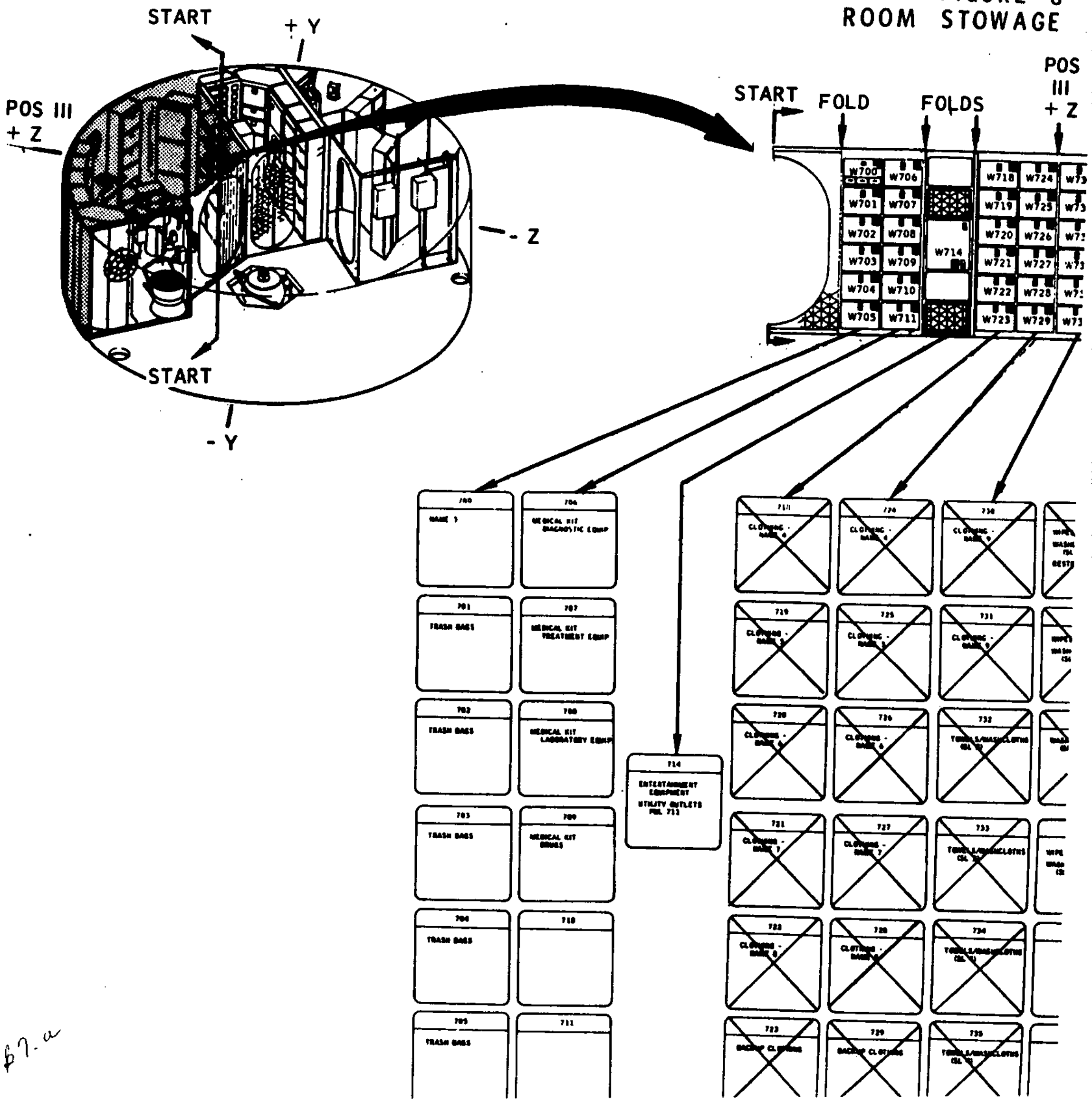
FOLDOUT FRAME 1

WARD ROOM (W700 - W799) GENERAL NOTES

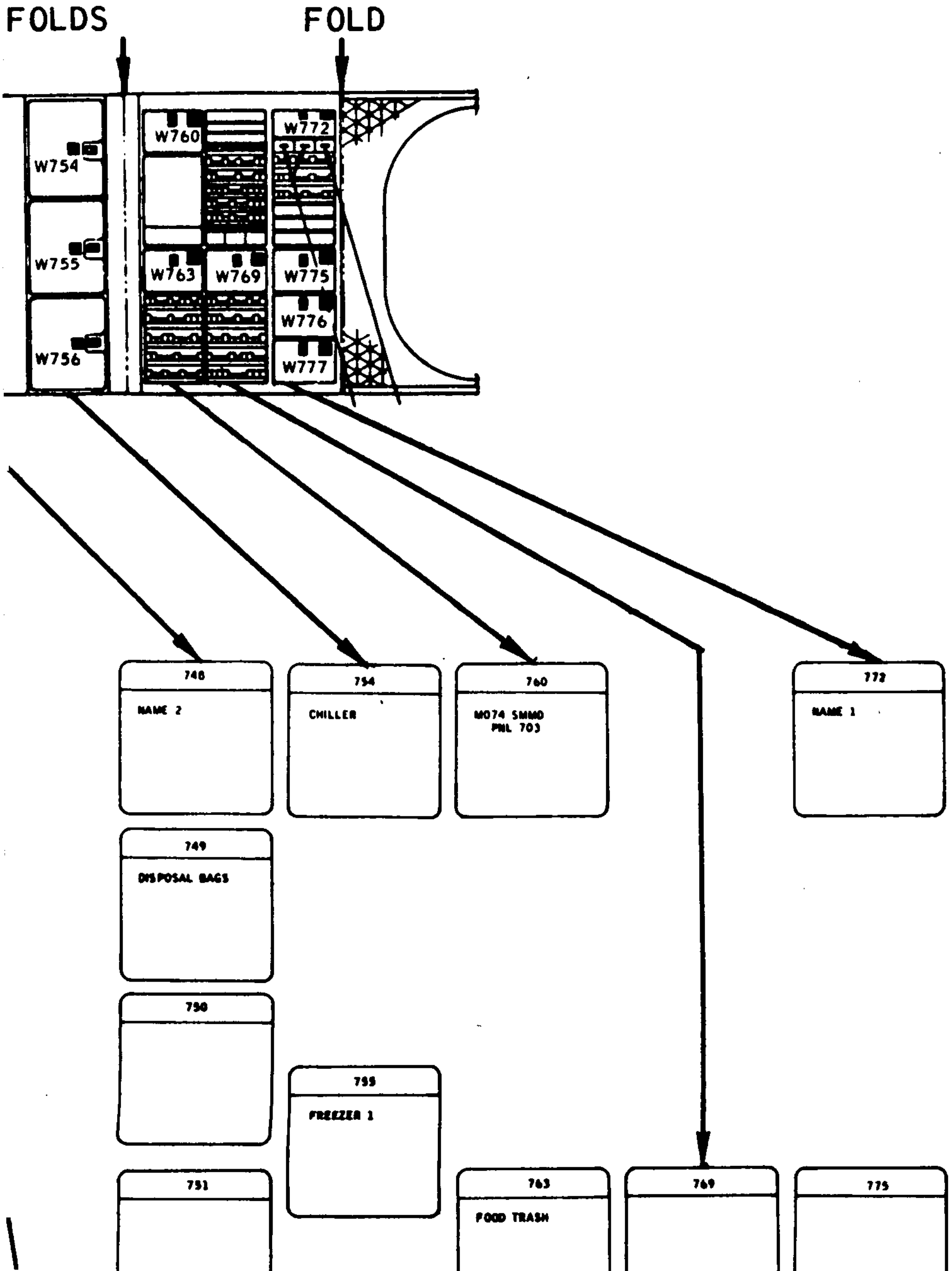
(W1) COMPARTMENTS SHOWN WITH "X" ARE THOSE THAT ARE NOT NOMINALLY USED ON THE MISSION BEING ILLUSTRATED.

FOLDOUT FRAME 2

FIGURE 6
ROOM STOWAGE



FOLDOUT FRAME 3



SL 1/2 LAUNCH

W700'S

OM

APPENDIX C

OPERATIONAL
LOCATION CODING SYSTEM
FOR
FUTURE MANNED SPACE STATION
PROGRAMS

PREPARED BY

GENERAL ELECTRIC

APOLLO & GROUND SYSTEMS
HOUSTON PROGRAMS

- A REVIEW OF PRESENT METHODS OF LOCATION CODING IN THE APOLLO AND SKYLAB PROGRAMS WAS CONDUCTED TO DETERMINE THE ADEQUACIES OF THESE METHODS FOR FUTURE SPACE STATION OPERATIONAL LOCATION CODING REQUIREMENTS.

- PRESENT SYSTEMS DID NOT APPEAR TO SATISFY ALL REQUIREMENTS FOR FUTURE SPACE STATION PROGRAMS.

- STUDY WAS INITIATED TO DEVELOP A STANDARD SPECIFIABLE METHOD OF LOCATION CODING FOR SPACE STATION APPLICATIONS.

THE OPERATIONAL LOCATION CODING SYSTEM

- SHOULD BE DESIGNED TO PROVIDE A STANDARD METHOD OF LOCATION CODING OF CREW INTERFACE ITEMS INCLUDING:
  - CONTROL/DISPLAY PANELS
  - STOWAGE AREAS OR LOCKERS
  - ACCESS PANELS
  - SYSTEMS COMPONENTS

  } FOR IN-FLIGHT SERVICING AND MAINTENANCE

- LOCATION CODE ALONE SHOULD PROVIDE DATA ON WHERE ITEM CAN BE FOUND:
  - WITHIN SPACE STATION CONFIGURATION
  - WITHIN MODULE (ROOM)
  - WITH ACCEPTABLE ACCURACY TO A SPECIFIC LOCATION WITHIN ROOM

THE OPERATIONAL LOCATION CODING SYSTEM (CONT.)

- MUST HAVE GENERIC APPLICATIONS FOR MAJOR STATION CONFIGURATIONS UNDER STUDY CONSIDERATION.

- SHOULD BE BRIEF, SIMPLY UNDERSTOOD AND USEFUL FOR:
  - DESIGNATIONS OF CONTROL/DISPLAY PANEL LOCATIONS ON SCHEMATIC DATA
  - STOWAGE LIST LOCATION DATA
  - FLIGHT CREW OPERATIONS AND IN-FLIGHT MAINTENANCE PROCEDURES DATA
  - MANUFACTURING AND GROUND PREPARATIONS
  - TEST AND CHECKOUT PROCEDURES DATA

STATION STUDY CONFIGURATIONS

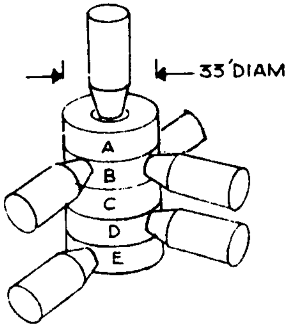
CONFIGURATIONS BEING CONSIDERED FOR SPACE STATIONS INCLUDE:

I. "ZERO G" CONFIGURATIONS

- INTEGRAL SPACE STATIONS*

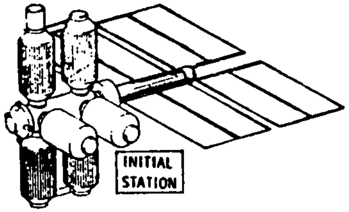
  INCLUDE:
  - LARGE INNER CORE (33' DIAMETER)
  - DOCKED PAYLOAD MODULES IN CRUCIFORM CONFIGURATION AROUND CORE

  *FURTHER STUDY IS NOT BEING CONDUCTED ON THIS CONFIGURATION AT PRESENT.

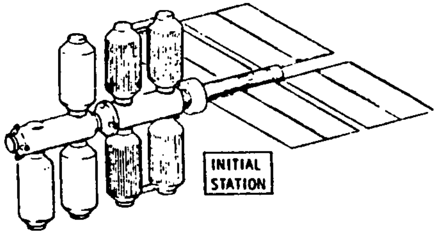


- MODULAR SPACE STATIONS (ALL MODULES LAUNCHED AS SHUTTLE PAYLOADS)

  INCLUDE:
  - CRUCIFORM CONFIGURATION
    - MODULAR CORE MODULES WITH MULTIPLE DOCKING PORTS FOR PAYLOAD MODULES ARRANGED AT 90° POINTS AROUND CORE GIVING "CROSS-FORM."

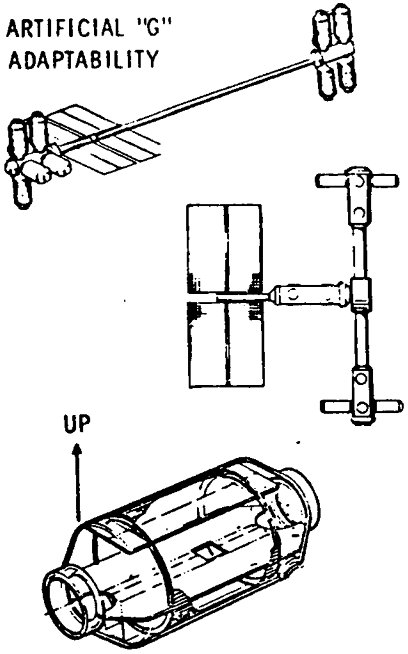


  - BARBELL CONFIGURATION
    - PAYLOAD CORE MODULES WITH MULTIPLE DOCKING PORTS FOR PAYLOAD MODULES ARRANGED AT 180° POINTS AROUND CORE OR IN "OPPOSITION" TO FORM "BARBELL" EFFECT.



STATION STUDY CONFIGURATIONS (CONT.)

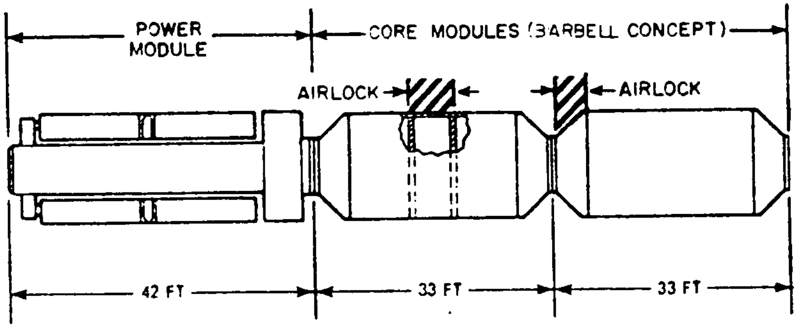
II. "ARTIFICIAL G" CONFIGURATION

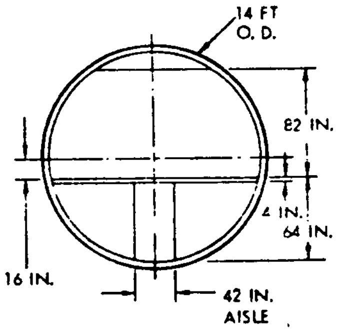


- CONSISTS OF BASIC "CROSS-FORM" WITH
- STATION MODULES AT OPPOSITE ENDS OF ONE SPOKE AXIS DOCKED INTO SPOKE MODULES IN BARBELL FASHION.
- POWER MODULES AND OTHER STATION MODULES ARRANGED ON OTHER AXIS.

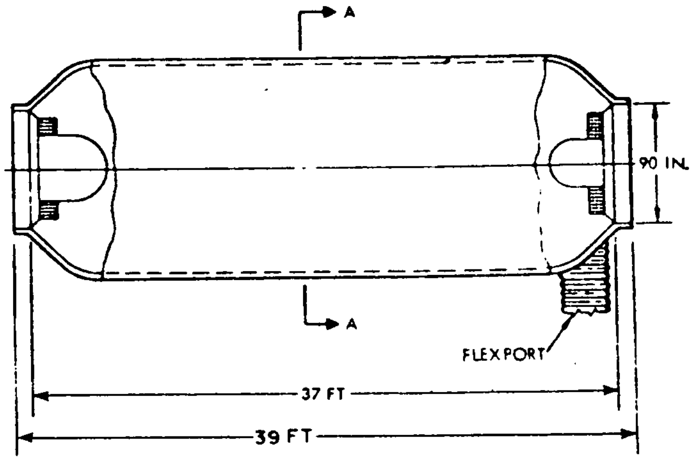
MODULAR SPACE STATION

(BASIC MODULE DIMENSIONS BEING CONSIDERED THAT CODING SYSTEM SHOULD BE CAPABLE OF HANDLING.)





SECTION A-A
ROTATED 90°



CODING SYSTEM STUDY BACKGROUND

- IF POSSIBLE, IT WOULD BE DESIRABLE TO HAVE A CODING SYSTEM DIRECTLY RELATED TO THE ESTABLISHED DESIGN AXES OF THE SPACECRAFT WITH UNIFORM STANDARD LOCATION CODING UNITS.

- HOWEVER, WHEN SUCH A 3-AXES CODING SYSTEM IS EMPLOYED, THE LOCKER DESIGNATIONS, WHEN OPERATIONALLY VIEWED IN THE SPACECRAFT, HAVE NO APPARENT ORDER OR MEANING IN THEIR NUMBERED ARRANGEMENTS.

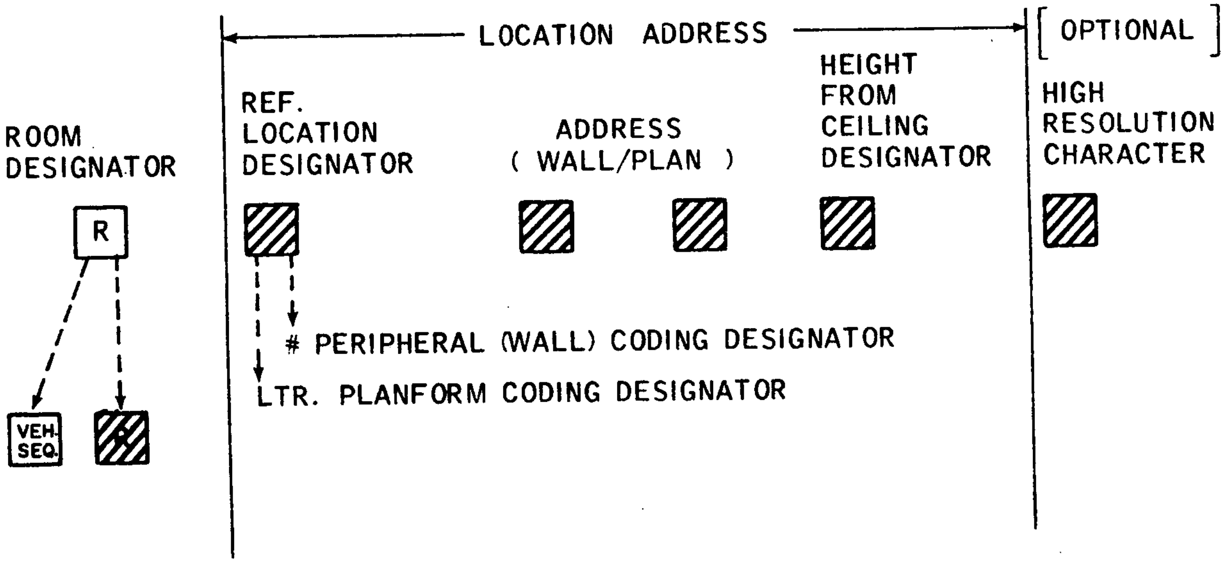
- THEREFORE, A NEED EXISTS FOR A SYSTEM THAT WILL APPEAR LOGICAL AND ORDERLY TO OPERATIONAL PERSONNEL.

- NUMEROUS SYSTEMS HAVE BEEN EXAMINED AND A COMBINATION WALL PERIMETER/PLANFORM GRID SYSTEM APPEARS TO BE THE MOST FEASIBLE SYSTEM FOR PROVIDING UNIQUE LOCATION DATA AND APPARENT ORDER FOR OPERATIONS PERSONNEL.

RECOMMENDED

OPERATIONAL LOCATION CODING SYSTEM

- IT IS BASICALLY A FIVE - CHARACTER CODING SYSTEM FOR EACH MODULE (A SIX - CHARACTER CODE FOR COMPLETE STATION IDENTIFICATION).



LOCATION ADDRESS

[OPTIONAL]

ROOM DESIGNATOR

R

VEH. SEQ.

REF. LOCATION DESIGNATOR

ADDRESS (WALL/PLAN)

HEIGHT FROM CEILING DESIGNATOR

HIGH RESOLUTION CHARACTER

\# PERIPHERAL (WALL) CODING DESIGNATOR

LTR. PLANFORM CODING DESIGNATOR

- "<u>MIDPOINT</u>" OF <u>ITEM TO BE LOCATED</u> IS CODED WITH REFERENCE TO A STANDARD ROOM AREA GRID.

- LOCATION ADDRESS CODING SYSTEM USES A STANDARD UNIT SIZE WHICH IS A FUNCTION OF VEHICLE SIZE.

RECOMMENDED OPERATIONAL LOCATION CODING SYSTEM
(PERIPHERAL/PLANFORM GRID SYSTEM)

ROOM	ROOM LOCATION REFERENCE		ADDRESS						
			WALL GRID (#'S)	PLAN GRID LETTERS #'S - OPT.	WALL GRID (#'S)	PLAN GRID LETTERS #'S - OPT.	HEIGHT GRID LETTERS #'S - OPT.	HIGH RESOLUTION CHARACTER LETTERS #'S	
(LETTERS) A ↓ Z * (#'S) 0 ↓ 9	PERIPHERAL	(#'S) WALL FRONT " — WALL HIDDEN " 0 ← 5 1 ← 6 2 ← 7 3 ← 8 4 ← 9	0 ↓ 9		0 ↓ 9		A ↓ Z *	(LETTERS) BEHIND WALL SCALING CODE A ↓ Z *	(#'S) DISCRETE FOR WITHIN LOCKER GRID, BACK-OF-LOCKER, OR IN FRONT OF HIDDEN WALL 0 ↓ 9
	PLANFORM	(LETTERS) A = ABOVE CEILING C = CEILING B = BELOW CEILING 0 = OVER FLOOR F = FLOOR U = UNDER FLOOR E = EXTERNAL		A ↓ Z * 0 ↓ 9 OPT.		A ↓ Z * 0 ↓ 9 OPT.	0 ↓ 9 OPT.	A ↓ Z * PLANFORM RESOLUTION CHAR. 1 ↓ 9 HT RESOLUTION CHAR.	

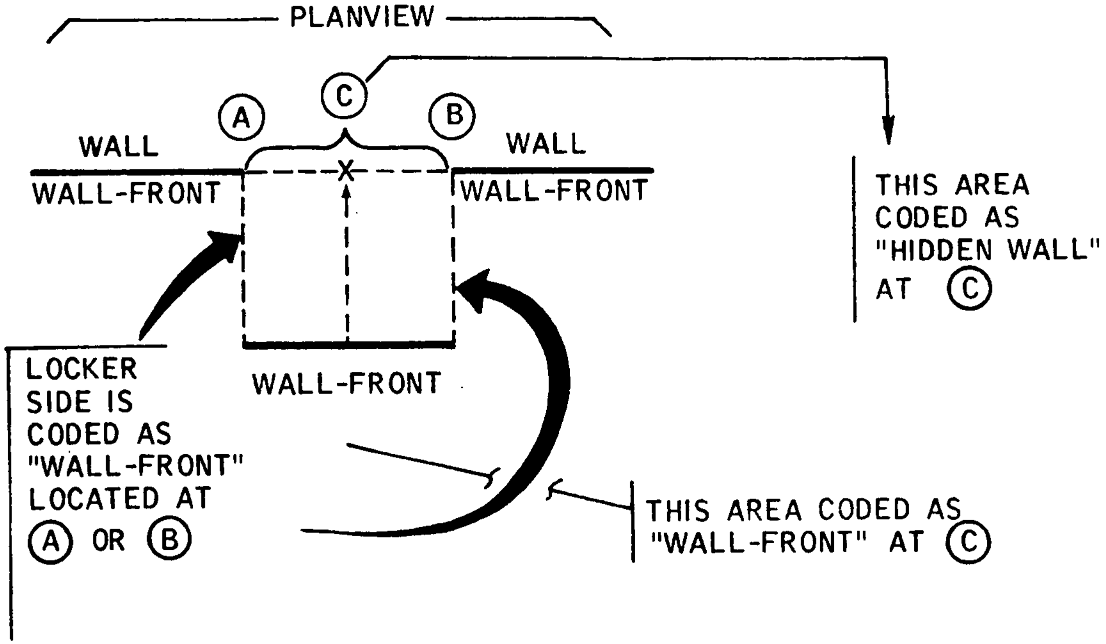
▨ ▨ ▨ ▨ ▨ ▨ = CODE DIGITS

▨ = S MODULE SEQ. + R ROOM

*LETTER "I" OMITTED, LETTER "O" = 0

DEFINITIONS

- **WALL - FRONT** - THE ROOM WALL AREA THAT IS "OPERATIONALLY" VISIBLE TO THE CREWMAN.



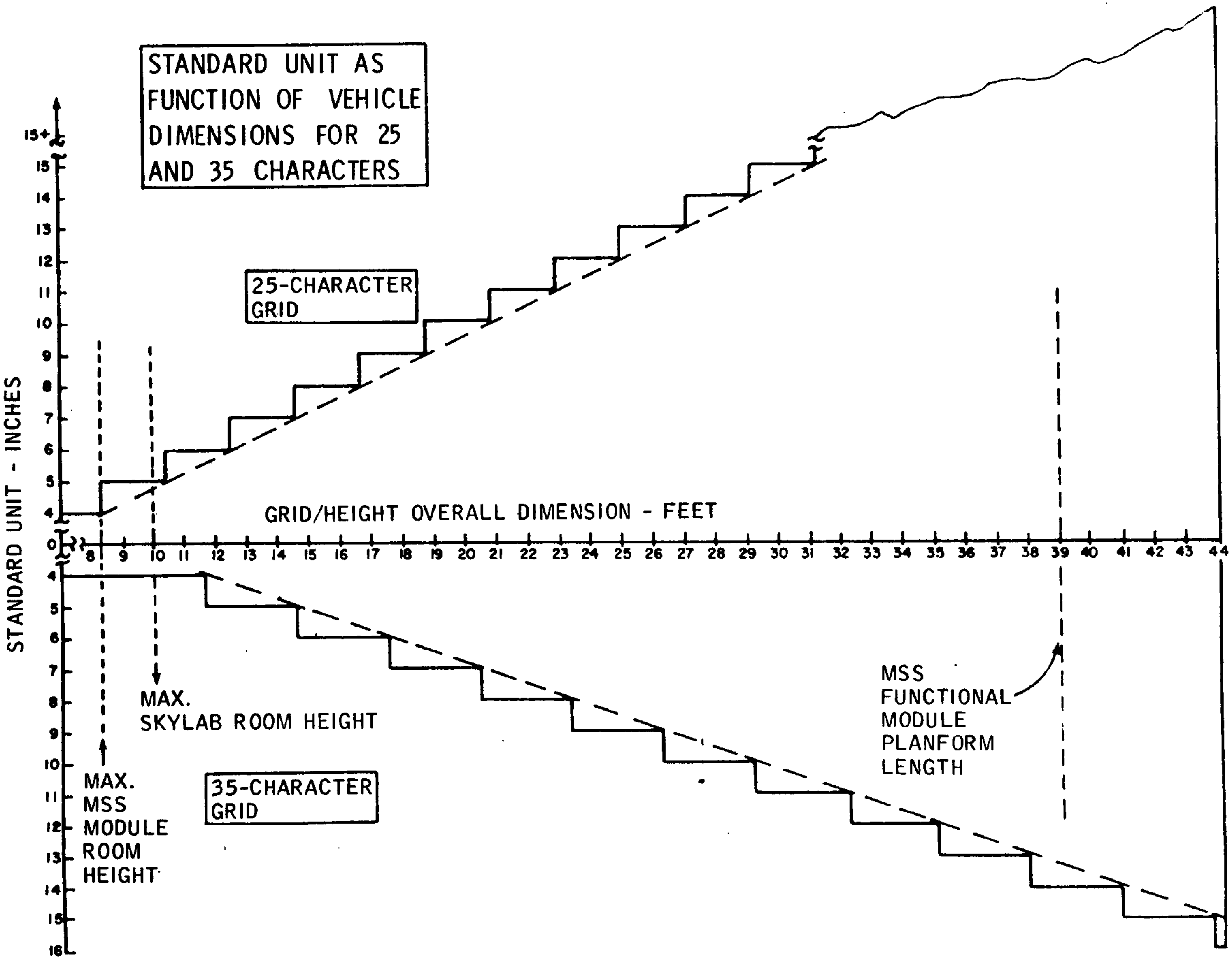
LOCKER SIDE IS CODED AS "WALL-FRONT" LOCATED AT Ⓐ OR Ⓑ

THIS AREA CODED AS "HIDDEN WALL" AT Ⓒ

THIS AREA CODED AS "WALL-FRONT" AT Ⓒ

- **WALL** - THE ROOM WALL PLANE THAT SEPARATES WALL-FRONT FROM "BEHIND - THE - WALL" LOCATIONS.

- **WALL (HIDDEN)** - LOCATION WHICH IS BEHIND A WALL - FRONT AND IS NOT NORMALLY "OPERATIONALLY" VISIBLE TO THE CREW.


STANDARD UNIT AS FUNCTION OF VEHICLE DIMENSIONS FOR 25 AND 35 CHARACTERS
25-CHARACTER GRID
35-CHARACTER GRID
STANDARD UNIT - INCHES
GRID/HEIGHT OVERALL DIMENSION - FEET
15+
15
14
13
12
11
10
9
8
7
6
5
4
0
4
5
6
7
8
9
10
11
12
13
14
15
16
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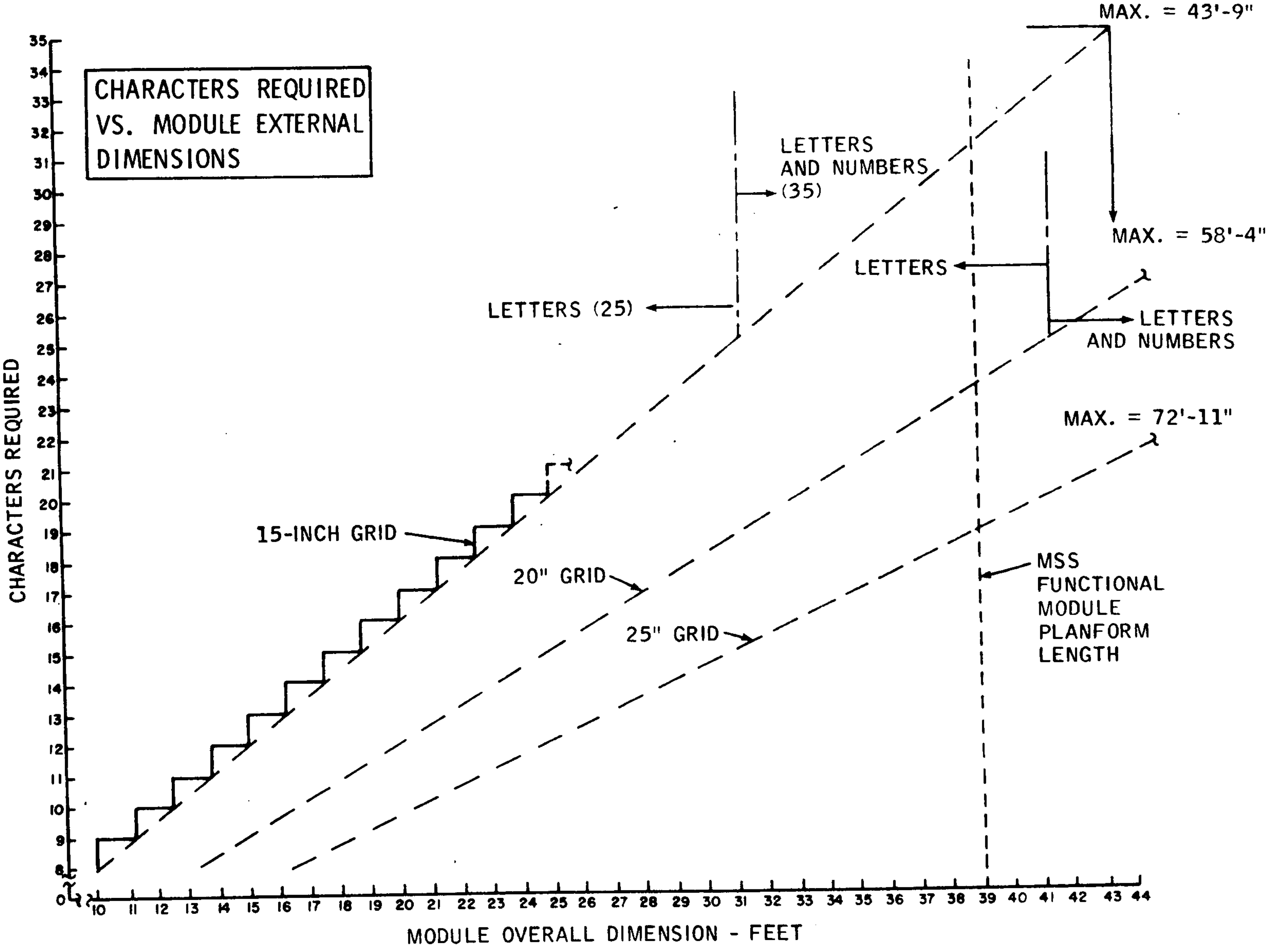
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
MAX. SKYLAB ROOM HEIGHT
MAX. MSS MODULE ROOM HEIGHT
MSS FUNCTIONAL MODULE PLANFORM LENGTH


CHARACTERS REQUIRED VS. MODULE EXTERNAL DIMENSIONS
CHARACTERS REQUIRED
0
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
MODULE OVERALL DIMENSION - FEET
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
15-INCH GRID
20" GRID
25" GRID
LETTERS (25)
LETTERS AND NUMBERS (35)
MAX. = 43'-9"
MAX. = 58'-4"
LETTERS
LETTERS AND NUMBERS
MAX. = 72'-11"
MSS FUNCTIONAL MODULE PLANFORM LENGTH

STANDARD UNIT RECOMMENDATIONS

MEASURED ELEMENT	RECOMMENDED STANDARD UNIT	REMARKS
WALL HEIGHT	4 INCHES	LETTERS ONLY ADEQUATE FOR WALLS 8'-4" OR LESS. LETTERS AND DIGITS ADEQUATE FOR WALLS 11'-8" OR LESS. 6" SCALE = 12-1/2 AND 17-1/2 FEET RESPECTIVELY.
WALL PERIMETER	4 INCHES (500 CODE UNITS, 000 - 499)	ADEQUATE FOR ROOM PERIMETER UP TO 166-2/3 FEET. IF FUTURE ROOMS EXCEED THIS AMOUNT, EXPAND WALL SCALE. 6" SCALE = 250 FEET.
PLANFORM GRID	15-INCH SQUARE	IF NUMBERS AND LETTERS ARE USED, THIS STANDARD UNIT IS ADEQUATE FOR ROOMS WHOSE LONGEST DIMENSION IS 43'-9". EXTRA RESOLUTION LETTER RESOLVES PLANFORM LOCATION TO A 3" SQUARE. IF LARGER ROOM DIMENSION CODING REQUIRED, RECOMMEND GRID SIZE INCREASE: • 20" = [58'-4" MODULE] RESOLUTION TO 4" SQUARE • 25" = [72'-11" MODULE] RESOLUTION TO 5" SQUARE

ROOM CODING

("DESIRABLE" CRITERIA FOR ROOM CODING SYSTEM)

1) SHOULD USE ONLY A 1 - CHARACTER CODE -

(MAXIMUM** CODING CAPABILITY = 35 ROOMS
A - Z (0 = 0; I IS OMITTED) + 0 THRU 9)

HOWEVER, REVIEW OF STATION CONFIGURATIONS INDICATE NUMBER OF ROOMS MAY EXCEED 35 IN THE INITIAL CONFIGURATIONS, AND WILL CERTAINLY EXCEED THAT NUMBER IN GROWTH STATIONS.

2) SHOULD PROVIDE DATA AS TO LOCATION OF ROOM AND ITS MODULE WITHIN STATION -

THE CAPABILITY TO RECONFIGURE A SPACE STATION AND THE CONTINGENCY OF NOT BEING ABLE TO DOCK IN PLANNED STATION LOCATION CAN DEFEAT THE PURPOSE OF ANY CODING SYSTEM BASED SEQUENTIALLY ON THE PLANNED LOCATION OF MODULES IN STATION.

3) SHOULD PROVIDE A USEFUL MNEMONIC RELATIONSHIP TO ROOM FUNCTION -

(E.G., S = SLEEP ROOM, IF POSSIBLE
H = HEAD
W = WARDROOM, ETC.)

THE CODING OF A ROOM'S FUNCTIONAL NAME LOSES ITS VALUE WHEN A LARGE NUMBER OF ROOMS WITH SIMILAR FUNCTIONS ARE REQUIRED.

**BASED ON ASSUMPTIONS THAT COMPUTER PRINTOUT AND CONVENTIONAL TYPEWRITERS WILL HAVE CAPABILITY TO REPRODUCE THESE CODES.

ROOM CODING EVALUATIONS

- ONE-CHARACTER CODE IS INSUFFICIENT TO DESIGNATE ROOMS OF STATION CONFIGURATIONS NOW UNDER STUDY. THEREFORE, A TWO-CHARACTER CODE IS REQUIRED FOR UNIQUE DESIGNATION CAPABILITY OF ALL THE ROOMS IN STATION. (CRITERIA 1 CANNOT BE SATISFIED.)

- DUE TO STATION LOCATION REDESIGNATIONS RESULTING FROM RECONFIGURATION, EXCHANGE OF MODULES OR "CONTINGENCY" DOCKING, IT APPEARS THAT A PREDETERMINED LOCATION DESIGNATOR FOR A MODULE IS NOT FEASIBLE. (CRITERIA 2 CANNOT BE SATISFIED IF STATION CONFIGURATION IS NOT STABLE.) HOWEVER, A MODULE DEVELOPMENT SEQUENCE WOULD BE USABLE AS A UNIQUE DESIGNATOR FOR THE MODULE. (1ST CHARACTER OF CODE) AND SUCH A DESIGNATION COULD BE TABULARLY RELATED TO STATION LOCATION, IF REQUIRED.

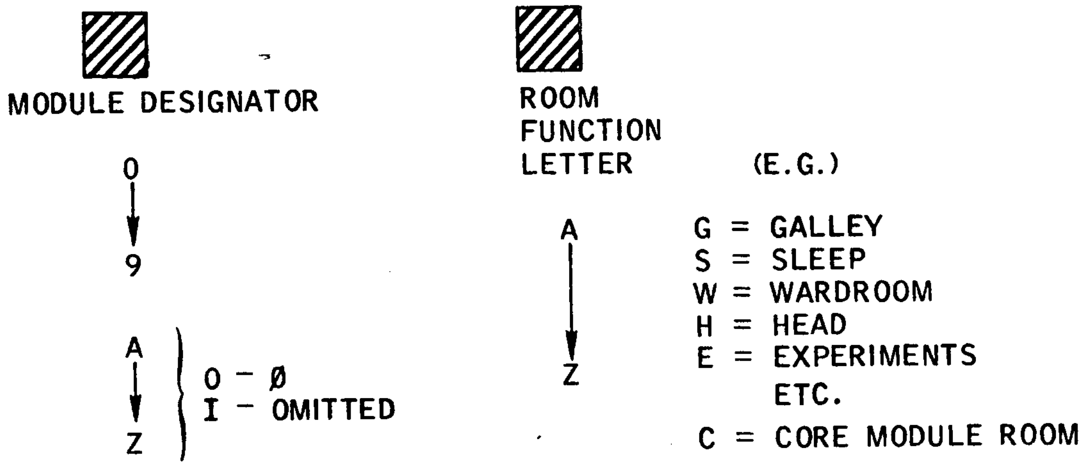
- IN CONJUNCTION WITH AN INITIAL MODULE DESIGNATOR CHARACTER, THE USAGE OF A FUNCTIONAL ROOM DESIGNATOR LETTER CHARACTER BECOMES FEASIBLE SINCE UNIQUENESS OF THE CODE NOW IS ONLY REQUIRED WITHIN THE MODULE.

SUMMARY

- A TWO-DIGIT ROOM DESIGNATOR CAN PROVIDE THE CODING CAPABILITY FOR A 35-LAUNCH MODULAR SPACE STATION WITH FUNCTIONAL ROOM DESIGNATORS BEING EMPLOYED IN EACH MODULE. THIS CAPABILITY FAR EXCEEDS PRESENT CONFIGURATION STUDIES.

ROOM CODE RECOMMENDATIONS

- USE TWO-DIGIT CODE
- 1ST CHARACTER (LETTERS AND NUMBERS) = SEQUENTIAL ALPHANUMERIC DESIGNATION OF MODULE DEVELOPMENT
- 2ND CHARACTER (LETTERS) = LETTER DESIGNATOR OF ROOM FUNCTION NAME



▨ ▨

MODULE DESIGNATOR

0 → 9

A → Z

O – 0
I – OMITTED

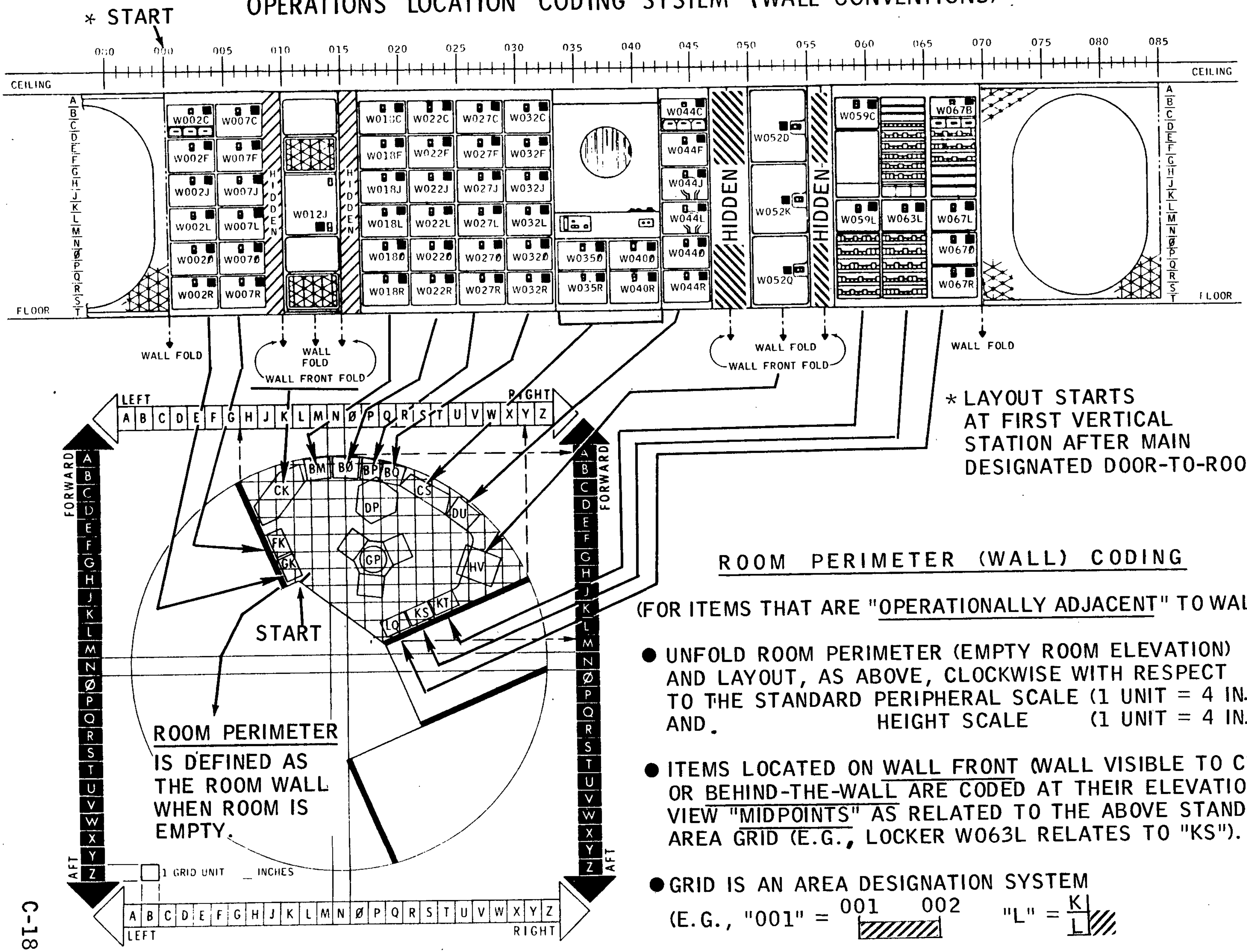
ROOM FUNCTION LETTER

A → Z

(E.G.)

G = GALLEY
S = SLEEP
W = WARDROOM
H = HEAD
E = EXPERIMENTS
ETC.
C = CORE MODULE ROOM

OPERATIONS LOCATION CODING SYSTEM (WALL CONVENTIONS)



* LAYOUT STARTS AT FIRST VERTICAL STATION AFTER MAIN DESIGNATED DOOR-TO-ROOM.

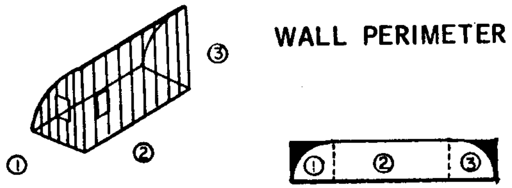
ROOM PERIMETER IS DEFINED AS THE ROOM WALL WHEN ROOM IS EMPTY.

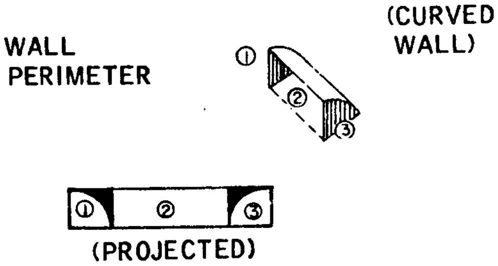
ROOM PERIMETER (WALL) CODING

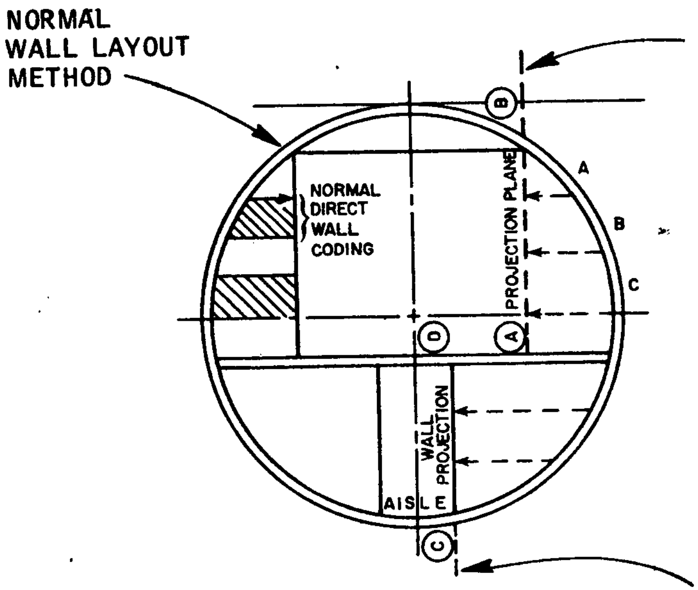
(FOR ITEMS THAT ARE "OPERATIONALLY ADJACENT" TO WALL)

- UNFOLD ROOM PERIMETER (EMPTY ROOM ELEVATION) AND LAYOUT, AS ABOVE, CLOCKWISE WITH RESPECT TO THE STANDARD PERIPHERAL SCALE (1 UNIT = 4 IN.) AND. HEIGHT SCALE (1 UNIT = 4 IN.)
- ITEMS LOCATED ON WALL FRONT (WALL VISIBLE TO CREW) OR BEHIND-THE-WALL ARE CODED AT THEIR ELEVATION VIEW "MIDPOINTS" AS RELATED TO THE ABOVE STANDARD AREA GRID (E.G., LOCKER W063L RELATES TO "KS").
- GRID IS AN AREA DESIGNATION SYSTEM (E.G., "001" = 001 002 ▨ "L" = K L ▨)

QUONSET-TYPE WALL CONVENTIONS

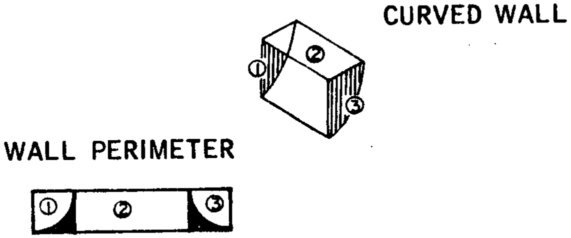






- **CURVED WALL ON PROJECTED PLANE**

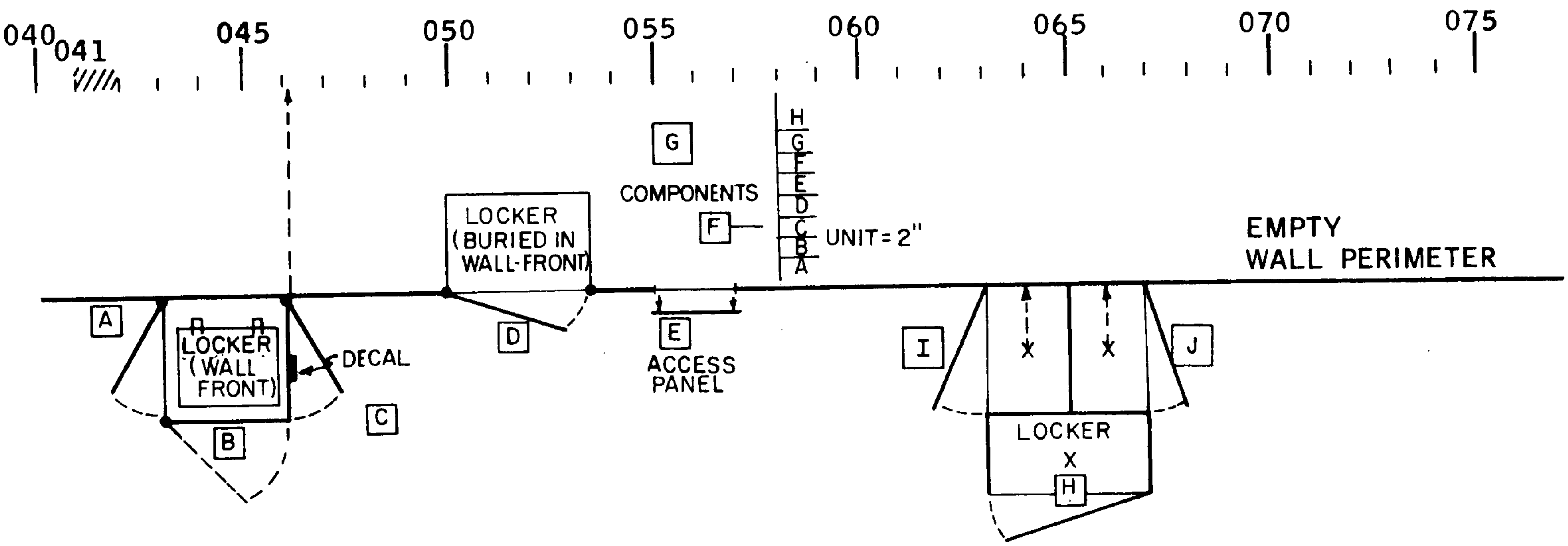
CODING OF CURVED (QUONSET) WALL (B) IS THRU PROJECTIONS OF THE WALL ONTO THE PROJECTION PLANE Ⓐⓑ WHICH IS ॥ TO THE VERTICAL (UP-DOWN) PLANE.



- **CURVED WALL ON WALL PROJECTION**

CODING OF CURVED (QUONSET) WALL ON WALL PROJECTION IS THRU PROJECTIONS ONTO PLANE (CD) WHICH IS ॥ TO VERTICAL PLANE.

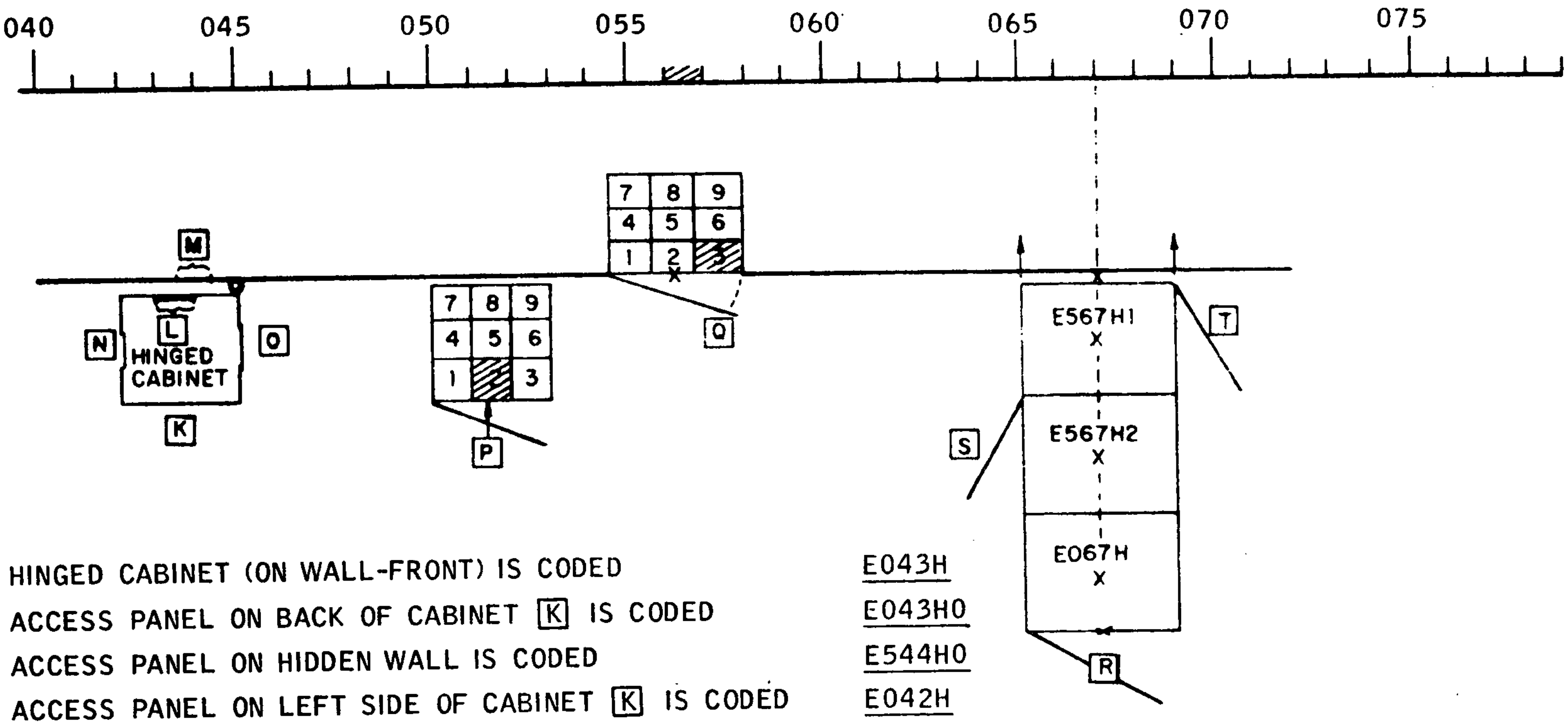
WALL PERIMETER CODING CONVENTIONS



A	EQUIPMENT ON WALL-FRONT IS CODED AS	E041H*	
B	LOCKER ON WALL-FRONT IS CODED AS	E044H	(DECAL PLACED ON DOOR-OPENING OF LOCKER)
C	DECAL LOCATION ON LOCKER B IS CODED AS	E046H	
D	LOCKER (BURIED IN WALL-FRONT) IS CODED AS	E051H	
E	ACCESS PANEL ON WALL-FRONT IS CODED AS	E055H	
F	COMPONENT (BEHIND WALL) IS CODED AS	E556HC	(BEHIND ACCESS PANEL E055H)
G	COMPONENT (BEHIND WALL) IS CODED AS	E555HH	(BEHIND ACCESS PANEL E055H)
H	LOCKER ON WALL-FRONT IS CODED AS	E065H	
I	HIDDEN LOCKER IS CODED AS	E564H1	
J	HIDDEN LOCKER IS CODED AS	E566H1	

*ALL HEIGHT CODES = "H" FOR SIMPLICITY IN EXAMPLES
ROOM CODE = "E" FOR SIMPLICITY IN EXAMPLES

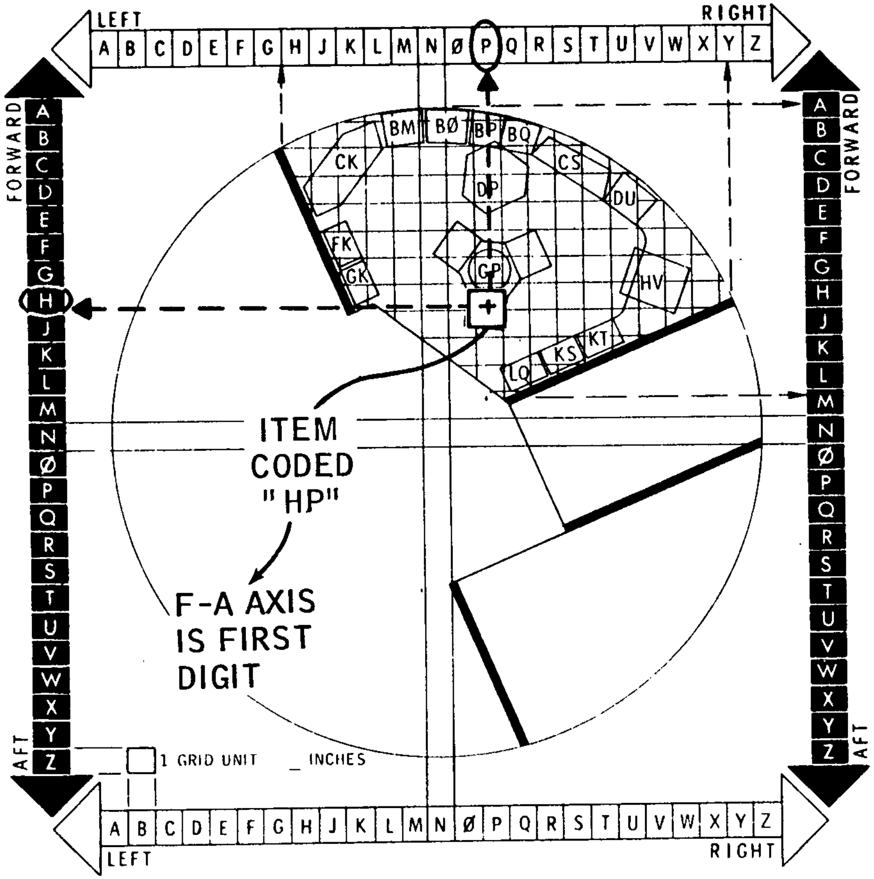
WALL PERIMETER CODING CONVENTIONS (CON'T)



K	HINGED CABINET (ON WALL-FRONT) IS CODED	E043H
L	ACCESS PANEL ON BACK OF CABINET K IS CODED	E043H0
M	ACCESS PANEL ON HIDDEN WALL IS CODED	E544H0
N	ACCESS PANEL ON LEFT SIDE OF CABINET K IS CODED	E042H
O	ACCESS PANEL ON RIGHT SIDE OF CABINET IS CODED	E045H
P	COMPONENT OR ITEM WITHIN WALL-FRONT LOCKER IS CODED	E051H2
Q	COMPONENT OR ITEM WITHIN BURIED WALL-FRONT LOCKER IS CODED	E056H3
R	LOCKER ADDED TO WALL-FRONT IS CODED	E067H
S	ADDED HIDDEN LOCKER IS CODED	E567H2
T	ADDED HIDDEN LOCKER IS CODED	E567H1

PLANFORM CODING CONVENTIONS (DECK)

(FOR ITEMS THAT ARE "OPERATIONALLY" REMOTE FROM WALL OR WALL-FRONT)



- ROOM PLANFORM (FLOOR, CEILING, ETC.) IS LAID OUT WITH RESPECT TO THE STANDARD PLANFORM SCALE

  FORWARD = AFT* (15" UNIT DIMENSION)
  LEFT = RIGHT* (15" UNIT DIMENSION)

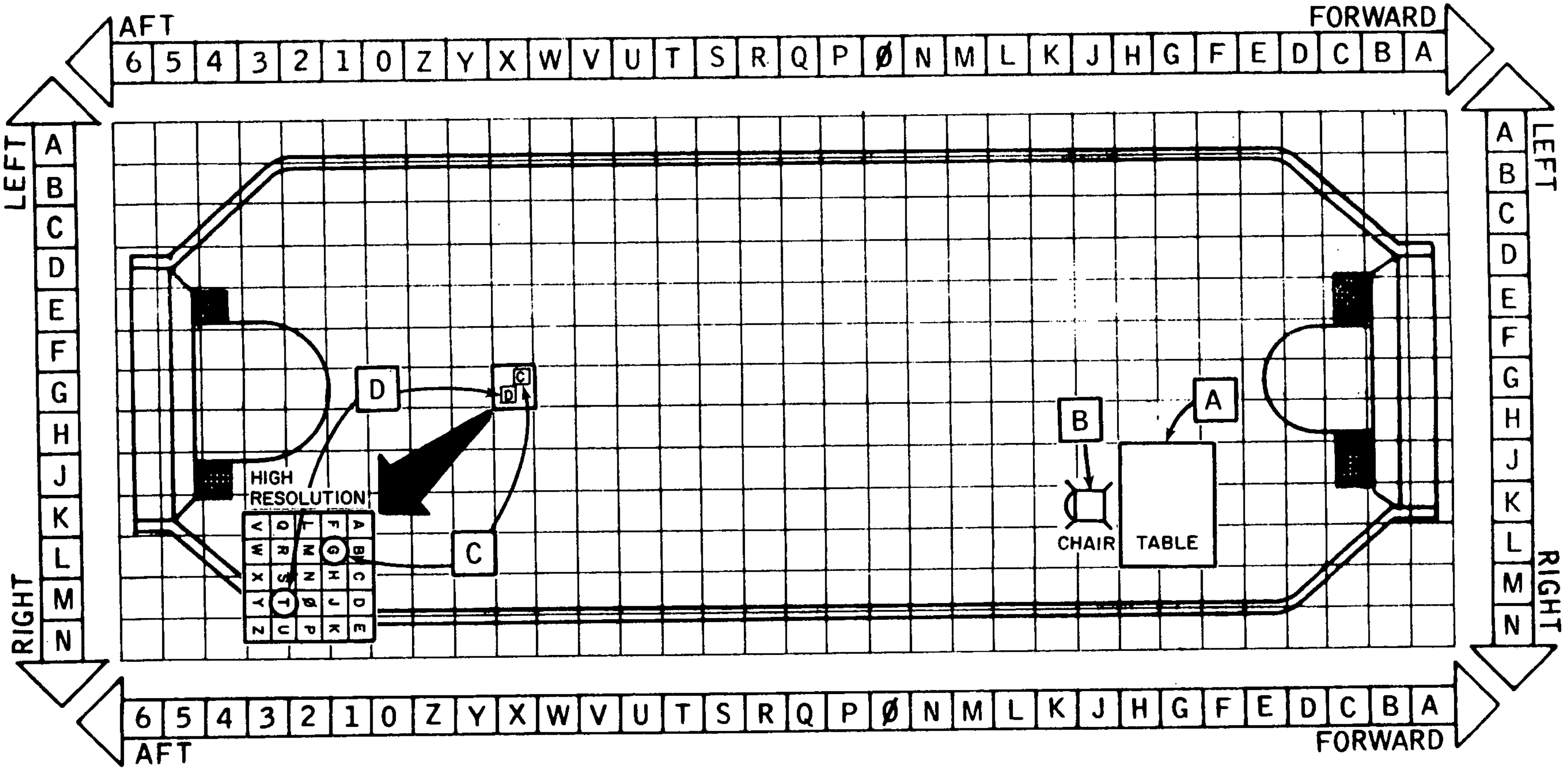
  *AXES ARE PARALLEL TO SPACECRAFT AXES.

- ITEMS REMOTE TO WALLS ARE CODED AT THEIR PLANFORM "MIDPOINTS" AS RELATED TO PLANFORM GRID. IN CONJUNCTION WITH HEIGHT CODE, THE PLANFORM GRID SYSTEM IS A 3-AXES CODING SYSTEM WITH DIRECT RELATIONSHIPS TO SPACECRAFT AXES AND THEREFORE POSSESSES "GROSS MASS PROPERTIES" MANAGEMENT APPLICATIONS.

- THE WALL (PERIMETER) SYSTEM CODING SYSTEM DOES NOT PROVIDE A DIRECT RELATIONSHIP TO SPACECRAFT AXES, BUT BY TRANSLATING THOSE WALL AREAS INTO THE PLANFORM SYSTEM CODES, THE NECESSARY "GROSS MASS PROPERTIES" RELATIONSHIPS MAY BE OBTAINED.

RECTANGULAR PLANFORM CODING CONVENTIONS (MSS MODULE)

- ROOM PLANFORM (FLOOR, CEILING, ETC.) IS LAID OUT WITH RESPECT TO THE STANDARD GRID AS SHOWN BELOW:



A	TABLE LOCATED <u>OVER FLOOR</u> IS CODED	WØGKT
B	CHAIR LOCATED <u>OVER FLOOR</u> IS CODED	WØJKU
C	EQUIPMENT LOCATED <u>ON CEILING</u> IS CODED	WCXGBG } HIGH RESOLUTION
D	EQUIPMENT LOCATED <u>BELOW CEILING</u> IS CODED	WBXGDT }

HEIGHT CODING CONVENTIONS

$\boxed{A}$ EQUIP. LOCATED ABOVE CEILING IS CODED WA--1*

$\boxed{B}$ EQUIP. LOCATED ABOVE CEILING IS CODED WA--A**

$\boxed{C}$ EQUIP. LOCATED ON CEILING IS CODED WC--B

$\boxed{D}$ EQUIP. LOCATED BELOW CEILING IS CODED WB--D

$\boxed{E}$ EQUIP. LOCATED OVER FLOOR IS CODED W0--L 2

$\boxed{F}$ EQUIP. LOCATED ON FLOOR IS CODED WF--N

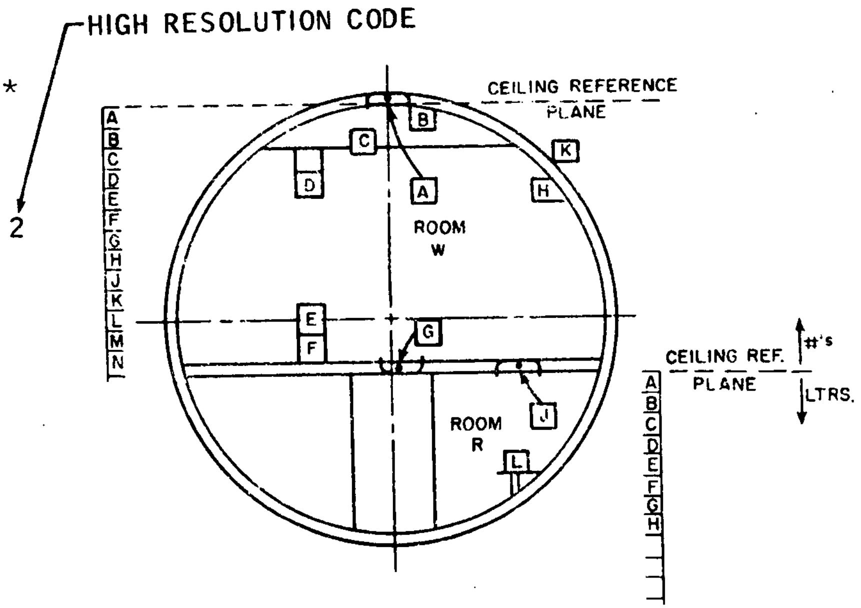
$\boxed{G}$ EQUIP. LOCATED UNDER FLOOR IS CODED WU--N

$\boxed{H}$ EQUIP. LOCATED ON WALL IS CODED W086E

$\boxed{J}$ EQUIP. LOCATED ABOVE CEILING IS CODED RA--1

$\boxed{K}$ EQUIP. LOCATED ON EXTERNAL SURFACE IS WE--C

$\boxed{L}$ TABLE LOCATED ON FLOOR*** IS CODED RF--E



*EQUIPMENT $\boxed{A}$ IS LOCATED ABOVE CEILING REFERENCE PLANE.

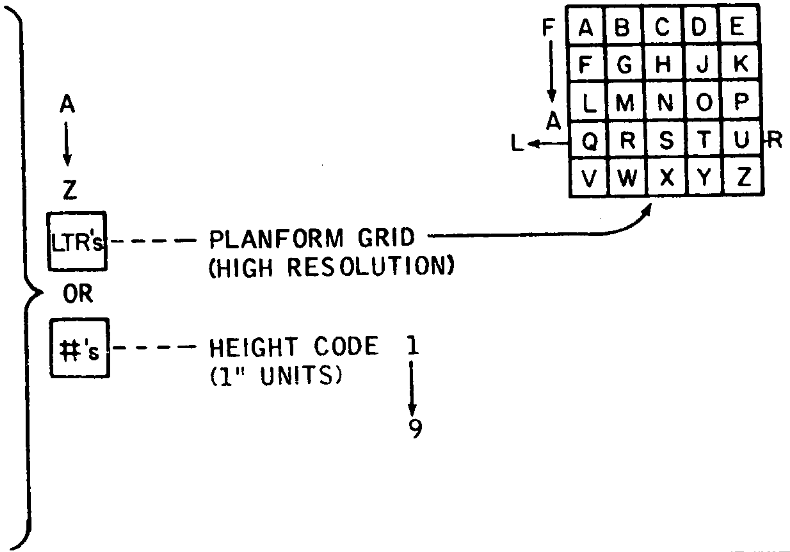
**EQUIPMENT $\boxed{B}$ IS LOCATED ABOVE CEILING, BUT BELOW CEILING REFERENCE PLANE.

***DESIGNATION OF TABLE $\boxed{L}$ IS ARBITRARILY ASSIGNED AS A FLOOR ITEM.

CODING EXAMPLES

		ROOM	LOC. REF.	ADDRESS		HEIGHT BELOW CEILING REF. PLANE	HIGH RESOLUTION CHARACTER
PERIPHERAL	WALL-FRONT	W	0	8	6	D	BLANK = NO RESOLUTION REQ'D. LTR = MULTIPLE LOCATIONS WITHIN WALL GRID

	WALL (HIDDEN)	W	5	8	6	D	# ZERO = ON WALL (HIDDEN LOCATION)
							LTR = DISTANCE BEHIND WALL (UNIT = 2")
							Z ↑ A

	BACK OF WALL-FRONT LOCKER	W	0	8	6	D	# ZERO = BACK OF LOCKER OR EQUIPMENT
	WITHIN WALL-FRONT	W	0	8	6	D	# = DISCRETE (9-PART GRID) DESIGNATOR WITHIN WALL-FRONT LOCATION 7 8 9 4 5 6 1 2 3
PLANFORM	ABOVE CEILING	W	A	G	K	DECK 3 DOME B CRP	 A ↓ Z LTR's ---- PLANFORM GRID (HIGH RESOLUTION) OR #'s ---- HEIGHT CODE (1" UNITS) 1 ↓ 9 A B C D E F G H J K L M N O P Q R S T U V W X Y Z
	CEILING	W	C	G	K	B	
	BELOW CEILING	W	B	G	K	G	
	OVER FLOOR	W	0	G	K	L	
	FLOOR	W	F	G	K	R	
	UNDER FLOOR	W	U	G	K	S	
	EXTERNAL	W	E	B	D	G	
	FLEXPORT	W	P	F**	1*	2*	

*MODULE SEQUENCE NUMBERS CONNECTED BY FLEXPORT.

**CONNECTED ON FORWARD END OF MODULES.

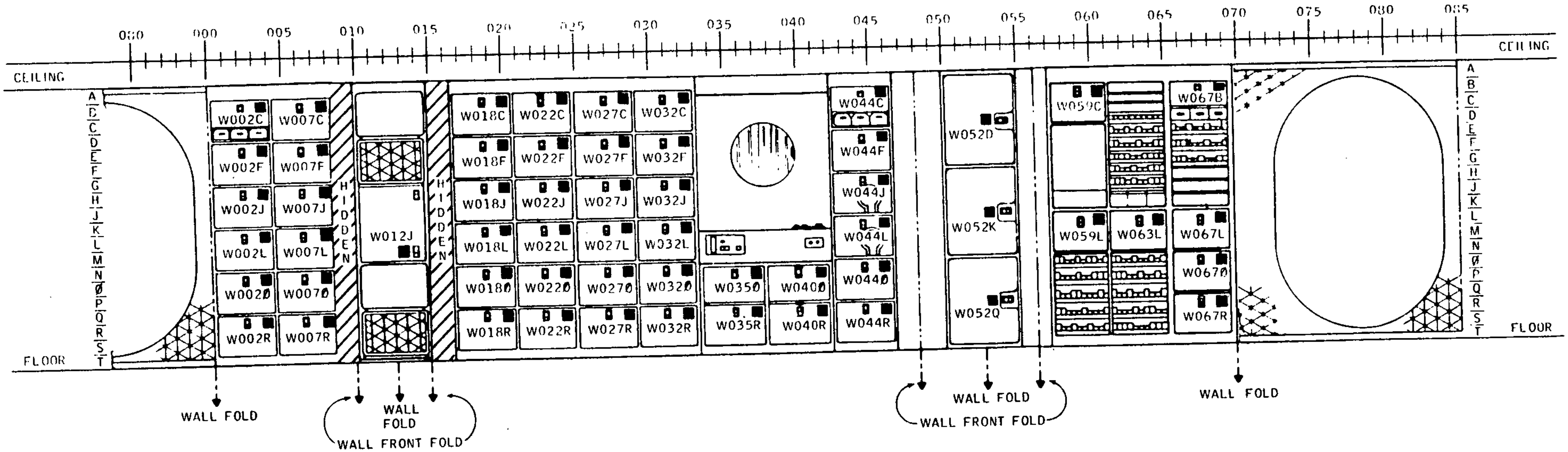
SUMMARY

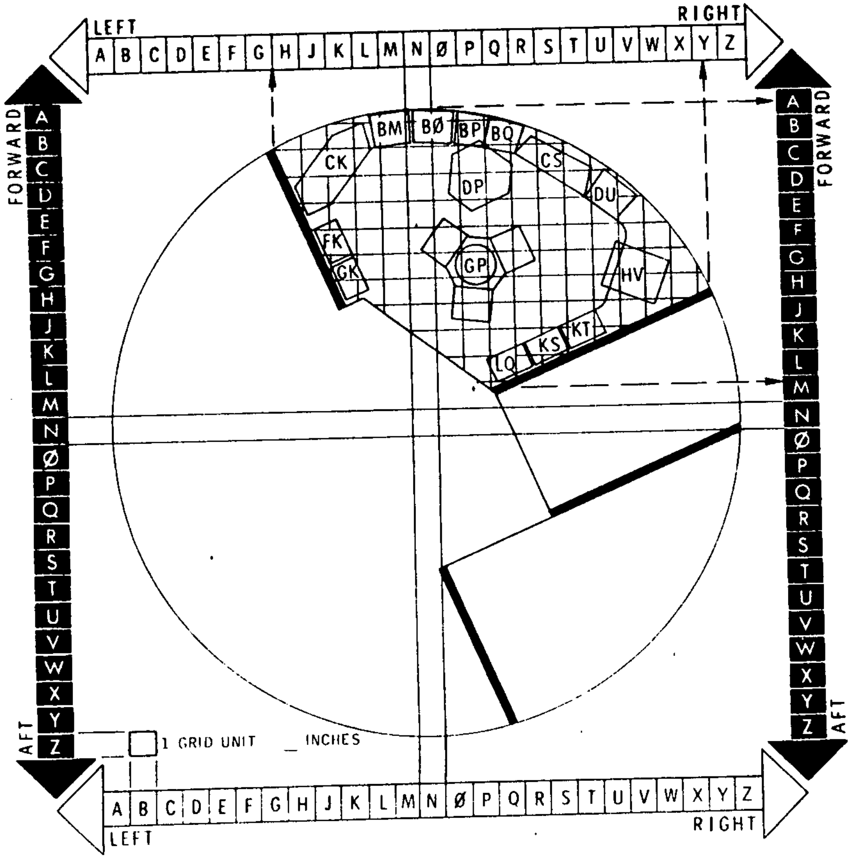
- PRIOR TO THE CRITICAL DESIGN REVIEW (CDR) OF THE STATION MODULE, THE ROOM WALL PERIMETER WILL BE RESCALED IF A MAJOR WALL INSERTION INTO A ROOM CONFIGURATION OCCURS.
- AFTER CDR, CHANGES IN THE ROOM WALL PERIMETER WILL BE CODED USING "HIDDEN WALL" CONVENTIONS, OR WITH PLANFORM DESIGNATION CONVENTIONS.
- ALL OTHER CHANGES WILL BE CODED USING NORMAL CODING CONVENTIONS.
- THIS OPERATIONS CODING SYSTEM (SIX DIGITS, ONE OPTION DIGIT) WILL PROVIDE CODING CAPABILITIES FOR UP TO A 35-LAUNCH MODULAR SPACE STATION AND WILL SERVE DESIGN, MANUFACTURING, TEST AND CHECKOUT, OPERATIONS, IN-FLIGHT MAINTENANCE, ASSEMBLY, SERVICING, AND STOWAGE PREPARATION AND MANAGEMENT PURPOSES.

ROOM DECALS

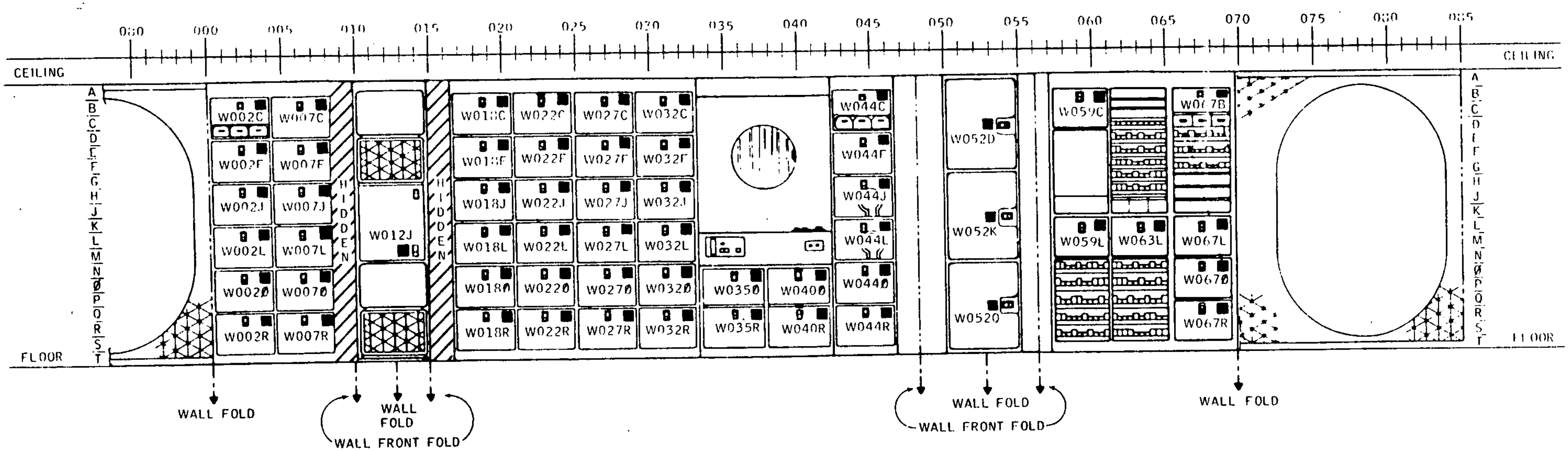
EACH ROOM SHOULD BE PROVIDED WITH ONE ROOM LOCATION DECAL IN EITHER OF THE FOLLOWING FORMS:

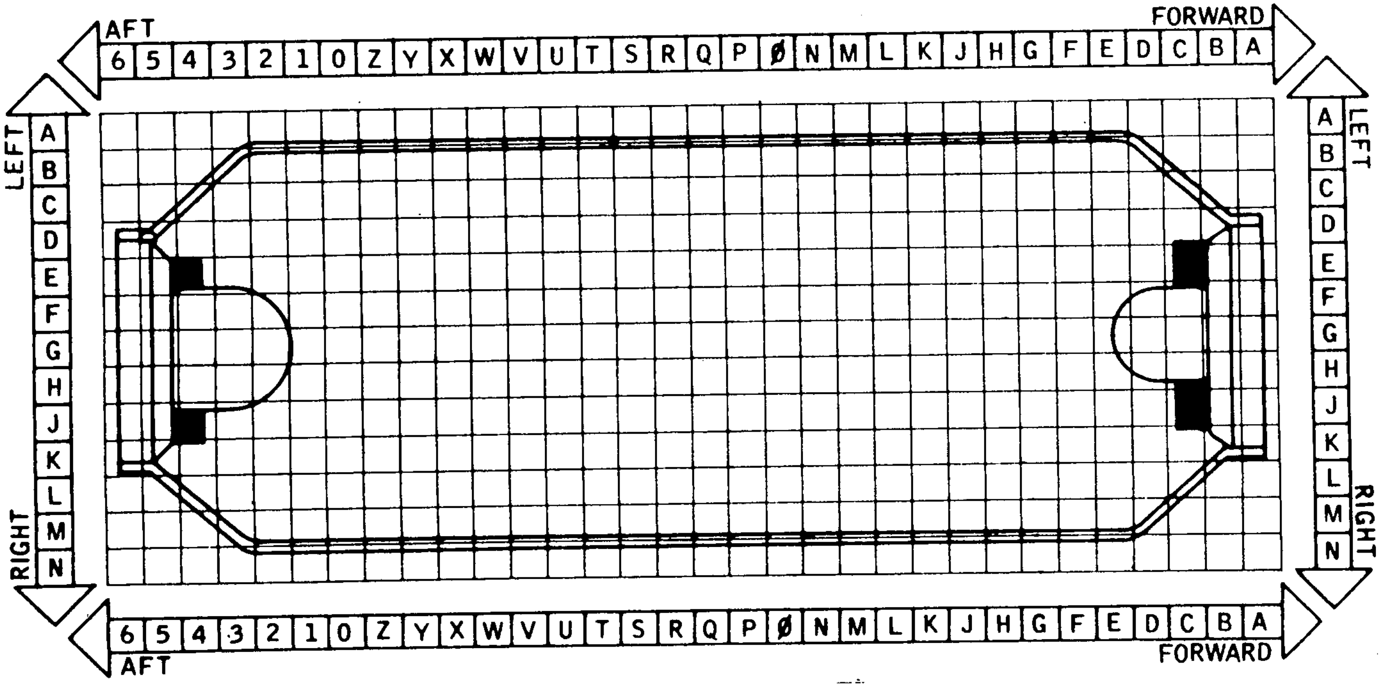
OPERATIONS LOCATION CODING SYSTEM ROOM DECAL (DECK TYPE)

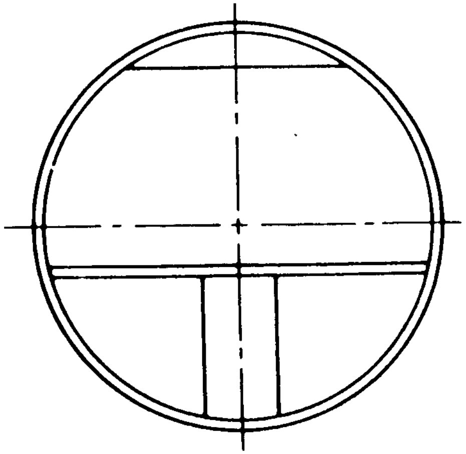




OPERATIONS LOCATION CODING SYSTEM ROOM DECAL (QUONSET TYPE)







SPECIAL CASES

(ADDITIONAL STUDY REQUIRED)

A POWER MODULE

B CREW STATION (COCKPIT) - SHUTTLE

C COMPLEX CONTROL/DISPLAY CONSOLE

D CORE MODULE

APPENDIX D
IN-FLIGHT MAINTENANCE

APPENDIX D (CONT.)

FIGURE 1
SKYLAB IN FLIGHT MAINTENANCE TASKS AND TOOLS

MULTIPLE DOCKING ADAPTER

SYSTEM	TASK	SPARES	TOOL CODE
ECS	REPAIR		
	●FLEXIBLE DUCT	N/A	AB
	REPLACE		
	●ECS VENT FAN	5	OPQV
	●WINDOW HEAT CONTROL	1	CLOP
	●"O"-RING	4	J
	●HABITATION VENT SEAL	1	NONE
	●WINDOW HEAT CABLE	1	CLP
	CLEAN		
	●FAN INLET SCREEN	N/A	D
COMMUNICATIONS	REPLACE		
	●INTERCOM	2	OPQV
	●CREW HEADSET	-	NONE
	●TV INPUT STATION	-	MNOP QST
	●TV SWITCH	1	LMNO QRST
	●CREW COMM UMBILICAL	-	NONE
STRUCTURES	REPAIR		
	●HATCH AXIAL PORT	N/A	HIK
	●METEOR DAMAGE	TBD	ABE
CAUTION AND WARNING	REPLACE		
	●FIRE SENSOR PANEL	1	OQ
	●UV FIRE DETECTOR	-	PQV
CREW SYSTEMS	REPLACE		
	●LIGHT BULB ASSY	-	-

AIRLOCK MODULE

SYSTEM	TASK	SPARES	TOOL CODE
ECS	REPLACE		
	●CO_2 ACTIVE FILTER #69 #70	2 2	NONE NONE
	●CO_2 PASSIVE FILTER #75 #77	2 2	NONE NONE
	●ECS VENT FAN	-	OPQV
	●PPO_2 SENSOR	-	NONE
	●MOL SIEVE FAN	1	NONE
	●SOLIDS TRAP	4 PAIRS	NONE
	●SIEVE CHARCOAL CAN	8	NONE
	●ATM WATER FILTER	2	NONE
	●HEAT EXCHANGER PLATES	4	NONE
	●EVA/IVA WATER SEPARATOR	2	TBD
COMMUNICATIONS	REPLACE		
	● INTERCOM	2	OVPQ
	● CREW HEADSET	1	NONE
	● CREW COMM UMBILICAL	3	NONE
	● TELEPRINTER CARTRIDGE	1	NONE
	● TELEPRINTER ASSEMBLY	1	OPV
	● TELEPRINTER SPOOL	2	NONE
INSTRUMENTATION	REPLACE		
	● BIOMED/COMM CABLE	1	-
	● TAPE RECORDER	1	W
STRUCTURES	REPAIR		
	● METEOR DAMAGE	TBD	ABE
CAUTION AND WARNING	REPLACE		
	● UV FIRE DETECTOR	8	PQV
CREW SYSTEMS	REPLACE		
	● TIMER BATTERY	2	X
	● TIMER BATTERY	2	X
	REPLACE		
	● LIGHT BULBS (3 TYPES)	1	NONE

APOLLO TELESCOPE MOUNT

SYSTEM	TASK	SPARES	TOOL CODE
TACS	REPLACE		
	●MANUAL POINT CONTROL	1	OPW
	●PRECISION CLOCK	1	NONE

TOOLS

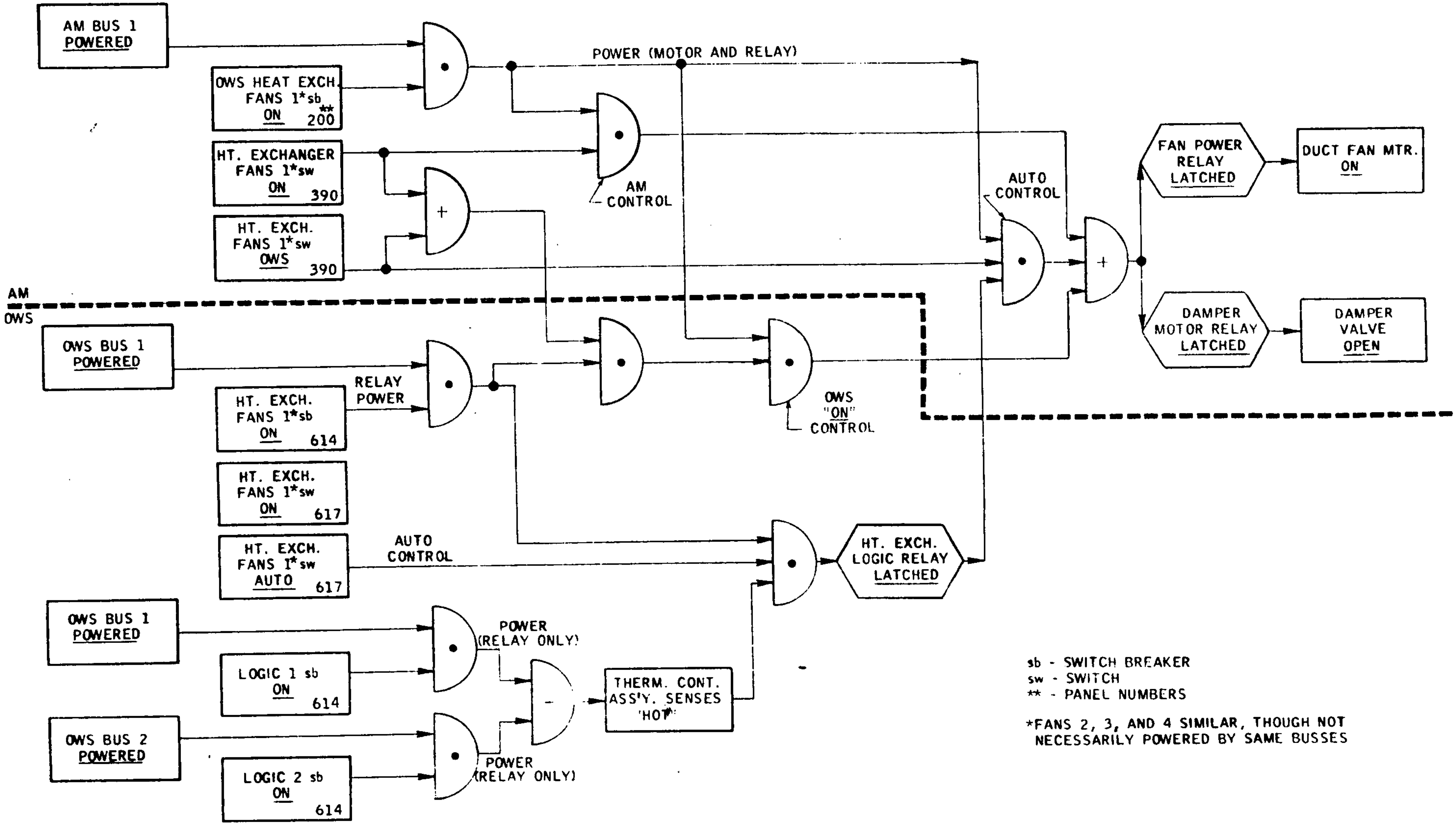
CODE	TOOL
A	SCISSORS
B	ALUMINIZED TAPE
C	MULTIMETER
D	VACUUM CLEANER
E	LEAK DETECTOR
F	EQUIPMENT CONTAINER
G	CIRCUIT BOARD EXTRACTOR
H	PIN REMOVAL TOOL
I	SEAL LOOSENER
J	"O"-RING EXTRACTOR
K	RETAINING RING REMOVER
L	CONNECTOR PLIERS
M	DIAGONAL CUTTERS
N	NEEDLE NOSE PLIERS
O	RATCHET 3/8
P	DRIVE 3/8
Q	EXTENSION DRIVE 3/8
R	DOUBLE HEX SOCKET 3/8
S	OPEN END WRENCH 5/16
T	OPEN END WRENCH 11/32
U	SCREWDRIVER HANDLE 3/8
V	SCREWDRIVER BIT 5/32
W	SCREWDRIVER 1/4 HEX
X	SCREWDRIVER BIT 3/16
Y	SCREWDRIVER BIT 3/32
Z	SCREWDRIVER PHILLIPS

ORBITAL WORKSHOP

SYSTEM	TASK	SPARES	TOOL CODE
ECS	REPAIR		
	●ECS DUCT	N/A	B
	REPLACE		
	●ECS VENT FAN	-	OPQV
	●ODOR FILTER	1	NONE
	●CHARCOAL CARTRIDGE	1	NONE
	●"O"-RING	1	J
	●HABITATION VENT SEAL	1	NONE
	CLEAN		
	●AIR MIX CHAMBER	N/A	D
	●VENT FILTER UPSTREAM	N/A	D
COMMUNICATIONS	REPLACE		
	●INTERCOM	2	OVPQ
	●CREW COMM UMBILICAL	-	NONE
	●CREW HEADSET	-	NONE
STRUCTURES	REPAIR		
	●METEOR DAMAGE	TBD	ABE
	REPLACE		
	●HEATED PROBE	1	OPX
CAUTION AND WARNING	REPLACE		
	●UV FIRE DETECTOR	-	PQV
CREW SYSTEMS	REPLACE		
	● HOT WATER VALVE	1	S
	● DRINK WATER ASSY	1	NONE
	● DRINK WATER VALVE	1	PV
	● VACUUM CLEANER POWER MODULE	-	NONE
	● LIGHT BULB ASSY	6	NONE
	● INBOARD TRASH SEAL	3	X
	● INDEX CLEAT	0	OPYZ
	● PROCESSOR PANEL	1	Z
	● HEATER ASSEMBLY	1	S
	● TRASH PLUG	1	PY

EXPERIMENTS

SYSTEM	TASK	SPARES	TOOL CODE
M-074	REPLACE		
	● ELECTRONICS MODULE	-	LNOP X
M-093	REPLACE		
	● VCG UMBILICAL	3	NONE
	● ELECTRODE HARNESS	3	NONE
M-171	REPLACE		
	● SIGNAL CONDITIONER	TBD	LNX
M-172	REPLACE		
	● ELECTRONICS MODULE	-	LNOP X
M-190	REPLACE		
	● LOGIC BOARD 1, 2, 3	1	GF
	● PMC CONTROL BOARD	1	GF
	● MAGAZINE DRIVE BOARD	1	GF
	● MAGAZINE DRIVE	1	TBD
	● DESSICANT	-	TBD F
M-192	REPLACE		
	● DETECTOR DEWAR	1	NONE
	● EREP TAPE RECORDER	1	LN



sb - SWITCH BREAKER
sw - SWITCH
** - PANEL NUMBERS

*FANS 2, 3, AND 4 SIMILAR, THOUGH NOT NECESSARILY POWERED BY SAME BUSSES

FIGURE 2 - OWS HEAT EXCHANGER FANS PROCEDURAL LOGIC (FAN ON)

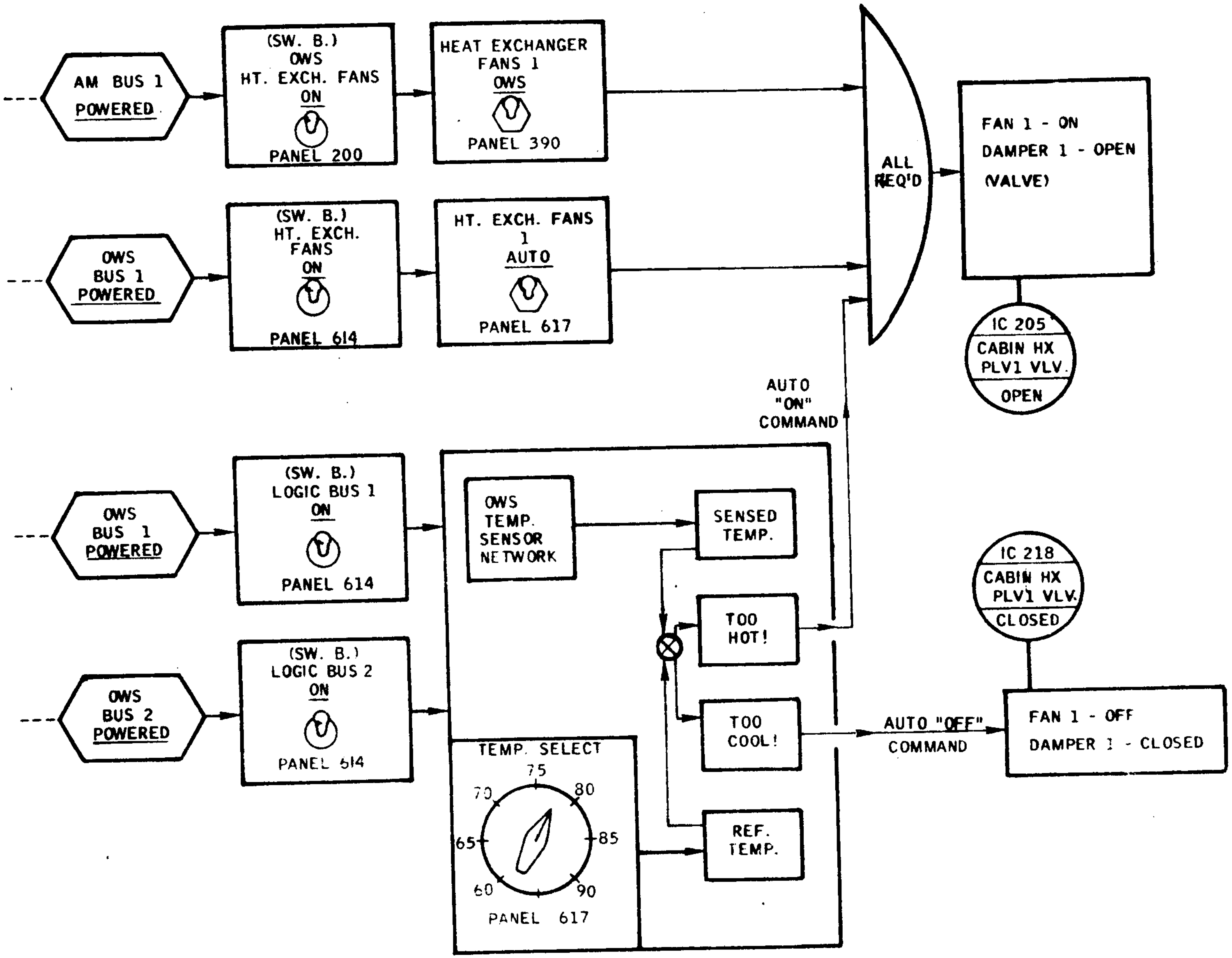


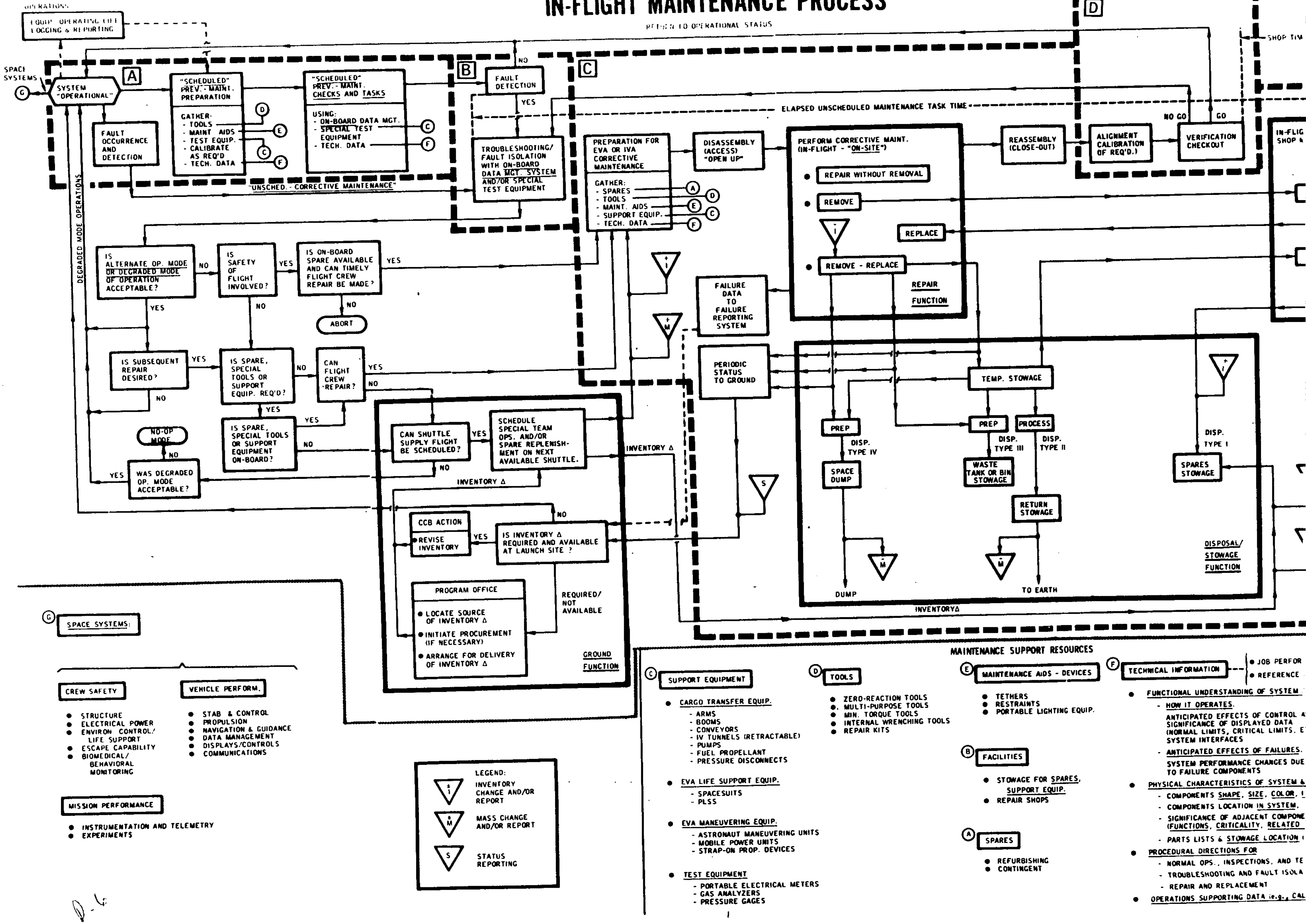
FIGURE 3 - OWS HEAT EXCHANGER FANS PROCEDURAL LOGIC (AUTO MODE)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE 4

IN-FLIGHT MAINTENANCE PROCESS



D-6

FIGURE 5 - INFORMATION REQUIREMENTS OF CREW IN-FLIGHT MAINTENANCE FUNCTIONS

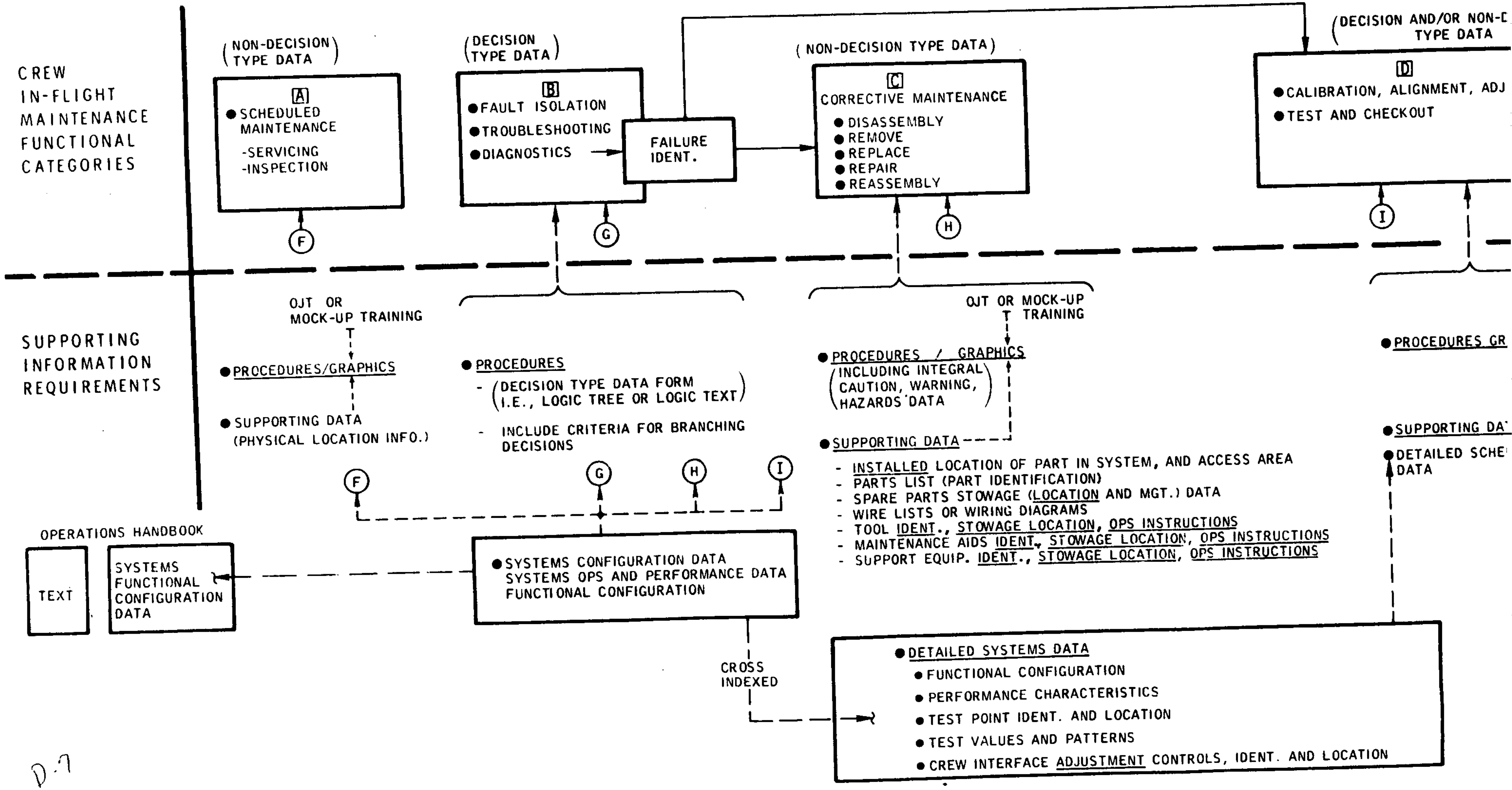


FIGURE 6

APOLLO TYPE NORMAL SYSTEM ACTIVATION CHECKLIST DATA (SEQUENTIAL/NONDECISION TYPE)

RCS PRESS

CDR

ACT-46

LMP

97:09

RCS PRESSURIZATION

1 RECYCLE: SYS A&B ASC FEED 2(2) - CLOSE
SYS A&B ASC FEED 1(2) - OPEN

2 RCS QUANTITY A&B - 100%
SYS A&B ASC FUEL & ASC OXID - tb (4) Remain-bp
SYS A&B THRUSTER PAIR QUADS - tb (8) gray
(Possible tb-Red, Cycle CWEA CB If Necessary)
RECYCLE: CRSFD-CLOSE
: SYS A&B MAIN SOV - OPEN
HTR CONT TEMP MON - CHECK RCS QUADS (113°-241°)

*********************************** UD - 1:00**

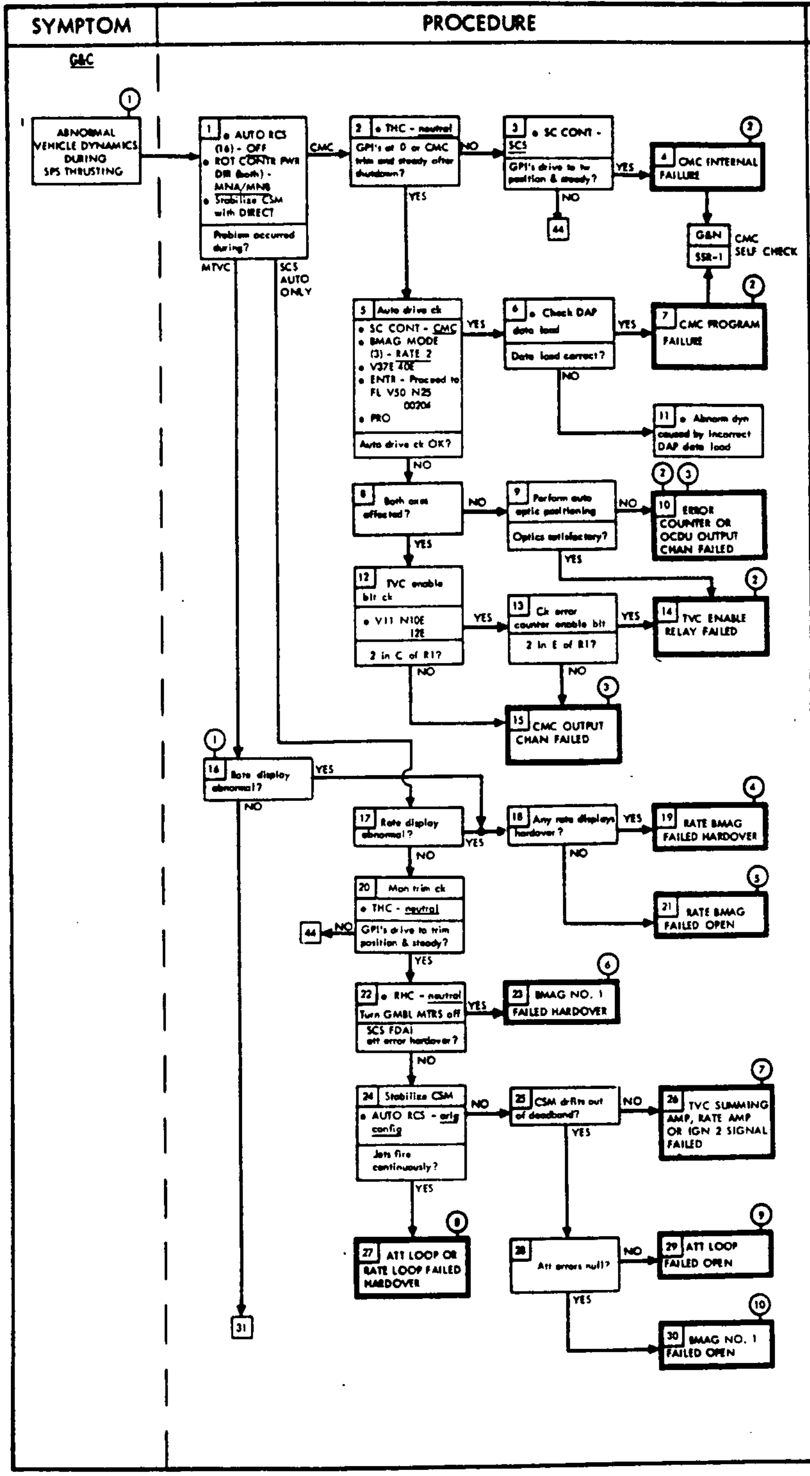
3 TEMP/PRESS MON - He
RCS A&B PRESS - 2625-3480 psia
TEMP/PRESS MON - PRPLNT (40°-100°/10-50 psi)
FUEL MANF (25-130 psi)
OXID MANF (25-130 psi)

4 MASTER ARM - ON
HE PRESS RCS - FIRE

LM-4

Basic Date April 18, 1969
Changed May 3, 1969

FIGURE 7
APOLLO CREW MALFUNCTIONS PROCEDURES



REMARKS

① Thrust is shut off and system returned to configuration at failure. If gmbl motors are off, they must be turned on before starting this procedure.

② CMC SPS control capability lost.

③ Auto optics lost

④ SCS auto ΔV lost. MTVC possible if redundant BMAG placed in RATE position.

⑤ An open rate BMAG may be confirmed by null rate displays. SCS ball drive lost in axis unless alternate rate BMAG used.
If YAW or ROLL-
If BMAG 1, after .05G, SCS roll att erroneous. If BMAG 2, after .05 G, EMS RAI erroneous unless in RATE 1. Rate damping and SCS auto ΔV lost. For MTVC, use alternate rate BMAG.

⑥ SCS auto ΔV lost if pitch or yaw. If roll, control attitude with Direct or ACCEL CMD.

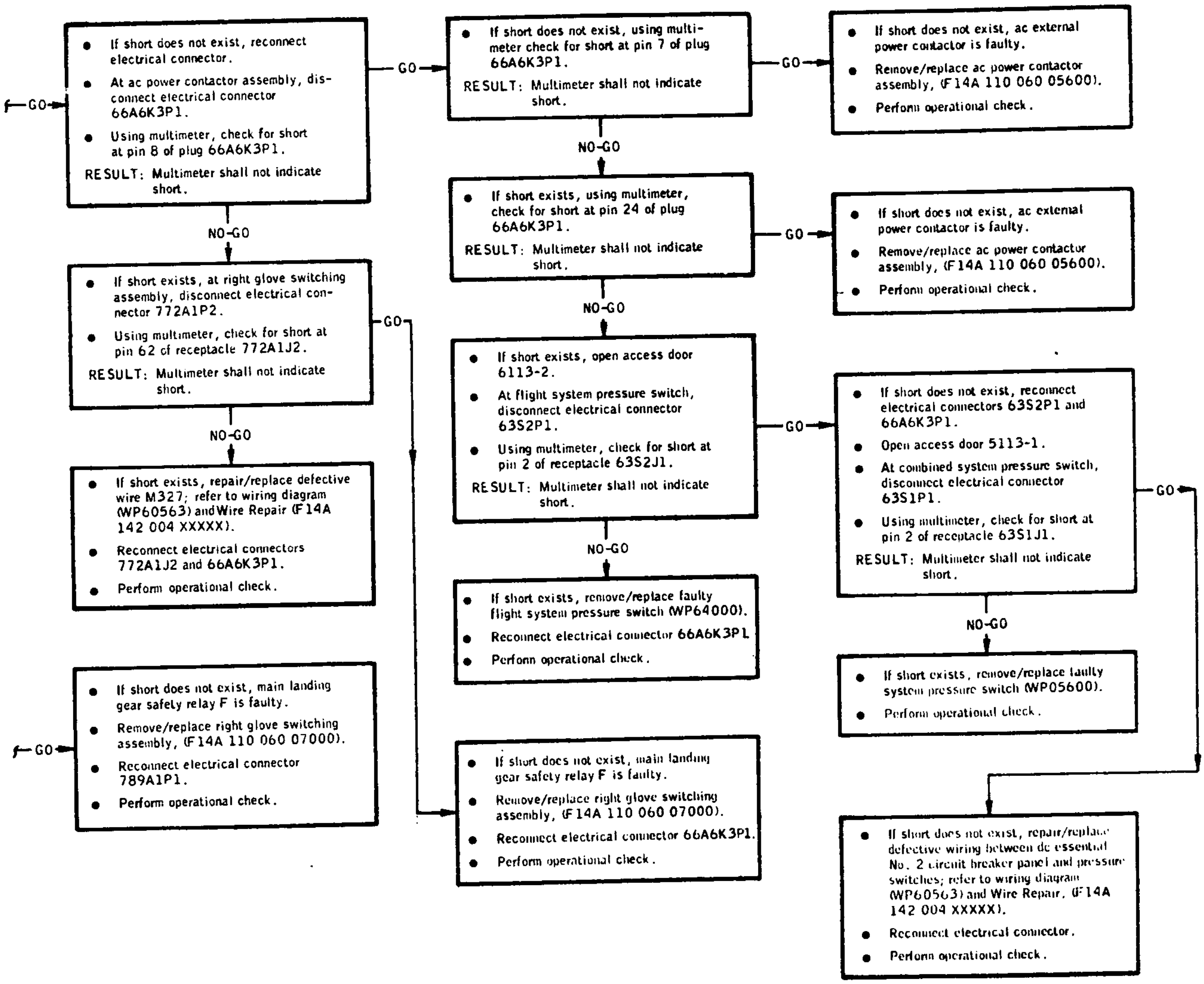
⑦ SCS auto ΔV capability lost.

⑧ SCS RATE CMD, att hold, and proportional control lost for affected axis. SC auto ΔV lost if pitch or yaw. Translations without att hold possible in MIN IMP. Further troubleshooting not recommended.

⑨ Att hold capability lost in affected axis. SCS auto ΔV lost if pitch or yaw.

⑩ For affected axis:
In ATT 1 RATE 2, att hold and att error display lost. After .05 G, SCS FDAI roll att erroneous if yaw or roll.

SM-2A-1941G



- If short does not exist, reconnect electrical connector.
- At ac power contactor assembly, disconnect electrical connector 66A6K3P1.
- Using multimeter, check for short at pin 8 of plug 66A6K3P1.

RESULT: Multimeter shall not indicate short.

- If short exists, at right glove switching assembly, disconnect electrical connector 772A1P2.
- Using multimeter, check for short at pin 62 of receptacle 772A1J2.

RESULT: Multimeter shall not indicate short.

- If short exists, repair/replace defective wire M327; refer to wiring diagram (WP60563) and Wire Repair (F14A 142 004 XXXXX).
- Reconnect electrical connectors 772A1J2 and 66A6K3P1.
- Perform operational check.

- If short does not exist, main landing gear safety relay F is faulty.
- Remove/replace right glove switching assembly, (F14A 110 060 07000).
- Reconnect electrical connector 789A1P1.
- Perform operational check.

- If short does not exist, using multimeter check for short at pin 7 of plug 66A6K3P1.

RESULT: Multimeter shall not indicate short.

- If short exists, using multimeter, check for short at pin 24 of plug 66A6K3P1.

RESULT: Multimeter shall not indicate short.

- If short exists, open access door 6113-2.
- At flight system pressure switch, disconnect electrical connector 63S2P1.
- Using multimeter, check for short at pin 2 of receptacle 63S2J1.

RESULT: Multimeter shall not indicate short.

- If short exists, remove/replace faulty flight system pressure switch (WP64000).
- Reconnect electrical connector 66A6K3P1.
- Perform operational check.

- If short does not exist, main landing gear safety relay F is faulty.
- Remove/replace right glove switching assembly, (F14A 110 060 07000).
- Reconnect electrical connector 66A6K3P1.
- Perform operational check.

- If short does not exist, ac external power contactor is faulty.
- Remove/replace ac power contactor assembly, (F14A 110 060 05600).
- Perform operational check.

- If short does not exist, ac external power contactor is faulty.
- Remove/replace ac power contactor assembly, (F14A 110 060 05600).
- Perform operational check.

- If short does not exist, reconnect electrical connectors 63S2P1 and 66A6K3P1.
- Open access door 5113-1.
- At combined system pressure switch, disconnect electrical connector 63S1P1.
- Using multimeter, check for short at pin 2 of receptacle 63S1J1.

RESULT: Multimeter shall not indicate short.

- If short exists, remove/replace faulty system pressure switch (WP05600).
- Perform operational check.

- If short does not exist, repair/replace defective wiring between dc essential No. 2 circuit breaker panel and pressure switches; refer to wiring diagram (WP60563) and Wire Repair. (F14A 142 004 XXXXX).
- Reconnect electrical connector.
- Perform operational check.

FIGURE 8 - NAVY MIL-SPEC EXHIBIT FOR LOGIC TREE TROUBLESHOOTING DATA (F-14A)

FIGURE 9
NAVY MIL-SPEC EXHIBIT FOR LOGIC TEXT TROUBLESHOOTING DATA

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

   Yes – Proceed to step 2.
   No – Proceed to step 4.

2. On navigation control panel does LONG window indicate WO7642?

   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 (see figure 4). Is there continuity?

   Yes – Troubleshoot ballistics computer per section 5.
   No – Repair defective wire. See NA 01–XXXXX–X.

7. Using multimeter check for continuity between TB002–10 and 0011P002–1 (see figure 4). Is there continuity?

   Yes – Troubleshoot inertial navigation system per section 6.
   No – Repair defective wire. See NA –01-XXXXX–X.

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 section 5.

9. Using multimeter check for continuity between 012P005–1 (see figure 4). Is there continuity?

   Yes – Replace navigation control panel. See NA 01–XXXXX–X.
   No – Repair defective wire. See NA 01–XXXXX–X.

10. On navigation mode panel set NAV MODE switch to ED. On navigation control panel does LONG window indicate WO7642?

    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 (see figure 4). Is there continuity?

    Yes – Troubleshoot ballistics computer per section 5.
    No – Repair defective wire. See NA 01–XXXXX–X.

13. Using multimeter check for continuity between TB002–11 and 011P002–2 (see figure 4). Is there continuity?

    Yes – Troubleshoot inertial navigation system per section 6.
    No – Repair defective wire. See NA 01–XXXXX–X.

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 section 5.

15. Using multimeter check for continuity between 012P005–2 and 014P001–2 (see figure 4). Is there continuity?

    Yes – Replace navigation control panel. See NA 01–XXXXX–X.
    No – Repair defective wire. See NA 01–XXXXX–X.

PRIOR TO FLIGHT

PREFLIGHT CHECKLIST

EXTERIOR INSPECTION

Consult the Naval Aircraft Flight Record (yellow sheet) to determine the status of the airplane, that it has been fully serviced with fuel, oil, liquid oxygen, compressed air, and hydraulic fluid. Inspect the exterior of the aircraft, proceeding as shown on figure 3-1.

Forward Fuselage (A)

1. Air refueling probe cover . . . . REMOVED
2. Air conditioning intake and exhaust ducts . . . . CLEAR
3. Static pressure vents (2 vents left side) . . . . CLEAR
4. Engine bleed static port (left side) . . . . CLEAR
5. Angle-of-attack vane . . . . CONDITION
6. Nose compartment panels . . . . CONDITION, SECURITY
7. Nose compartment cooling air inlet . . . . CLEAR
8. Static pressure vent (right side) . . . . CLEAR
9. Controls access panel (right side) . . . . SECURE
10. Nosewheel well door . . . . CONDITION, SECURITY
11. Nosegear strut . . . . EXTENSION, NO LEAKAGE
12. Nosewheel steering wire bundle . . . . CONDITION
13. Nosewheel tire . . . . CONDITION
14. Nosegear downlock pin . . . . INSERTED
15. Emergency generator . . . . RETRACTED, SECURE
16. External canopy jettison handle (left and right side) . . . . . STOWED: ACCESS DOORS CLOSED
17. Gun flash suppressors and guns . . . . SECURE
18. Forward engine compartment . . . . CONDITION AND SECURITY
19. Guncharger pneumatic pressure gage . . . . CHECK
20. Aileron power package . . . . CHECK ALIGNING MARKS
21. External canopy control handle . . . . STOWED: ACCESS DOOR CLOSED

Right-Hand Wheelwell (B)

1. Main wheelwell doors . . . . CONDITION, SECURITY

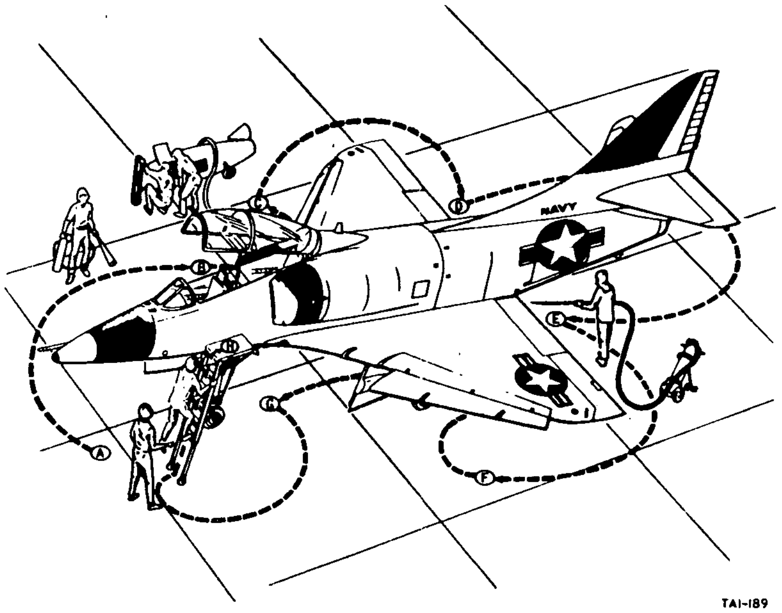


Figure 3-1. Exterior Inspection

2. Taxi light . . . . SECURITY
3. Gun pneumatic pressure gage . . . . CHECK
4. Armament safety disable switch . . . . SAFE
5. Catapult hook . . . . PRELOAD, SECURITY
6. Maingear downlock pin . . . . . . INSERTED
7. Mainwheel strut . . . . EXTENSION, NO LEAKAGE
8. Mainwheel tire . . . . CONDITION
9. Brakes . . . . CONDITION, NO LEAKAGE
10. Fuel system vent . . . . CLEAR

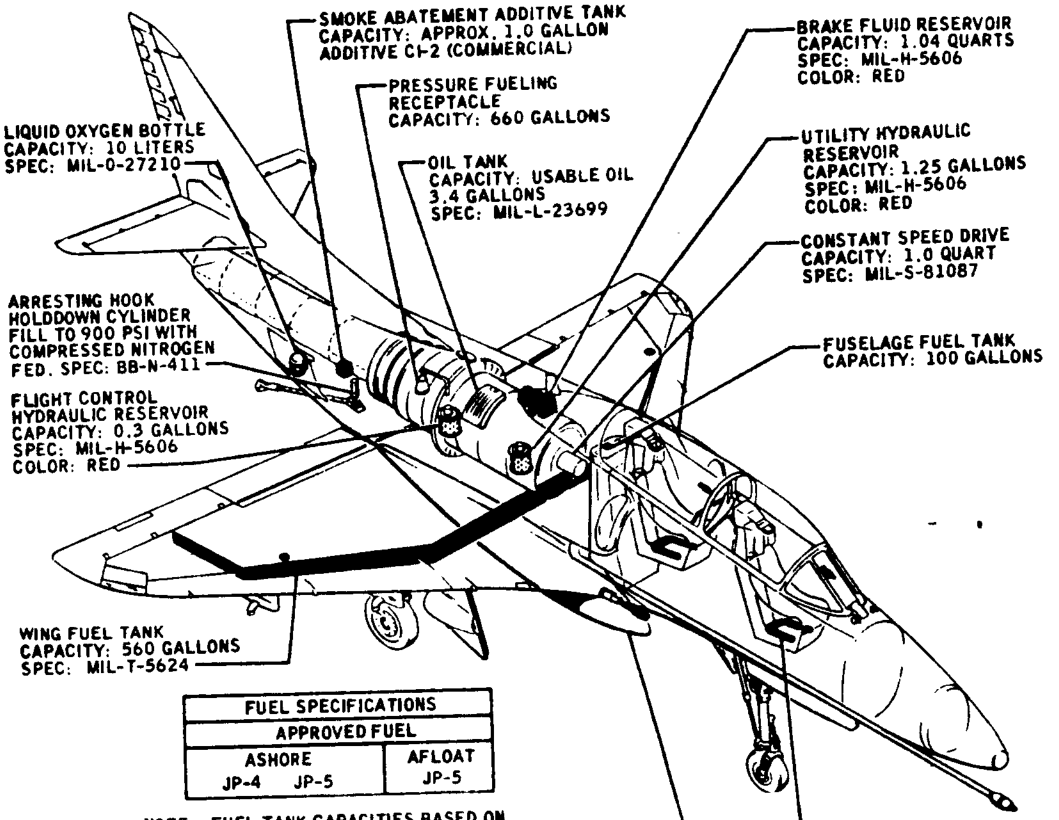
Right-Hand Wing (C)

1. General condition . . . . WRINKLES, CRACKS LOOSE RIVETS: FUEL DEPOSITS
2 Wing rack stores . . . . SECURE
3. Drop tank . . . . REMOVE FILLERCAP, VISUALLY DETERMINE LOADING, REPLACE FILLERCAP

FIGURE 10
TYPICAL WALK AROUND INSPECTION DATA (TA4F AIRCRAFT)

FIGURE 11

SERVICING DIAGRAM (TA4F AIRCRAFT)



FUEL SPECIFICATIONS	
APPROVED FUEL	
ASHORE	AFLOAT
JP-4 JP-5	JP-5

NOTE: FUEL TANK CAPACITIES BASED ON USABLE FUEL AND PRESSURE FUELING.

TANKS	US GAL	IMP GAL	LITERS
FUSELAGE FUEL CELL	100	83.3	369.8
WING INTEGRAL FUEL TANK	560	466.2	2119.6
EXTERNAL FUEL TANK, AERO 1C	147	122.3	556.3
EXTERNAL FUEL TANK, AERO 1D	295	245.6	1116.5
AIR REFUELING STORE	295	245.6	1116.5
EXTERNAL FUEL TANK, ATP-D1B	396	329.7	1498.8

TA1-153-C

Figure 1-30. Servicing Diagram

4. Using locking bracket as a wrench, rotate hexagon shaft until pointer on outside of valve is aligned with index for grade of fuel being added.

5. Replace locking bracket over hexagon shaft so that slotted end fits over retaining stud on housing.

6. Secure bracket to retaining stud with washer and nut.

7. Close left-hand engine access door.

PRESSURE FUELING

The preferred pressure fueling method requires the use of external ac power. This method will be used at all times when external ac power is available.

FIGURE 12

SERVICING PROCEDURES (TA4F AIRCRAFT)

WARNING

- Ground aircraft and fueling equipment during all fueling operations.
- Stop all maintenance on aircraft during fueling.
- Ensure that adequate firefighting equipment is available in immediate area.
- Make certain that proper fuel is used for refueling. (See figure 1-30).
- Do not connect external electrical power to aircraft when gravity fueling.
- Do not start fueling or defueling operations within 100 feet of aircraft operating with radar equipment.

GRAVITY FUELING FUSELAGE FUEL CELL

(See figure 1-34.)

1. Open fuselage cell gravity filler access door; remove cap from gravity filler port.

2. Insert nozzle grounding jack in grounding receptacle directly aft and outboard of access door; insert refueling nozzle in gravity filler port.

3. Fill fuselage cell until fuel level is at bottom of gravity filler port neck.

CAUTION

Stop fueling when fuel comes out of the vent line.

4. Remove refueling nozzle from gravity filler port; disconnect grounding jack from receptacle.

5. Install gravity filler port cap and secure access door.

GRAVITY FUELING WING INTEGRAL FUEL TANK

(See figure 1-35.)

1. Remove wing integral fuel tank filler cap.

2. Insert refueling nozzle grounding jack in grounding receptacle on wing nose.

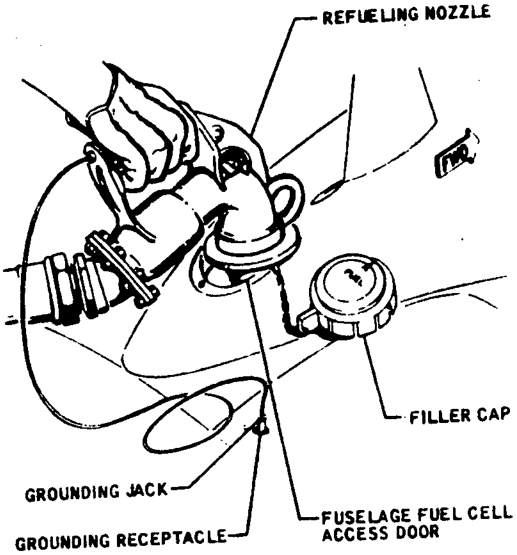


Figure 1-34. Gravity Fueling Fuselage Fuel Cell

CAUTION

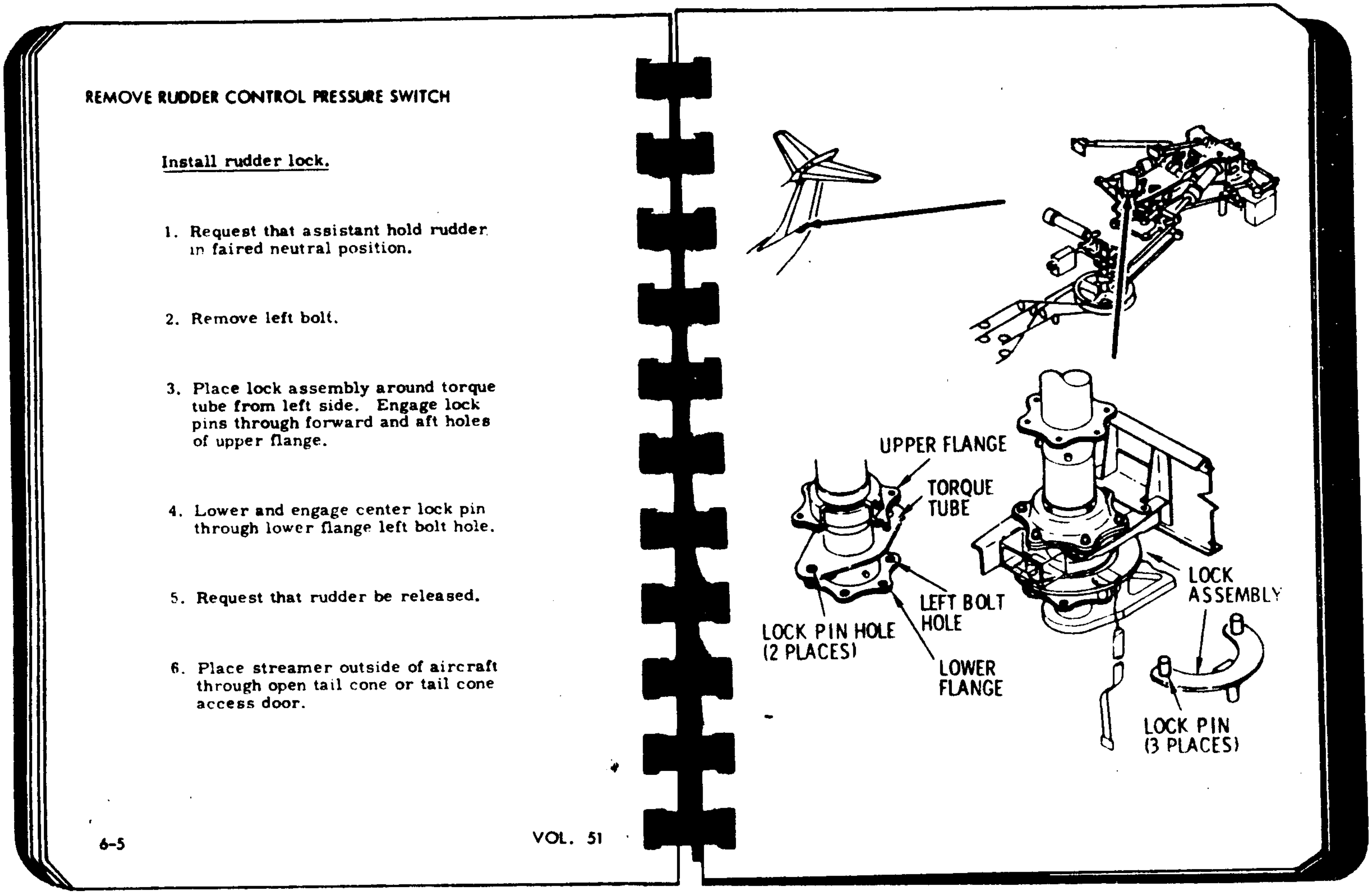
Do not drop fueling nozzle in wing tank filler port because nozzle will damage lower surface of tank. Do not pull fueling hose over wing slats.

3. Insert refueling nozzle in gravity filler port. Hold refueling nozzle in one hand and support refueling hose with other hand.

4. Fill wing fuel tank until fuel is at bottom of gravity filler port neck.

5. Remove refueling nozzle from gravity filler port; disconnect grounding jack from receptacle.

6. Install wing fuel tank gravity filler port cap and lock securely in place.



REMOVE RUDDER CONTROL PRESSURE SWITCH

Install rudder lock.

1. Request that assistant hold rudder in faired neutral position.
2. Remove left bolt.
3. Place lock assembly around torque tube from left side. Engage lock pins through forward and aft holes of upper flange.
4. Lower and engage center lock pin through lower flange left bolt hole.
5. Request that rudder be released.
6. Place streamer outside of aircraft through open tail cone or tail cone access door.

6-5 VOL. 51

FIGURE 13
FORMAT FOR MAINTENANCE INSTRUCTIONS (AF JOB PERFORMANCE AID)

B, MET DEPLOYMENT

7 REMOVE THERMAL BLANKET 7/A AND . . .

7A PULL WHEELPIN LANYARD #3 11/F AND REMOVE BOTH WHEELLOCK PIP PINS #4 & #5 12/H .
(THIS UNLOCKS WHEELS FROM FRAME.)

8 DEPLOY WHEELS: LIFT UPPER WHEEL UNTIL LOCKED.

8A PUSH LOWER WHEEL DOWN UNTIL LOCKED.

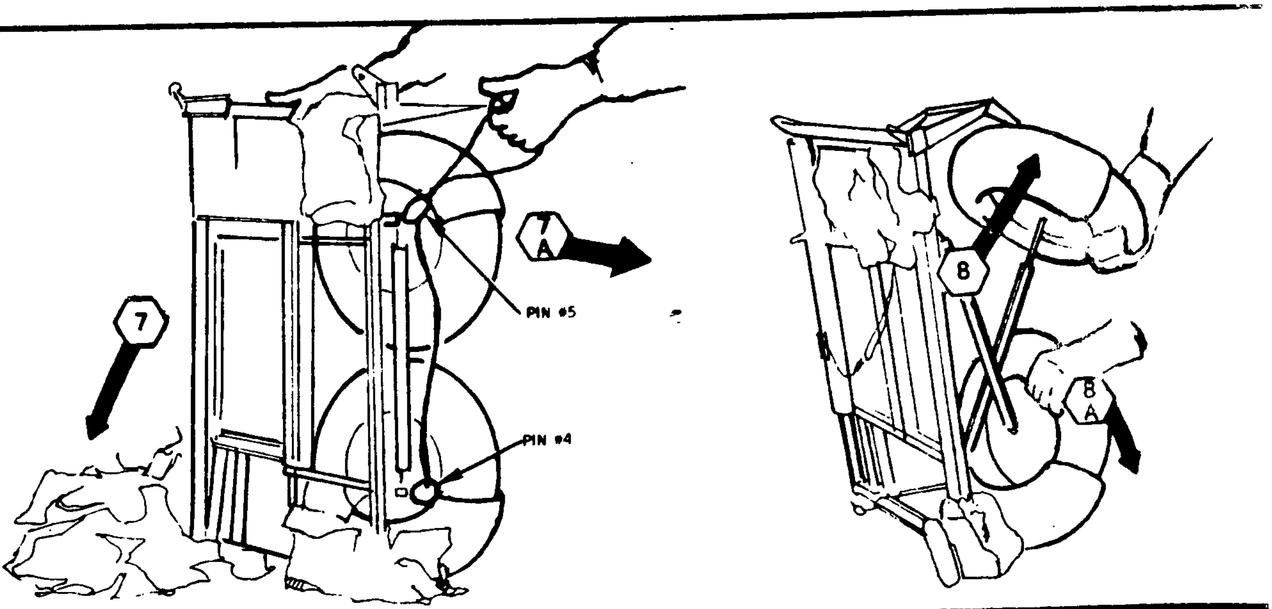


FIGURE 14
GE DEVELOPED OPERATIONS HANDBOOK DATA FOR THE MODULAR EQUIPMENT TRANSPORTER

FIGURE 15

PRELIMINARY GE CONCEPT FOR SCHEDULED MAINTENANCE DATA FORMAT

(ORGANIZED BY EQUIPMENT SERVICE TIMES
AND BY INSPECTION AREAS)

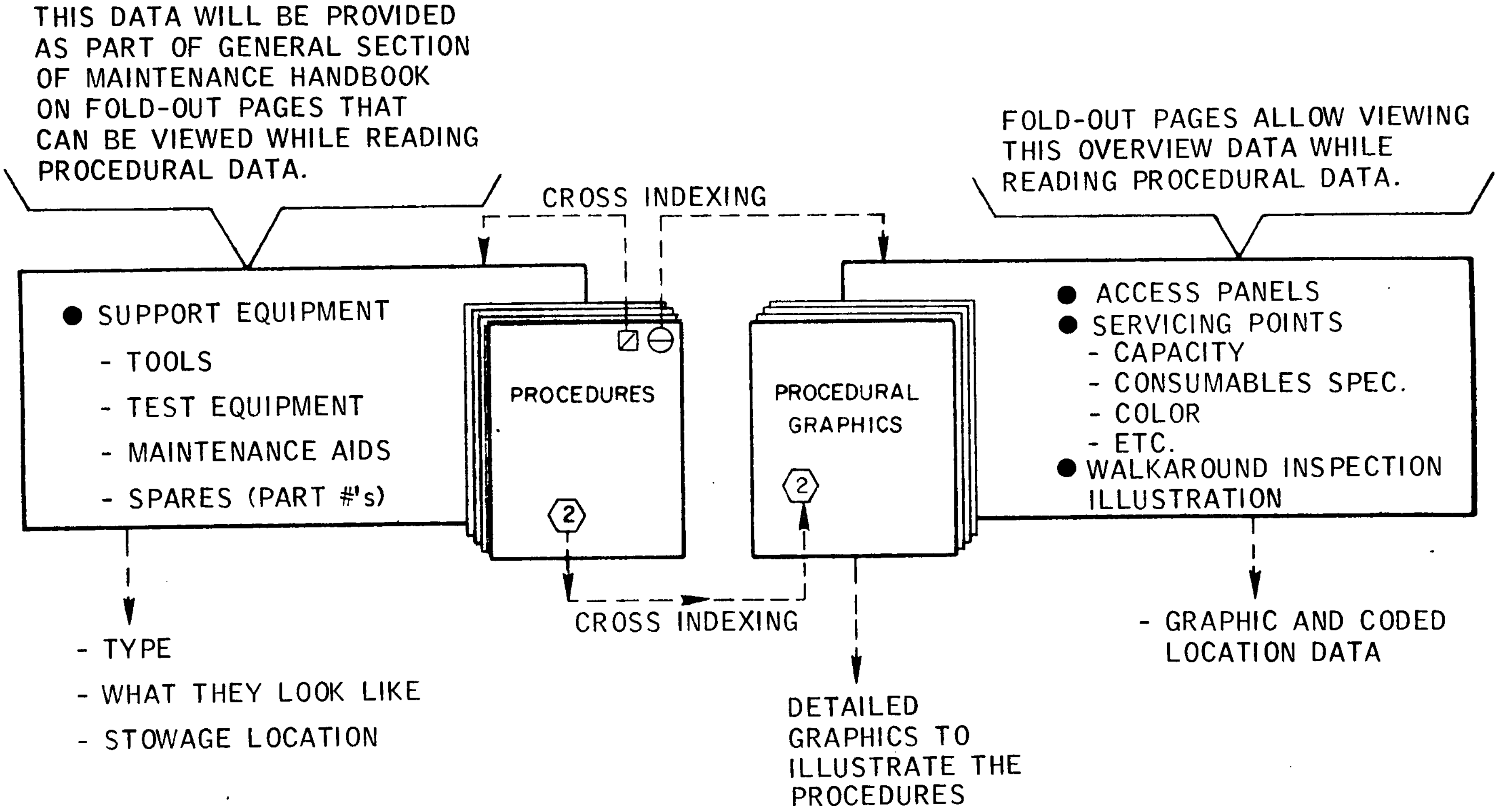
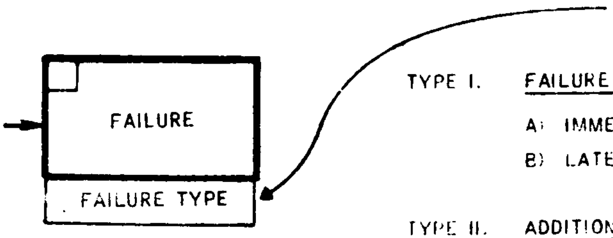


FIGURE 16

PRELIMINARY GE RECOMMENDATIONS FOR FORMAT AND SYMBOLOGY MODIFICATIONS TO THE APOLLO TYPE CREW MALFUNCTION PROCEDURES DATA

THIS FOLLOWING SYMBOLOGY PERMITS ORDERLY INTERFACE WITH CORRECTIVE MAINTENANCE WORK PACKAGES.



FAILURE TYPE CLASSIFICATIONS

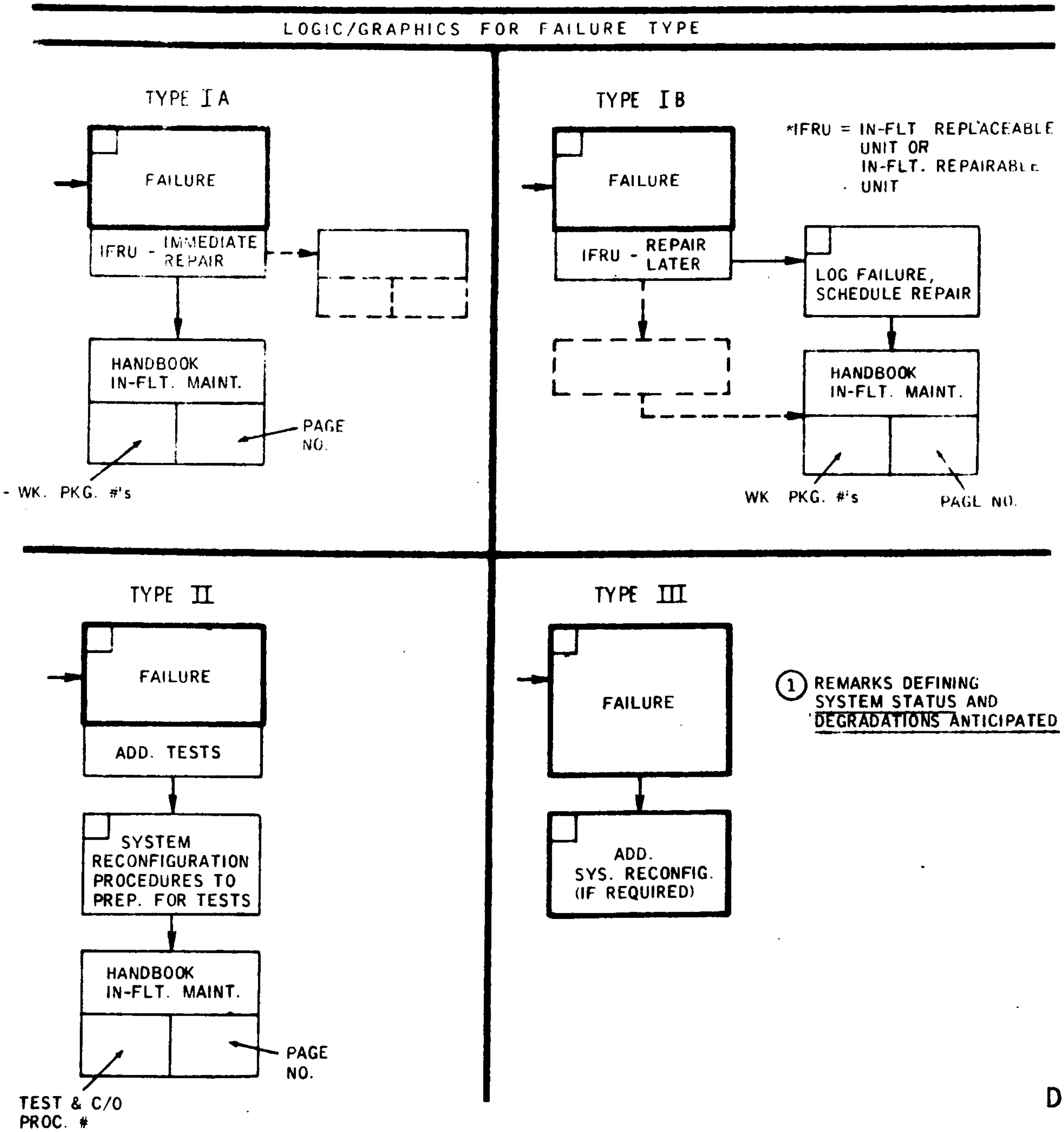
TYPE I. FAILURE IS AN IN-FLIGHT REPAIRABLE OR REPLACEABLE UNIT

A) IMMEDIATE REPAIR REQUIRED

B) LATER REPAIR POSSIBLE

TYPE II. ADDITIONAL TESTS REQUIRED TO IDENTIFY IFRU*

TYPE III. NO IN-FLIGHT MAINTENANCE POSSIBLE (SAME AS APOLLO)



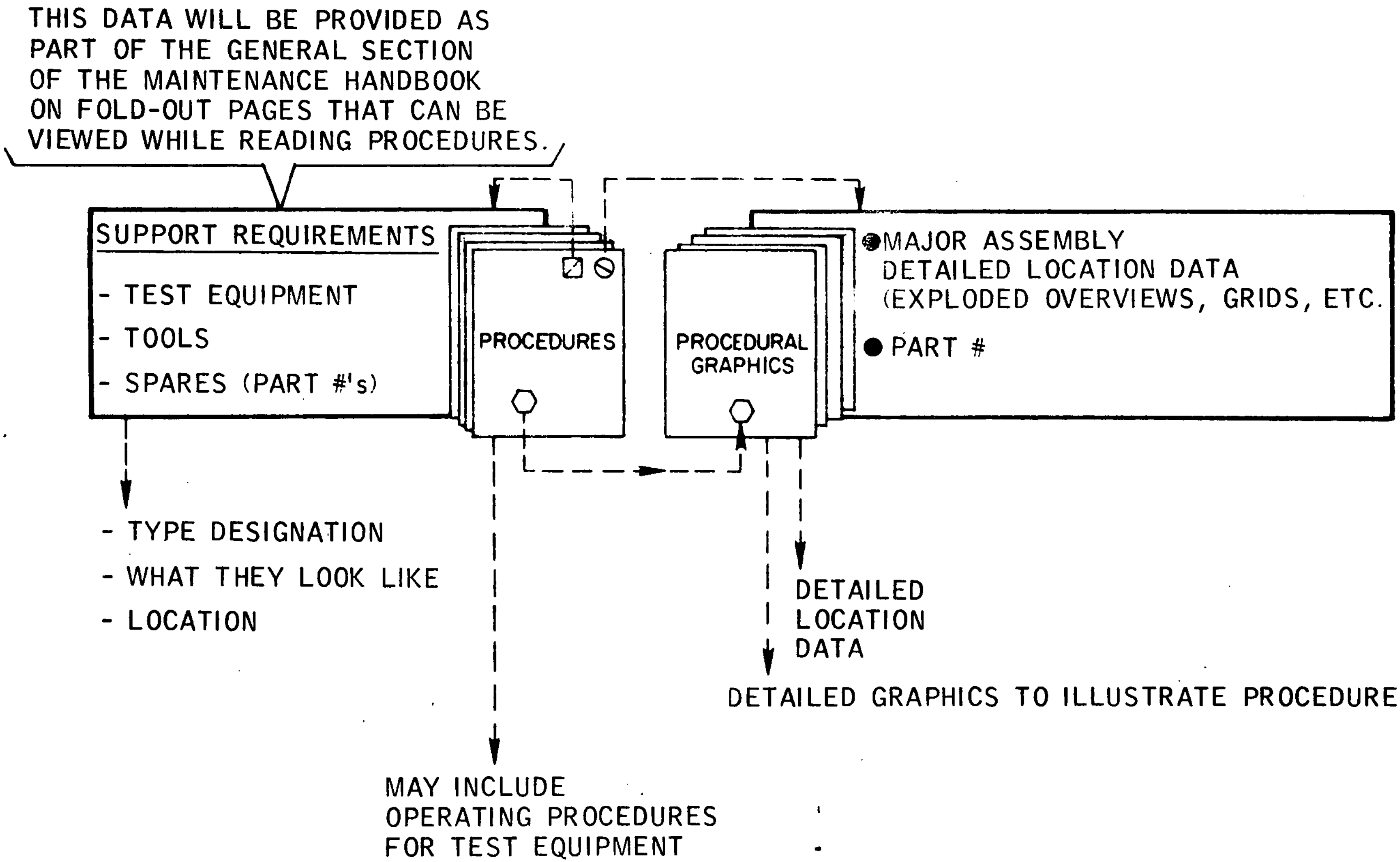


FIGURE 17
PRELIMINARY GE RECOMMENDATIONS FOR CORRECTICE MAINTENANCE
DATA FORMAT

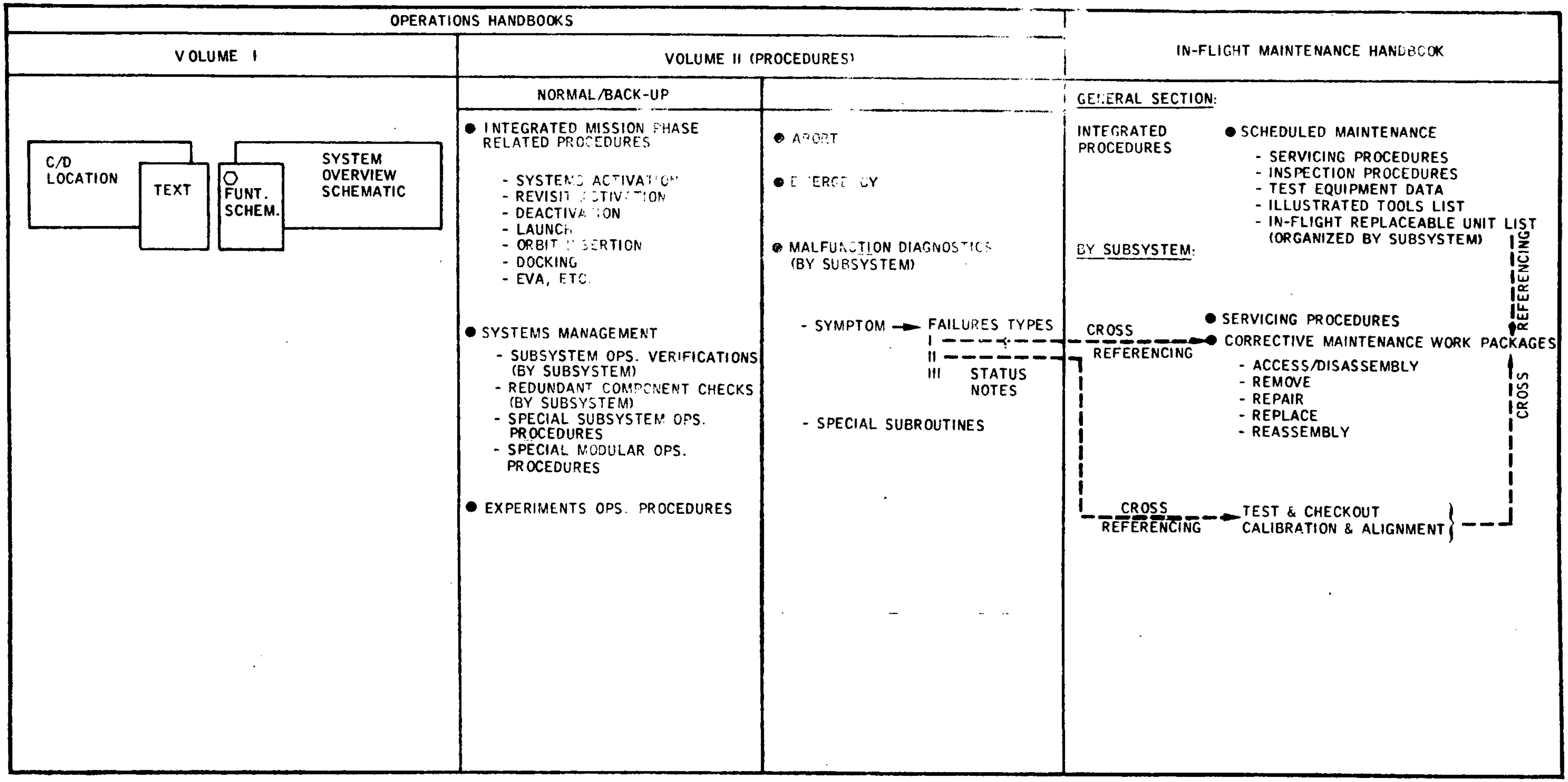


FIGURE 18

PRELIMINARY GE RECOMMENDATIONS FOR ORGANIZATION OF IN-FLIGHT OPERATIONS AND MAINTENANCE DATA

APPENDIX E

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