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ABSTRACT

This document defines the Boeing-Vertol Division Maintainability Program Plan for the Externally Mounted, Automatically Expelled/Inflated, Multiplace Life Raft for Helicopters (Automated Life Raft) (ALR) Program. The Plan defines the approach, identifies the tasks, and describes the methods to be used for assuring that appropriate maintainability considerations are incorporated in the Life Raft System Components.

1

KEY WORD

Automated Life Raft (ALR)  
Maintainability  
Maintenance Engineering Analysis  
Maintenance Requirements  
Maintenance Man Hour Per Flight  
Maintenance Concept  
Advanced Technology Component  
Disciplines  
Objective  
Quantitative Requirements  
Qualitative Requirements  
Interface  
Systems Engineering  
Measurement of Performance

ABBREVIATIONS

ALR	AUTOMATED LIFE RAFT
GSE	GROUND SUPPORT EQUIPMENT
PDR	PRELIMINARY DESIGN REVIEW
MMH/FH	MAINTENANCE MANHOUR PER FLIGHT HOUR 1
DS	DIRECT SUPPORT
GS	GENERAL SUPPORT
ILS	INTEGRATED LOGISTICS SUPPORT
<u>M</u>	MAINTAINABILITY
R	RELIABILITY
S	SAFETY
S/V	SURVIVABILITY/VULNERABILITY
HF	HUMAN FACTORS
MRA	MAINTENANCE REQUIREMENTS ANALYSES
MEA	MAINTENANCE ENGINEERING ANALYSIS

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## 1. INTRODUCTION

This plan presents the Automated Life Raft Maintainability Program, prepared in accordance with NADC Contract. The plan describes the maintainability activities which will be accomplished during design, fabrication and test phases of the ALR Program. The plan was prepared using MIL-STD-785A as a guide and complies with the intent thereof.

## 2. SCOPE

The Maintainability Program Plan defines the organization, controls and tasks to ensure the achievement of maintainability requirements as defined in NADC Contract N62269-76-C-0341 and to ensure the design of ALR components requiring minimum maintenance and support cost during their life cycle.

The program defined in this document places major responsibility for the development of maintainable components on the basic design unit. The Maintainability Unit, as one of the System Disciplines within the Product Assurance organization, is the principal unit designated to accomplish the tasks defined in this plan. These tasks include the definition of specific qualitative and quantitative requirements which are translated into maintainability design features.

Maintainability is a function of the interactive effects of a number of variables implicit in system requirements and configuration, hardware characteristics, support equipment and facilities, personnel skills, repair level decisions, manuals, spares, related maintenance techniques, policies and customs. Therefore, a maintainability program is essential to integrated logistics support development. Inherent in this maintainability program is a single integrated system maintenance analysis from which all logistics elements can be developed and which forms the framework for an integrated logistics support development program.

The program plan is directed primarily towards the ALR development program; however, the activities described herein will also be related to the requirements for the total aircraft system. These requirements will be described in enough detail to establish interfaces between the ALR components and other subsystems to assure that M considerations for the ALR are kept in concert with H46 system M objectives.

Following is a summary of the elements included within the scope of the M program:

- a. Accomplish a maintainability analysis to define qualitative and quantitative maintainability design requirements.
- b. Assign maintainability engineers to provide design assistance and monitor drawing boards on a day-to-day basis.
- c. Support design trade studies.
- d. Accomplish maintenance concept studies.
- e. Accomplish informal maintainability design reviews and participate in ALR design reviews.
- f. Accomplish detailed maintenance analyses to identify the maintenance tasks, task times, maintenance personnel, and GSE and test equipment requirements.
- g. Specify requirements for, and monitor and control subcontractor/vendor maintainability achievements.
- h. Continuously evaluate progress towards achievement of maintainability requirements and periodically update maintainability predictions.
- i. Preserve inherent maintainability characteristics of all design changes through maintainability reviews.
- j. Monitor ALR tests and evaluate the data obtained to determine the degree to which maintainability requirements have been achieved and update maintainability criteria and goals.

### 3. OBJECTIVES

The objective of this program is the development of ALR components which will meet the operational requirements with the least total investment in support resources. The objective for the H46 aircraft ALR system is shown below.

This system shall be designed so that Turnaround/Serviceing requirements will not exceed .01 MMH/FH based upon current aircraft utilization levels.

#### 4. DESIRED GOALS

The quantitative maintainability desired goals are as follows:

- a. 1800 hour MTBR and 3600 hour retirement life for essential ALR components
- b. On condition between Periodic Depot Level Maintenance (PDLM)
- c. 90% survival ready rate based on average of 50 and 150 flight hours per month per aircraft
- d. 30 minute (maximum) elapsed time to change each Life Raft

#### 5. PROGRAM MANAGEMENT, ORGANIZATION AND CONTROL

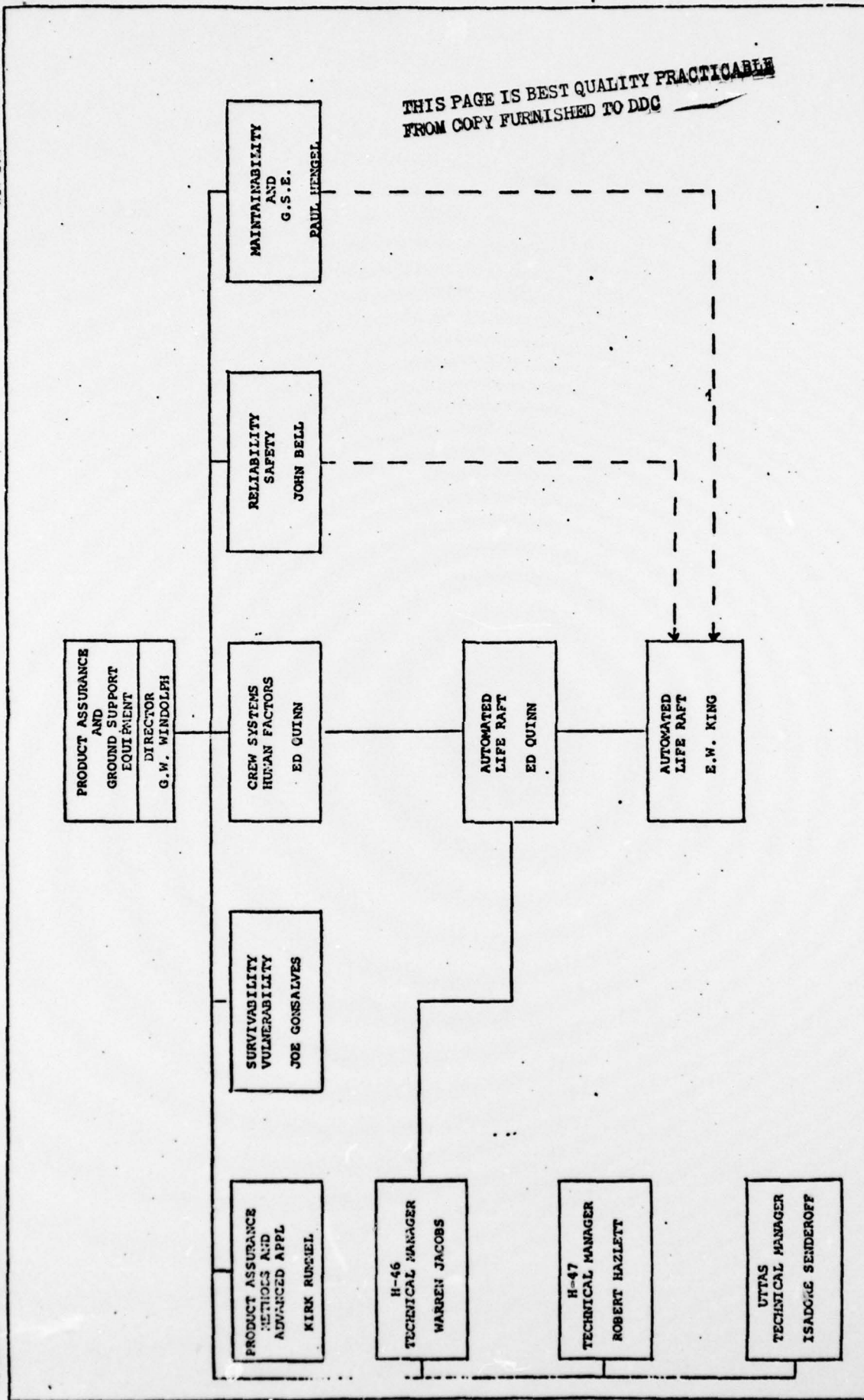
##### 5.1 ORGANIZATIONAL STRUCTURE AND RESPONSIBILITY

The organizational structure established for the ALR Program emphasizes the importance of the Product Assurance Disciplines and ILS Development. Primary responsibility for the Product Assurance Disciplines and ILS development is vested with the ALR Project Engineer in a single staff organization directly supervised by the Project Manager. The Product Assurance Engineer serves as a focal point of contact for internal and external organizations on maintainability matters. (See Figure 1)

##### 5.2 MAINTAINABILITY RECORDS

In order to provide continuous maintainability program visibility, the following records will be established and maintained by the Maintainability Unit:

- a. Descriptions of design changes caused by maintainability recommendations together with appropriate sketches, drawings and specifications.
- b. All maintainability design recommendations including those rejected and reasons therefore.
- c. Design review results, associated corrective action, and current status.
- d. A list of engineering drawings which have been signed off by Product Assurance manager.
- e. Maintainability and maintenance analyses, predictions and program maintainability verification results.



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FIGURE 1 ORGANIZATION CHART

### 5.3 APPROVAL OF DRAWINGS AND SPECIFICATIONS

In accordance with Boeing Drafting Standards Manual, DSM 93L1, Section 14, the Product Assurance Manager will receive for review and approval, prior to final release, all engineering drawings, system and subsystem specifications, procurement specifications, and documents defining criteria, objectives or requirements. This approval will assure that the aforementioned technical data reflects the specific product assurance requirements or meets the criteria, objective or requirement for the survival subsystem. The Product Assurance Manager's signature will indicate that the drawing or document complies with all requirements of the maintainability, reliability, safety, survivability/vulnerability and human factors engineering disciplines.

### 5.4 SUBCONTRACTOR/VENDOR CONTROL

Subcontractor/vendor selection and control is accomplished based on vendor capability and trade study results. Maintainability requirements and qualitative and quantitative maintainability design requirements will be imposed on subcontractor/vendors through contract end item specifications. These design requirements will be based on the results of the maintainability analyses defined in paragraph 6.1 of this plan. (See Figure 2)

## 6. MAINTAINABILITY ACTIVITIES

Primary design development maintainability activities include:

- a. Establishment of qualitative and quantitative maintainability requirements for the total ALR system
- b. Development of maintenance concepts
- c. Design support
- d. Assessment of hardware progress towards meeting M objectives

Sequential flow for task accomplishment is shown schematically in Figure 3.

### 6.1 MAINTAINABILITY ANALYSIS

A maintainability analysis of the ALR subsystems will be accomplished as an integral part of the maintainability program. The maintainability analysis will serve two purposes: The first, to define the qualitative and quantitative maintainability requirements to be incorporated into the ALR designs; and the second, to evaluate the degree of fulfillment of these requirements.

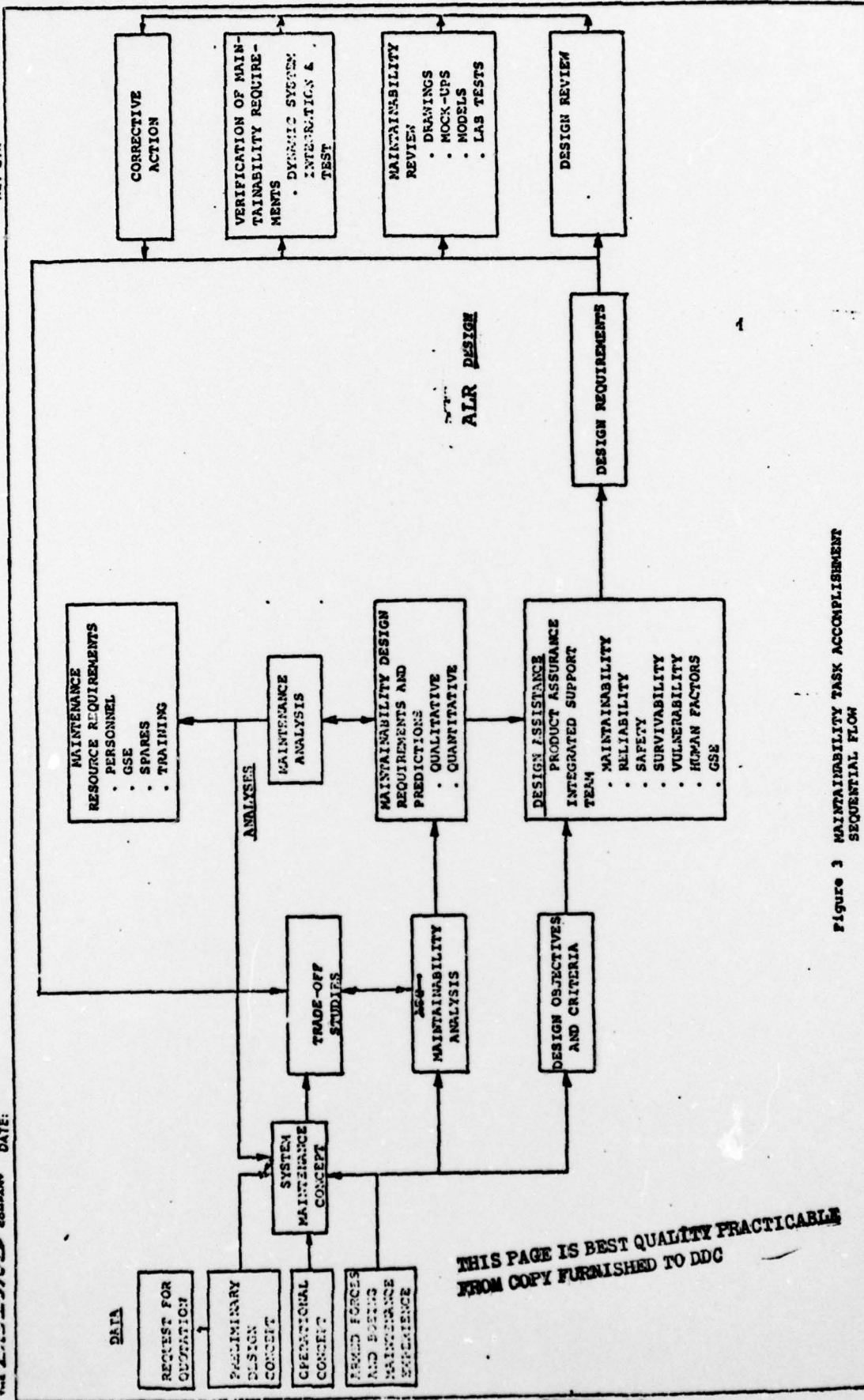


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Figure 3 MAINTAINABILITY TASK ACCOMPLISHMENT SEQUENTIAL FLOW

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### 6.1.1 Qualitative Maintainability Requirements

Qualitative maintainability requirements are those considerations which improve maintainability and minimize the requirements for special tools, GSE, facilities, manpower, high skill levels, training, inspection, servicing and testing. Maintainability engineers will analyze the ALR design concepts to assure that qualitative maintainability considerations will be incorporated in the designs.

### 6.1.2 Quantitative Maintainability Requirements <sup>1</sup>

Quantitative maintainability requirements are measurable units of time and effort required to accomplish a specific maintenance task in relation to the applicable performance requirements. The quantitative requirements must be achieved in order for the ALR to meet its operational requirements. Included in the quantitative requirements are: maintenance manhours per flight hour; turnaround time, reaction time, and repair time. Quantitative maintainability requirements will be allocated to the ALR subsystems. The allocations will be on the basis of the following considerations:

- a. Operational concepts and preliminary maintenance concepts
- b. Results of maintainability trade studies
- c. Subsystem preliminary reliability analyses
- d. Maintenance experience retention data which may be factored by judgment values based on improvement or degradation in the following areas: accessibility, size, component count, complexity, weight, modularity, interchangeability, and use of diagnostics.

### 6.1.3 Maintainability Requirements Achievement Evaluation

The purpose of the achievement evaluation will be to assure that the maintainability requirements have been incorporated into the ALR designs. The end objective will be ALR designs having characteristics that will enable military personnel to maintain the H46 within the MMH/FH requirements identified in section 3.0 of this plan.

## 6.2 MAINTENANCE ANALYSIS, CONCEPT AND PLAN

The Maintainability Unit will conduct a maintenance analysis to develop a detailed maintenance concept and plan. The maintenance concept and plan will be based on established military maintenance and operational management systems, capabilities and requirements. Primary objective of the maintenance concept and plan will be the support of the operational mission.

Preliminary maintenance concepts based on the H46 operational plan will be fundamental in the identification of the qualitative and quantitative maintainability requirements. These concepts will be expanded and refined to the detail design level, as the designs progress, to guide the designers in consonance with the maintainability requirements. The maintenance plan will evolve from the maintenance concept through repetitive maintenance analysis. The maintenance concept and plan will form the basis for justifying acquisitions of maintenance resources. Development of the maintenance concept and plan will continue throughout the ALR program and will become more definitive as designs are completed, and hardware is fabricated and tested.

### 6.2.1 Maintenance Analysis

The maintenance analysis forms the basis for the development of the detailed maintenance concept and plan. The maintenance analysis will identify the maintenance action requirements to be performed, the technical constraints which establish the need for scheduled maintenance requirements, and the maintenance resources necessary to perform the maintenance activities.

The maintainability engineer will identify the maintenance activities by making a preliminary analysis of the component resulting in a list of requirements which may be performed on the component. This list will provide the maintainability engineer with an outline to follow during the detailed analysis. As the analysis progresses the maintainability engineer will establish additional maintenance requirements or delete those not valid.

The maintainability engineer will conduct the detailed maintenance analysis of the component by gathering all drawings, reliability data, information available on the component and studying this data to obtain a good background on the component maintenance characteristics and the design approach. The maintainability engineer will analyze the data and identify "what" has to be done and how often to insure that the component is maintained in

satisfactory condition. The maintenance activities are normally oriented to the particular maintenance characteristics of the item under consideration. These maintenance actions will include the following:

- a. Servicing (lubrication, cleaning, etc.)
- b. Inspections
- c. Adjustments/calibration and rigging
- d. Functional tests
- e. Remove and Replace
- f. Troubleshooting
- g. Repairs

The number of maintenance actions will be kept to a minimum. The need for performing the maintenance action will be related in specific terms to the technical characteristics of the component or the mission demands of the system which employs it. Technical justification will be provided for the performance of scheduled maintenance actions and those without valid technical justification will be eliminated.

Once the maintenance activity list has been completed, a detailed maintenance task analysis will be initiated to identify the tasks which must be performed to satisfy the maintenance requirements. The task analysis will identify the individual tasks; and describe how the task is performed only in sufficient detail to identify the resources required to accomplish the task. The maintenance task analysis will provide a basic outline for the contents of the maintenance manuals and forms the basis for descriptions of sequential troubleshooting procedures.

During the maintenance analysis the maintainability engineer will define design features which would simplify the maintenance requirements at the organizational level. Maintainability design features thus identified will be discussed with the appropriate designers for possible action.

Maintenance resource requirements will be determined based on the results of the maintenance requirements and task analyses. The following maintenance resource requirements will be identified:

- a. Maintenance level to perform the maintenance action
- b. Personnel requirements (numbers and skill level)
- c. Parts required
- d. Tools and equipment necessary. Required GSE will be identified. The installation of sensors and the use of diagnostics, modularity in design, and throwaway concepts all of which reduce the need for special GSE, will be discussed with the designers for possible inclusion.

- e. Consumable materials necessary
- f. Task time estimates based on field experience historical data and personal experience
- g. Training
- h. Technical publications

The results of the complete maintenance analysis will be used to form the framework of the ILS program to identify requirements for spares, GSE, technical publications, and personnel training.

#### 6.2.2 Maintenance Concept

To develop the maintenance concept the maintainability engineer will take the results of the maintenance analysis and the reliability analysis and compare the two in relation to each other. The reliability analysis results will be defined quantitatively in terms of component failure rate. The comparison analysis will assure that the two areas are compatible. Where significant differences exist an investigation will be conducted to determine the cause of the difference and necessary corrective adjustments will be made. Results of safety, survivability/vulnerability, and human factors engineering analyses will be reviewed and integrated into the concept where appropriate. The completed integrated effort will establish the maintenance concept.

#### 6.2.3 Maintenance Plan

The maintenance times generated by the components will be measured against the predicted maintainability parameters. Build up of manhours which exceed the parameters can be readily detected. Components which require excessive portions of the maintenance time allotted to their particular subsystem/system which may adversely affect that subsystem/system will thus be identified and corrective adjustments will be made. Maintenance times will be grouped by categories such as maintenance levels, inspections, servicing, etc. Accrual of time against the predicted parameters of the various categories will be continually monitored. When a parameter is exceeded the design will be reviewed from a maintainability standpoint. If the design is acceptable or design revision is impractical, the maintenance concept will be adjusted to bring the parameter into line. In this manner controlled development of the maintenance plan will take place. Deviations from the parameters and design objectives will be controlled to avoid creating definable risks from a standpoint of operational readiness, safety and economy.

### 6.3 DATA COLLECTION

An existing data system which uses military, Boeing and industry sources historical data will be utilized to provide the baseline for assessing the ALR System. (See Figure 4)

### 6.4 MAINTAINABILITY DESIGN OBJECTIVES AND CRITERIA

Maintainability design criteria in general will be those listed in Boeing Document D8-1007, Maintainability Design Guide, Vertol Division. Attainment of the maintainability design objectives will be reviewed with individual designers as the detailed ALR designs progress and during design reviews. Specific criteria will be identified for the ALR System.

### 6.5 DESIGN TRADE-OFF TECHNIQUES

The Maintainability Unit will participate in design trade-offs under consideration by the ALR design unit. The trade-off factors involved are critically of failure, reliability of equipment, economic limitations, and operational performance requirements. The Maintainability Unit will perform a maintenance analysis of the design concepts under consideration. These analyses will produce quantitative maintainability and maintenance resource data and identify any unusual maintenance problems. Where possible, these data are used to provide the comparative maintenance impact of each alternative on life cycle logistics costs. The effect on the ALR subsystem as a result of any trade-off compromise of maintainability will be evaluated, documented and reflected in the overall maintainability analysis. Figure 5 depicts the process by which the trade-offs are accomplished.

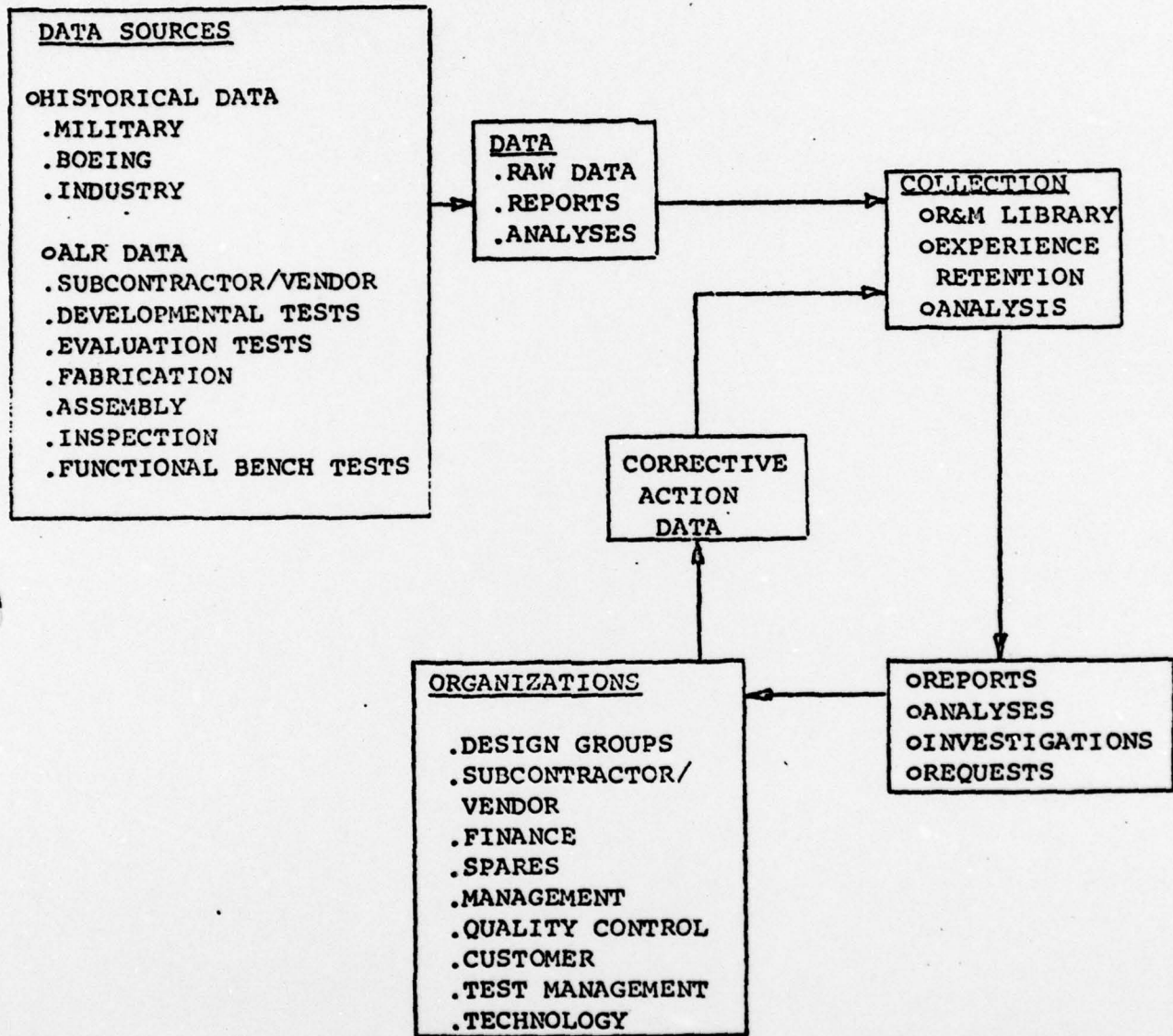


Figure 4 DATA COLLECTION SYSTEM

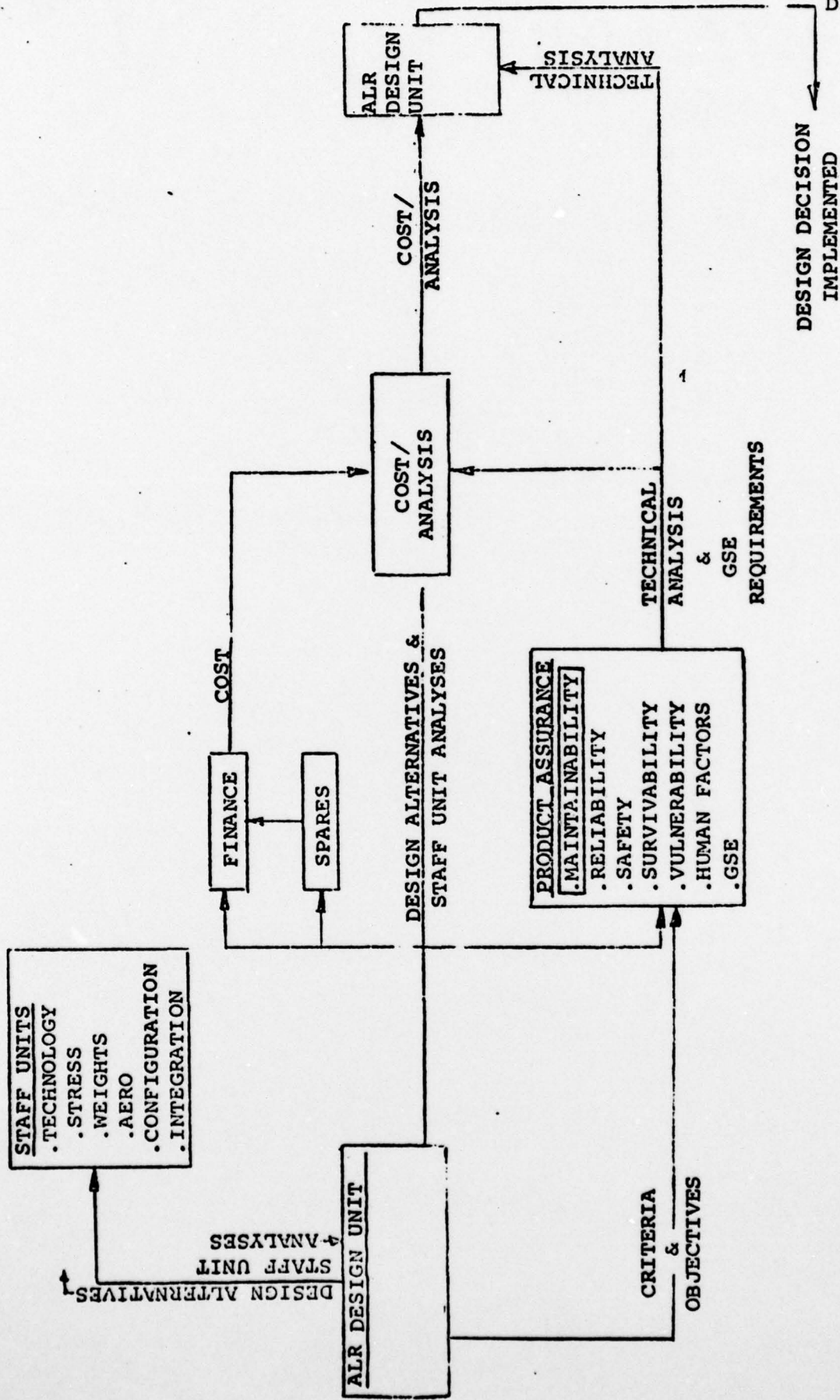


Figure 5 DESIGN TRADE-OFF STUDY FLOW

## 6.6 DESIGN ASSISTANCE

In order that the established maintainability design criteria be interpreted correctly and translated into acceptable designs, the Maintainability Unit will provide assistance to the ALR design unit. The Maintainability Unit will integrate its efforts with that of the other Product Assurance Disciplines. The total Product Assurance assistance effort will thus be that of an integrated design support team representing maintainability, reliability, safety, survivability/vulnerability, and human factors engineering. This team will be physically located in close proximity to the ALR design unit to ensure timely and effective design support. The Maintainability Unit will be responsible for the following design assistance efforts:

- a. Monitoring drawing boards to continually review design progress.
- b. Identifying maintainability problems.
- c. Submitting maintainability recommendations to the ALR design unit.
- d. Reviewing, evaluating, and approving drawings and specifications for appropriate maintainability considerations.
- e. Participating in design reviews to verify that the designs will satisfy all maintainability design criteria and objectives.
- f. Monitoring and participating in engineering development and test activities.
- g. Reviewing and approving engineering changes to released drawings and evaluating the effect on maintainability.
- h. Participating in design trade studies.
- i. Identifying critical maintenance items and initiating proper design action.
- j. Evaluating the interface relationships between the individual subsystems for the impact on maintainability.

## 6.7 DESIGN REVIEWS

Maintainability engineers will participate in design reviews when required.

## 6.8 MAINTAINABILITY APPORTIONMENTS & PREDICTIONS

Maintainability quantitative apportionments for the ALR subsystems will be made as part of the H46 maintainability program. Subsequent predictions will be performed to evaluate the ability of the design to achieve the maintainability quantitative objectives and identify design features requiring corrective action.

Baseline maintainability data used in the predictions will be provided by the data collection system. Primary data source will be CH-46 maintainability field experience historical data. The maintainability engineers will formulate factors for each subsystem against the maintainability parameters. These factors will be judgment values which will be weighted by the maintainability engineers on the basis of available subsystem definition against the maintainability baseline data. Factors will give consideration to improvement or degradation in the following areas; accessibility, size, component count, complexity, weight, modularity, interchangeability, and use of diagnostics. A factor of 1.0 will represent no significant change or an absence of definition. A value greater will show a degradation for the parameter and a value less an improvement.

Predictions of maintenance task times will be accomplished as part of the maintenance analysis. Maintenance task times derived from the maintenance analysis will be grouped by subsystem/and types of maintenance categories. These task time groups will be measured against the predicted parameters as part of developing the maintenance plan.

## 6.9 MAINTAINABILITY HARDWARE REVIEWS

Wherever and whenever possible during ALR hardware fabrication, assembly, laboratory and developmental tests, maintainability engineers will conduct informal observations to identify maintainability problem areas. Primary purpose of the reviews will be to identify maintenance tasks likely to be difficult to perform once the component is installed in its subsystem. The reviews will allow the refinement of certain maintenance task analyses established during the maintenance analysis and will identify problem areas for possible early corrective action.

## 6.10 UPDATING PREDICTIONS

The quantitative maintainability predictions undergo refinement during design development until interim predictions are established at the time of drawing release. Changes to the design after drawing release may affect the maintainability predictions. Maintainability engineers will evaluate all design changes and update predictions as required. Final predictions will be established after hardware reviews have been accomplished and test data evaluated.

#### 6.11 CORRECTIVE ACTION

Despite efforts during design to produce components with the desired maintainability characteristics, some problems requiring corrective action may be discovered during fabrication and test. When the problem directly involves maintainability, a maintainability engineer will be assigned responsibility to investigate the problem, make appropriate recommendations, and follow-up. The Maintainability Unit will monitor and coordinate all corrective actions for maintainability. 4

#### 6.12 DESIGN CHANGE REVIEWS

Proposed design changes after drawing release will be analyzed by the Maintainability Unit for their maintenance impact and effect on maintainability predictions. Results of this analysis will be evaluated in trade-offs and held for design reviews. Maintainability engineers will participate in design reviews when required.

#### 7. TECHNICAL PERFORMANCE MEASUREMENT

Measurement of technical performance in achieving the established maintainability objectives (reference Section 3. ) will be conducted using the methodology developed to measure technical performance relative to impact on design gross weight. However, the technique will be simplified somewhat, by making the evaluation at the subsystem level and measuring directly in maintenance manhours per flight hour.