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RELIABILITY PROGRAM PLAN

FOR THE

KILOWATT ISOTOPE POWER SYSTEM (KIPS)

TECHNOLOGY VERIFICATION PHASE

Sundstrand Report Number RE-4089

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KIPS Program Manager

COO-4299-037

DISCLAIMER

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RELIABILITY PROGRAM PLAN

KIPS TECHNOLOGY VERIFICATION PHASE

1.0 INTRODUCTION

1.1 Scope

This document is an integral part of the Kilowatt Isotope Power System (KIPS) Program Plan. This document defines the KIPS Reliability Program Plan for the Technology Verification Phase and is referenced in the KIPS Program Plan as Task 7.0. This document delineates the reliability assurance tasks that are to be accomplished by Sundstrand and its suppliers during the design, fabrication and testing of the KIPS.

2.0 GENERAL PROGRAM REQUIREMENTS

2.1 Purpose

The reliability program is established and will be implemented to assure that reliability is considered in the design, fabrication, and testing of the KIPS. The reliability program plan is based on DOE Specification SNS-2 "Reliability Engineering Program Requirements" dated June 17, 1974.

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2.2 Plan Preparation

The plan defined herein is the KIPS reliability program plan. The plan format follows the format of DOE Specification SNS-2. The reliability program defined herein complements and supports functions required by the KIPS program plan.

2.2.1 Revisions

This document shall be updated as necessary if the work effort or contract is modified and any revisions and deviations shall be submitted to DOE for approval.

2.2.2 Implementation

The reliability program plan presented herein defines the total reliability effort for the KIPS Technology Verification Phase without further reference to DOE Specification SNS-2. The approved program plan shall be the standard used by DOE to evaluate Sundstrand's reliability performance.

3.0 ORGANIZATION AND DOCUMENTATION

3.1 Organization and Management

3.1.1 Reliability Organization

The Reliability Manager reports functionally to the KIPS Program Manager.

The formal reliability organization consists of technical experts, engineers, and statisticians reporting to the Test and Reliability Engineering Department Manager, responsible directly to the Vice President of Engineering. The reliability organization acts as director of reliability efforts, interprets specifications, gathers and analyzes results, critiques and publishes performance data, coordinates supplier reliability efforts where necessary, and participates in design analysis and testing.

The KIPS program organization is shown in Figure 1.

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3.1.2 Reliability Manager

The Reliability Manager is responsible for the planning implementation and management of the reliability program. The Reliability Manager has the necessary authority and resources to discharge reliability program responsibilities. Direct liaison between DOE personnel and the Reliability Manager is authorized.

3.1.3 Interface with Other Organizations

Direct liaison between the Reliability Manager and technical and support groups is to be accomplished through participation in component analysis design and test; system design tradeoffs and reviews; system testing and data reduction, etc.

3.1.4 Personnel and Training

Trained and competent reliability engineering personnel are assigned to implement the reliability program. Indoctrination of the program managers and personnel from technical and support groups with reliability diciplines, techniques and procedures will be conducted. If unique circumstances dictate, a special training program for reliability, technical and support personnel will be initiated.

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3.2 Program Documentation

Formal written reports covering the program and results obtained during the performance of the reliability tasks will be prepared and submitted.

3.2.1 Reliability Milestones

The reliability program is planned and implemented to meet the KIPS program milestones scheduled in Task 1.0 of the KIPS program plan. The reliability task/milestone schedule is presented in Figure 2.

3.2.2 Program Reviews

The progress and significant accomplishments of the reliability program will be documented and reported at the formal design reviews scheduled in Task 1.0. Reliability reviews, informal design reviews and working meetings will be held as needed in conjunction with and preparation for the regularly scheduled Design Reviews.

3.2.3 Facilities Review

Quality Assurance may conduct surveys of suppliers' facilities as provided in the Quality Program Plan.

3.2.4 Progress Reports

Progress and accomplishments of the reliability program will be included in the monthly Program Technical Report of Task 8.0. Formal reliability reports will be distributed with the monthly Technical Report. The overall results of the reliability program will be summarized and presented in the Final Flight System Design Report.

3.2.4.1 Progress Report Content

Progress reports will in general include the following:

a. Progress of each reliability task including significant accomplishments and milestones during the reporting period.

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3.2.4.1 Progress Report Content (Continued)

b. Reliability problem areas and proposed corrective action.

c. Failures that occurred during the reporting period and the corrective action taken.

d. Further action of unresolved failures.

e. Decisions and actions during the reporting period having impact on the reliability effort and descriptions of their anticipated effect on reliability.

f. Anticipated reliability program changes, their effects, and corrective action taken.

g. A description of formal or informal reliability recommendations, an evaluation of the effect of the change on the system, and the action taken.

3.2.4.2 Reports of Meetings

Sundstrand will submit the minutes of each Sundstrand/DOE reliability meeting within ten days.

4.0 DESIGN RELIABILITY ELEMENTS

4.1 Design Specification

Design specifications will be prepared by Design Engineering to describe the requirements of special purpose, non-standard and off-the-shelf components. These design specifications will include, as appropriate, functional, environmental, physical, reliability, and performance requirements against which purchase can be made and operational characteristics assessed. Reliability will review all design specifications to insure compatability with reliability requirements.

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4.2 Reliability Design

The use of stress derating, tolerance studies, redundancy, stress strength analysis, materials analysis, variables analysis, design trade-off studies and similar reliability oriented design techniques will be practiced in designing equipment to reduce the likelihood of critical failure modes and early wearout.

4.2.1 Expected Environments

An expected environments study will be developed based on inputs from DOE and Sundstrand generated data. The expected environments study will describe the expected environmental inputs to the system from the time the system is accepted to its end use environment.

4.3 System Variables Analyses

During Phase I of the KIPS Program, a system optimization program was used to examine the effect of component design variables on the performance of other system components and on the thermal performance of the entire system. The optimization program consists of a computerized mathematical model of the system incorporating both cycle analysis and component design. The system performance analysis will be updated during the KIPS design phase to ascertain the effect of design and parameter changes on system requirements. Results of the system performance analysis will be considered and included in the FMECA of Paragraph 5.4 herein.

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5.0 RELIABILITY ENGINEERING PROGRAM ELEMENTS

5.1 Reliability Goal

The reliability objective for the flight system is established by DOE as .93 for 7 years.

5.2 Demonstrated Reliability

Not applicable for technology verification program since requirement is for program which extends beyond development.

5.3 Reliability Participation and Analysis

Reliability organization participation began with the Phase I request-for-proposal and will continue throughout the KIPS program.

5.4 Failure Modes, Effects and Criticality Analyses (FMECA)

The FMECA provides a systematic, detailed, and continuous review of all system components and functions at the earliest possible phase of design. The FMECA will be performed to identify potential failure modes upon mission requirements. An FMECA was prepared for subassemblies and major components during Phase I. During the Technology Verification Phase, the FMECA will be continued incorporating changes in the KIPS baseline design.

5.4.1 Failure Modes and Ranking

All credible failure modes will be identified to include relationships with single or multiple components. Worst case environments will be assumed. Failure modes will be ranked on a relative scale of likelihood from 1 to 100 with 100 the most likely.

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5.4.2 Failure Effects and Ranking

A systematic and detailed review shall be made of all possible effects resulting from the identified failure modes. Failure effects will be ranked from 1 to 100 with 100 being the worst case. Failure effect categories and rankings are as follows:

FAILURE EFFECTS CATEGORIES AND RANKING

Category	Failure	Rank
I	Results in catastrophic or imminent loss of power and mission.	100
II	Results in a reduction in power causing a partial mission failure.	50
III	Results in failure or out of specification condition not affecting power. Presuming KIPS is ground started and operates during launch, start failures are included in this category.	5

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5.4.3 Criticality

The rankings of 5.4.1 and 5.4.2 will be multiplied to obtain a criticality ranking.

5.4.4 Failure Mode Elimination

Failure modes having high criticality ranking will be given special emphasis for elimination. Those that cannot be eliminated will be highlighted and analysis will be performed to provide justification for their retention in the design. No special tests are planned to verify an acceptably low probability of occurrence for failure modes having high ranking. A listing of particularly critical parts and processes, with critical characteristics described, will be prepared based on the results of the FMECA and the table of design criteria created in Paragraph 5.5.2.2. This list will be provided to project engineering and quality assurance in refining the design to achieve the highest practical reliability.

5.4.5 FMECA Reporting

A FMECA report will be prepared which includes hardware description and function, design specification, expected environments, assumptions, and support documentation. Detailed FMECA worksheets will be provided and include the information required from Sections 5.4.1, 5.4.2, and 5.4.3 and 5.4.4. The format for the FMECA tabulation will be similar to the format of Figure 3. Summary sheets will be used to highlight failure modes having a high relative criticality ranking.

5.5 System Logic Synthesis

A System Logic Synthesis will be prepared to indicate the logical combination of failure modes leading to a critical system failure, provide a basis for allocating the failure probabilities of the system to the failure modes, and to assess system reliability from the assessed failure mode probabilities. The system logic synthesis is defined in the following subparagraphs.

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5.5.1 Logic Diagrams

System logic block diagrams will be developed to accurately depict the logical association between various modes of failure that individually or in combination can cause a critical system failure. The system logic block diagram will generally follow the functional logic of the system and will be capable of describing synergistic and dependent modes of failure as well as multiple modes of failure from the same component or components. Logical symbols such as AND, OR, NOR gates, etc., will be used as needed.

5.5.2 Probability Equations

System failure (or success) equations will be developed to describe the association between the failure modes and their impact on the system.

5.5.2.1 Allocations

The logic diagram and probability equation will be used as a guide to perform an allocation study to allocate failure probabilities to components based on the requirements of Paragraph 5.1.

5.5.2.2 Assessment

The logic diagram and probability equation will be used to assess system reliability. The results of the assessment will be compared with the reliability goals. In general, failure rate sources for the reliability prediction will be as follows:

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5.5.2.2 Assessment (Continued)

-Sundstrand failure rate data
-AVCO Corp. Reliability Engineering Data Series
-MIL-HDBK-217B, Reliability Prediction for Electronic Equipment
-Supplier Failure rate data
-Current literature
-Engineering judgement

In addition, to support the assessment, a table of design criteria (e.g., environment, stress levels, safety factors) will be prepared for critical components.

5.5.2.3 Sensitivity Analysis

The reliability equation will be used where necessary to determine the sensitivity of the system assessment to possible ranges of failure mode assessments.

6.0 TEST PROGRAM

6.1 Purpose

The purpose of the test program is to evaluate and verify the KIPS design.

6.2 Requirements

The test program will be conducted according to the approved KIPS test plans prepared in Task 5.0. Data from the tests will be used, to substantiate the FMECA and give additional confidence to the reliability assessment.

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6.3 Data Sources

Test data, along with any other DOE contract data, will be used, to the extent possible, to substantiate failure modes and to assess their criticality.

6.4 Failures and Corrective Action

6.4.1 Failure Definition

An item which does not meet the performance requirements of its specification is defined as failed.

6.4.2 Failure Reporting

Failures which occur during the reliability, performance, and endurance tests of the KIPS test plan will be recorded and analyzed. Failure analysis and corrective action will be recorded on the Sundstrand Malfunction and Trouble Report form.

6.4.2.1 Description and Analysis

Each reliability, performance, and endurance test failure will include a description of the failure, test conditions, cause of failure, and corrective actions.

6.4.3 Failure Review Board

Failures and/or malfunctions occurring during performance and endurance testing will require review by the failure review board. Membership of the failure review board will consist of the following personnel or their designees:

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6.4.3 Failure Review Board (Continued)

a) KIPS Program Office

b) KIPS Project Engineering

c) KIPS QA Engineer

d) KIPS Reliability Engineer

e) KIPS Design Engineer

f) DOE Representative-observer capacity only

When a failure or malfunction is experienced, the responsible personnel will take the following actions:

1) Test Personnel will take whatever actions are necessary for the protection of test personnel and test hardware.

2) Test Engineering will place a hold on the test.

3) KIPS Project Engineer/Q.A. Engineer will convene the FRB.

4) Failure Review Board determines the root cause of the failure or malfunction. If not possible within a reasonable length of time, the FRB will collect all available evidence for determining the root cause of failure or malfunction at a later time.

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6.4.3 Failure Review Board (Continued)

5) Failure Review Board determines disposition.

6) Failure Review Board determines corrective action or defer a decision until a later time if not practical prior to resuming test.

7) Failure Review Board will obtain safety concurrence.

8) Failure Review Board only may release the hold on the test.

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7.0 MAINTAINABILITY

7.1 Maintenance Free Design

The system will be designed to be maintenance free or as near maintenance free as is practicable.

7.2 Tolerance Control

As a design goal, tolerances will be controlled to allow interchangeability of replaceable components.

7.3 Maintenance and Operation Analysis

Maintenance and operation will be considered during the design stage.

8.0 HUMAN FACTORS ANALYSIS

8.1 Human Problems and Failures

Human problems and failures will be considered during the design stage.

8.2 Reports

Human factors considerations will be included, where appropriate, in other reliability program reports.

KIPS ORGANIZATION

The accompanying chart is presented to show the Sundstrand organization elements which are directly involved in the KIPS program.

The KIPS program is in Energy Systems, Division of Sundstrand Corporation. The Program Manager is directly responsible to the Energy Systems General Manager for the successful operation of all aspects of the program.

The three product line units, Aviation Mechanical, Electric Power and Energy Systems, in the Advanced Technology Group, are shown along with the Operations unit. The Operations unit supports the three product line units in the functional areas of Engineering (Research, Test, Design), Production (Material, Quality Assurance, Manufacturing) and Administration (Data Control, Management, Accounting, Pricing).

For specific programs such as KIPS, it is the responsibility of the Reliability, Quality Assurance and Hardware Managers to assign individuals to support the program and functionally report to the Program Manager. For major subcontractors such as Teledyne, the Materials Department of the Operations unit is responsible for assigning an individual to the program to perform the contractual interface function with the subcontractor.

In the Operations unit, the Vice President of Engineering is responsible for the research, test and design functions. Due to the nature of the KIPS program, a Research Engineering Manager has been assigned to functionally work within the program organization. The test and design functions are directed by task assignment originating from the KIPS Project or Research Engineering Managers.

Likewise, the Contracts Manager in the Energy Systems unit has assigned Program Control and Cost Control personnel to functionally report to the KIPS Program Manager.

SUNDSTRAND - KIPS PROGRAM

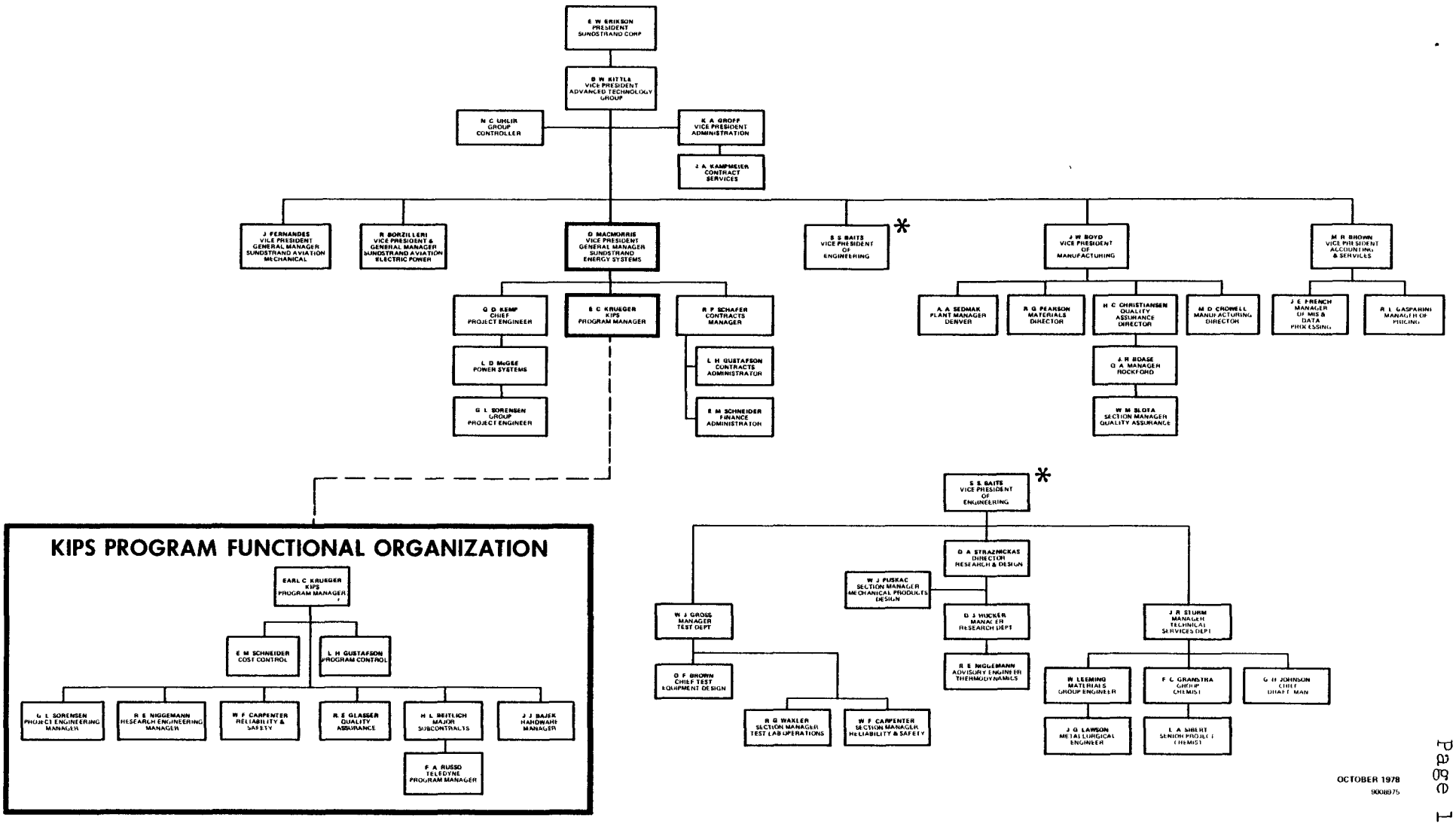

FIGURE 1 - KIPS PROGRAM ORGANIZATION

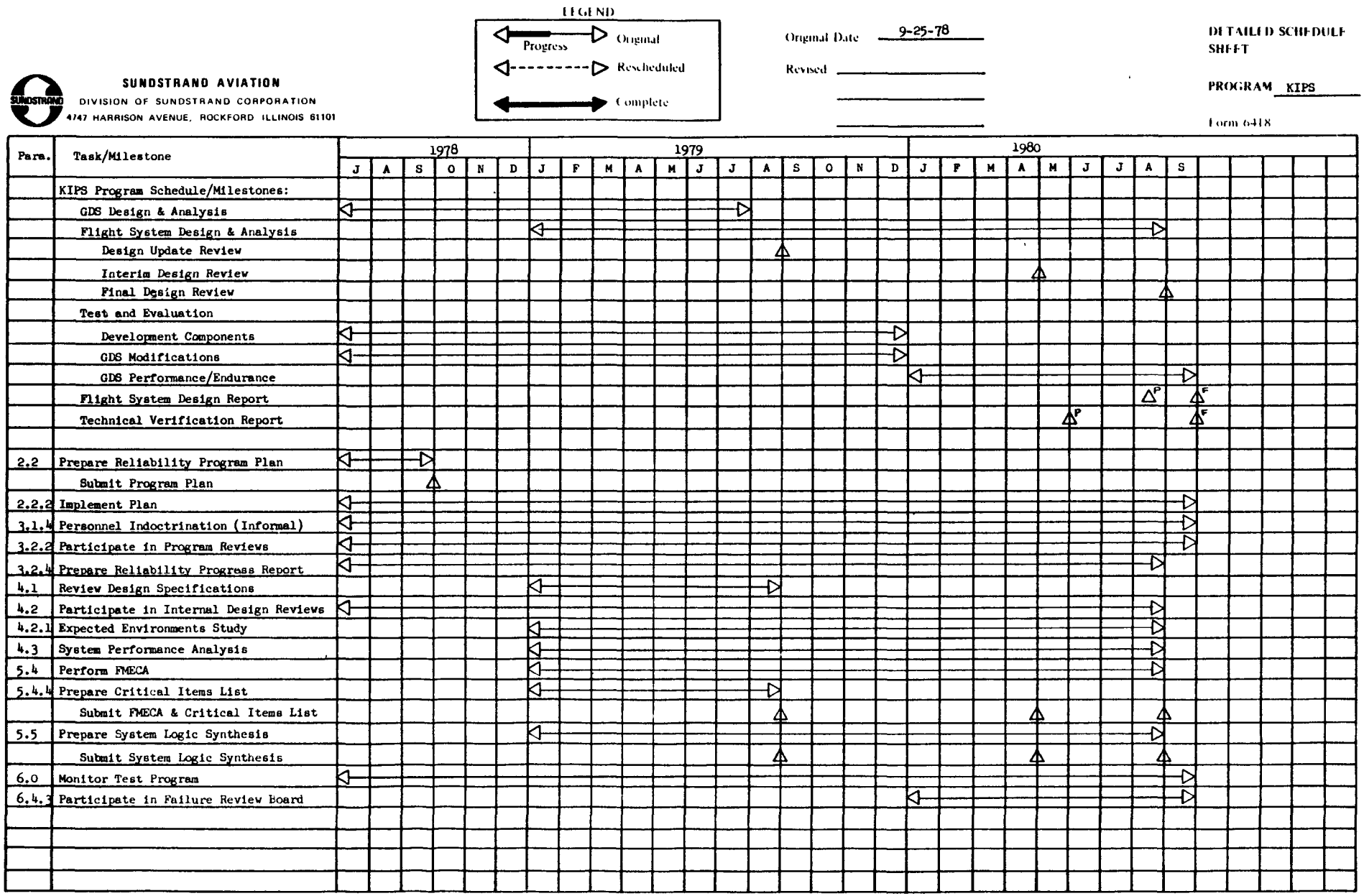

FIGURE 2 - TASK AND MILESTONE SCHEDULE

FAILURE MODE AND EFFECTS ANALYSIS

NO.	COMPONENT & FUNCTION	FAILURE MODES (FM)	POSSIBLE FAILURE CAUSES	FAILURE EFFECT (FE)	③ CRITICALITY RANK, ① × ② = ③ ② FE RANK ① FM LIKELIHOOD DESIGN/SAFETY CONSIDERATIONS	①	②	③

FIGURE 3 FMECA FORM