MSFC ROUTING SLIP

CODE	NAME	INIT.	☐ ACTION	☐ INFORMATION

REMARKS

This document was cited in the Saturn contracts before NPC-250-1 was written.

The sense of this document is the backbone of NASA reliability today and has become a generally accepted element of engineering rationale.

Sam McCrary

CODE	NAME	DATE

MSFC - Form 183 (Rev. February 1961)

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REVISION 2

RELIABILITY ENGINEERING PROGRAM PROVISIONS

FOR

SPACE SYSTEM CONTRACTORS

Document No. M-REL-M-131-62

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SECTION 1: INTRODUCTION

1.1 GENERAL

This document, "Reliability Engineering Program Provisions for Space System Contractors", document number M-REL-M-131-62, sets forth common, general requirements for Marshall Space Flight Center contractor reliability programs necessary to insure that complete launch vehicle systems, stages, subsystems, components, and associated ground support equipment shall meet the reliability requirements of the contract. These requirements include the establishment, control and maintenance of an effective reliability engineering program from the design conception to the delivery of articles that meet the intended design with a satisfactory reliability level. This document is consistant with existing MSFC reliability policies, reliability policy board directives, and reliability scopes of work. It amplifies in considerable detail, the requirements which may be invoked in a space system contract.

1.2 APPLICABILITY

This document is applicable when invoked by reference to it in the prime contracts for MSFC launch vehicle systems and elements thereof. It also applies to those major subcontracts to which its provisions are pertinent, as determined by the MSFC Deputy Director for R&D, by the cognizant MSFC project system office, or by the prime contractor. The reliability requirements herein shall also be utilized by potential MSFC contractors as guidelines in preparing a proposed reliability program for a space system in response to a request for proposal.

1.3 RELATION TO DETAIL REQUIREMENTS

Reliability program requirements set forth in this document shall be satisfied in addition to all detail requirements contained in the statement of work, or in other parts of the contract. Regardless of the requirements of this document, the contractor is responsible for compliance with all provisions of the contract and for furnishing specified articles which meet all the requirements of the contract.

1.4 RELATION TO MSFC DIVISION REQUIREMENTS

The reliability program provisions herein shall not be construed as requiring a duplication of effort to requirements set forth by design, engineering, test, and quality assurance divisions of the MSFC. Certain requirements herein, such as testing, design reviews, reliability control, manufacturing reliability; etc., may be considered common to other programs carried out by the contractor. Where appropriate, testing or other reliability program requirements with similar objectives shall be combined. The contractor's reliability program shall be oriented toward achieving mission reliability in the most effective, economical manner.

1.5 RELIABILITY PROGRAM PLAN

The contractor's reliability program plan will conform to the detail requirements set forth in the contract and the general reliability requirements herein. Also, the reliability program plan shall be compatible with requirements of the NASA Quality Publication 200-2 (NPC 200-2).

1.6 ACTION AND PREROGATIVES OF THE GOVERNMENT

The reliability engineering programs of the contractor and of his major subcontractors shall be subject to continuous evaluation, review, and inspection by the cognizant MSFC project systems office or its designated representatives. The contractor's existing reliability engineering program will be considered adequate upon a satisfactory demonstration, to the cognizant MSFC project system office, that it continuously provides an equivalent to the reliability requirements as set forth in this document. Where appropriate, existing MSFC launch vehicle or stage system contracts shall be evaluated and revised as required in order to satisfy the reliability requirements set forth in this document.

1.7 REVISIONS

When this document is revised, the contractor is encouraged to follow and to authorize the subcontractors to follow the applicable portions of the revised documents. The contractor is not required to comply with revisions made after the effective date of the contract except as a contract change. If the contractor elects to follow the revised document without a contract change, he shall notify the contracting officer, the cognizant MSFC project system office and its designated representatives in writing.

1.8 SUPERSEDING NOTE

This document supersedes documents with same title and number dated August 6, 1962 and Septemeber 17, 1962 (Revision 1). It also replaces document No. M-REL-MA-1-62, Revision 2, "MSFC Contractor Reliability Program Requirements for System, Sub-system and Equipment", dated June 1962.

SECTION 2: BASIC RELIABILITY REQUIREMENTS

2.1 GENERAL

The contractor shall maintain an effective and timely reliability program, planned and developed in conjunction with all other contractor's functions necessary to satisfy the contract requirements. The program shall insure that launch vehicle system reliability goals are met throughout all phases of the contract performance, from preliminary design to the launch of the vehicle. The contractor and his major subcontractors shall perform all necessary investigations, studies, engineering, and reporting documentation as may be required to accomplish this objective and to assure the MSFC that this objective has been achieved.

2.2 RELIABILITY ORGANIZATION

The prime contractor shall provide for the establishment of a reliability management group, or reliability policy board, to direct and monitor the efforts of the overall reliability program. The members of this group shall consist of responsible representatives from the contractor's executive offices and the operating divisions to insure a consistant divisional policy. The reliability policy board shall:

a. Establish organizational responsibilities for the development of specific activities required to compliment the policies and objectives that have been established by the MSFC and by the contractor's reliability group.

b. Approve the issuance of reliability policy statements or other authorized media which define the specific reliability activities and the scope and application of these activities.

c. Establish policy for major subcontractor reliability programs.

2.2.1 The reliability engineering program shall be accomplished through a reliability group, separately identifiable within the contractor's organizational structure. This group shall provide, through assigned authority and responsibility, for reliability policy establishment and implementation. The reliability group shall be staffed with technically competent personnel in order to advise design engineers as to potential reliability problems; plan and execute a comprehensive reliability engineering and control program; have access to an adequate laboratory; perform evaluations; and identify areas or items in need of improvement.

2.2.2 The person directly charged with the responsibility for the reliability engineering program shall have the authority necessary for effective execution of the program, and shall have unimpeded access to top management.

2.2.3 The reliability management and organization chart shall be shown in the reliability program plan. Reliability management, engineering functions, and responsibilities shall be detailed in the reliability program plan.

2.3 RELIABILITY PROGRAM PLAN

The prime contractor shall prepare and submit for approval, within two months after first contract date, a reliability program plan for the accomplishment of the contractor's reliability program. The plan shall be a detailed reliability document which clearly describes the areas of responsibilities and the activities of the reliability engineering group. The plan shall also describe the associated reliability activities of the contractor's other departments or organizations in order to assure a sound and effective coverage of the reliability program.

2.3.1 The reliability program plan shall be regarded as an important contractual document which explains the specific details of the contractor's internal reliability program as it relates to specific equipment or space systems being developed. The reliability program plan shall describe reliability procedures and methods required to implement the reliability plan. The reliability program plan shall be prepared such as to permit the cognizant MSFC project systems office or its designated representatives to determine the adequacy of the reliability engineering program.

2.3.2 The reliability program plan shall describe in detail all areas of reliability work to be accomplished during the entire development and production program. The plan shall include generalized reliability technical and administrative concepts, operational details of the program, and specific documentation to be generated in the operational phase.

2.3.3 Reliability schedules shall indicate starting dates and completion dates of all reliability tasks to be performed. A detailed cost analysis expressed in man hours, materials, hardware for test, and facilities needed shall be detailed in the supplementary document to the program plan.

2.3.4 The reliability program plan and supplements thereof shall be reviewed for revision on a yearly basis in order to reflect the latest program requirements. Pertinent data or documents representing changes, additions, or deletions to the plan shall be coordinated and disseminated by the contractor's reliability engineering group as required between formal revision periods.

2.4 RELIABILITY GOALS

Quantitative reliability goals shall be developed for each launch vehicle or stage system (to the component level) such that the inherent capability of the system shall be acceptable for manned usage. Consideration shall be given to both the flight hardware and the ground support equipment.

2.4.1 The prime contractor's reliability group shall develop and use reliability mathematical techniques and models for predicting and evaluating the reliability goals of the stage system, subsystems, and components. These goals shall be expressed in probability of survival, in mean-time-to-failure, and in safety margins at any given phase of the program. These values shall be correlated with the values for the inherent design reliability.

2.4.2 The reliability group shall develop and use reliability apportionment, prediction, and assessment methods to predict and assess the achieved reliability. The general requirements for reliability mathematical models are outlined in section 8 of this document.

2.5 RELIABILITY FAILURE MODE AND EFFECT ANALYSIS

The contractor shall develop reliability failure mode and failure effect analyses for the stage systems and the individual systems, subsystems, and components. The objectives of the analyses shall be to indicate critical failure areas and to remove all critical failure modes from the dynamic components of the systems regardless of the occurrence probability. The analyses shall also provide a major criteria for establishment of hardware checkout and monitoring frequency during automatic checkout, final countdown and launch. Requirements for the failure mode and effect analysis are outlined in section 6 of this document.

2.5.1 The reliability failure mode and effect analyses shall be used as an aid to the reliability design review. The results of these analyses and the results of the statistical test analyses shall also be used to establish priority of test items, hardware criticality ranking according to failure effect, and provide for early reliability recommendations to the contractor's design groups.

2.5.2 In addition to the reliability failure mode and effect analyses, the reliability group shall conduct a failure cause analysis in order to provide for quality control measurement parameters.

2.6 RELIABILITY SPECIFICATIONS AND REQUIREMENTS

The contractor's reliability group shall prepare and maintain general reliability specifications defining various elements of subcontractor and supplier reliability technical and management control effort to supplement

the procurement specifications. Reliability specifications and specific reliability requirements shall be available to the MSFC reliability representative, located at the contractors plant, for review and approval.

2.6.1 Specific reliability program requirements shall be clearly described and documented in the specifications. These specifications, which may be included as part of equipment procurement specifications, shall outline requirements and procedures for reliability program areas, such as design review, confidence development testing, reliability criteria, and reliability requirements.

2.6.2 The contractor's reliability group shall have approval authority of all procurement and test specifications where reliability may be affected. Engineering changes to drawings and specifications shall be evaluated by the reliability engineering group to determine their effect on reliability.

2.7 SUPPLIER CONTROL

Potential suppliers shall be surveyed by the prime contractor to determine their capability to furnish components or assemblies having the required reliability and quality. Suppliers will be required to submit a description of their reliability engineering and control programs with specific reference to the launch vehicle objectives and program standards. To determine the degree of conformance for specified reliability goals, the contractor shall require the suppliers, of critical reliability items, to conduct failure mode and effect analyses as well as development and evaluation tests. Section 10 of this document outlines the general requirements for subcontractor and suppliers reliability programs.

2.8 RELIABILITY DESIGN REVIEW

The contractor shall perform an effective reliability design review program on a continuing basis. The design review group shall include qualified personnel from design, reliability, quality control, manufacturing, and other pertinent groups to verify that the presented design does meet the requirements and environmental criteria, and the product can be manufactured with no degradation of reliability or quality.

2.8.1 Preliminary design reviews shall be conducted while the design is in the layout and initial draft stage. Major design reviews shall be conducted prior to production design release, and Application approval design reviews shall be conducted prior to the reviewed item usage. The scope of these reviews shall be such as to insure that all significant factors affecting function and reliability have been evaluated and properly included in the product design. Reliability review requirements are outlined in section 5 of this document.

2.8.2 The reliability design review general requirements set forth in this document shall not be construed as requiring a duplication of effort with the drawing specification review requirements set forth in the Quality Program document NPC 200-2.

2.9 RELIABILITY REQUIREMENTS STUDIES

Reliability requirements for the sub units of the system, shall be compatible with the over-all reliability requirements. These reliability requirements shall provide an input for subcontract specifications when a supplier will be required to supply large sub-assemblies. These requirements will give the individual design teams of the contractor a goal upon which to base their design. The reliability requirement studies shall be considered as reliability control measures over the complexity which will be allowed in each of the subsystems, and a guide for placing engineering emphasis on problem areas. These studies shall consider the requirement for derating, redundancy, multimode operation, or other means of increasing reliability and for recommending these features to be built into the system or equipment. The reliability requirements shall also supply the necessary input to the testing activity in order to plan a program for reliability testing.

2.9.1 The reliability requirement study effort shall be guided by the contractor's reliability engineering group in order to supply the input to the prediction and allocation mathematical models. The reliability engineer shall have access to design engineers who will predict the complexity of the production systems or equipment which will ultimately be required to meet the performance requirements. Where appropriate, the reliability engineer and the contractor's system engineering group shall consider the trade offs of weight, complexity, input and output variabilities, and their effects on other portions of the systems or equipment.

2.9.2 The reliability requirements study shall determine the component population of the system and determine the failure rates of critical components from previous usage or published literature. The failure rates shall be summed and their reciprocal taken to obtain the system or equipment mean-time-between-failure. The reliability over any given time interval shall be determined and this reliability prediction shall be compared to the reliability requirements.

2.9.3 The reliability estimates shall be kept current as the development progresses. A follow-up program shall be conducted such that will allow the testing results and other studies, such as variability and environmental results, to be taken into account when evaluating reliability.

2.10 ENVIRONMENTAL STUDIES

Environmental studies shall be conducted by the contractor's reliability group in order to determine the local environmental conditions

imposed upon the components of the systems. The failure rate of these components shall be a function of the local environment and not of the environment called out in the general specifications or in the detail equipment specifications. Environmental stresses shall be determined in order to properly derate the components. The environmental studies shall also determine ways of controlling and isolating the environments and sufficient experimental testing shall be scheduled to verify the predictions of environment. The initial environmental studies should begin at the acceptance of the contract and proceed from the external environment at each of the subsystems and describe the local environments. As soon as models which approach the final hardware configurations are available, these models shall be tested to confirm the environmental predictions. System changes shall be evaluated for their effect upon the local environment of the components and the reliability group shall consider derating factors and their effect on component reliability.

2.11 TEST REPORTING AND ANALYSIS

Failures and analysis of all test results shall be reported. Analysis of test results will be based on the correlation of laboratory conditions with actual damage potential under field and induced environments. These reports shall be prepared by the contractor's reliability engineering group and submitted to the cognizant MSFC project systems office or its designated representative for review.

2.11.1 Corrective action shall be taken to preclude malfunction recurrences. Statistical evaluation of all data accumulated from research and development through application approval testing shall be performed by design and reliability engineers assigned to the specific equipment being tested. All evaluation data will be utilized in the assessment mathematical model.

2.11.2 Reliability test reports shall include test data and evaluation, hardware status, and approval milestones.

2.12 VARIABILITY STUDIES

Variability studies on the systems and subsystems shall be accomplished early in the program so that variations in the system specifications can be made. As circuits or systems become more defined, they shall be subjected to an analysis to determine their variability and the effect of environmental changes. The variability studies will take into account the effect on circuit or system performance of variation within the components. The contractor's reliability group shall establish procedures and techniques for the statistical and analytical analysis of systems effects due to variability of components. Inspection by variables shall be considered so that a continuous evaluation will be available to the design and engineering groups.

2.13 ENVIRONMENTAL DESIGN CRITERIA

The prime contractor shall prepare an environmental design criteria document outlining the detailed environmental design criteria for the vehicle or stage systems, subsystems, components, and the associated ground support equipment. This document shall specify the environmental conditions, including stress levels, time, and sequence parameters. Each mission and stage system configuration shall be defined and specified separately. This document will be revised, as necessary, to be current with the latest available data. The contractor shall submit this document to the cognizant MSFC project systems office and its designed representatives for approval.

2.14 RELIABILITY REVIEW CONFERENCES

The contractor shall provide attendance of qualified personnel at reliability review conferences to be held either at the contractor's facilities, the Marshall Space Flight Center, or other possible locations as may be appropriate to discuss the Stage system program or possibly other phases of the complete Launch Vehicle System.

2.15 HUMAN ENGINEERING AND EVALUATION

The contractor shall establish and coordinate a human engineering and evaluation program to insure that the Launch Vehicle or stage system is capable of being handled and operated without hazard or undue degradation of performance when subjected to its intended functions. Consideration shall be given to both flight hardware and ground support equipment. This program should begin in the design conception phase and surveillance should be continued throughout the complete life of a given system. Usually this effort is performed by the contractor's System Engineering group; in that case, the reliability effort will be detailed in the reliability program plan and the group responsible for the major effort will be identified.

2.16 RELIABILITY TESTING

The contractor's test and development program shall provide for an integrated development and demonstration program to assure that the launch vehicle system, stage system, subsystems, components, parts, and ground support equipment will meet mission reliability requirements. Section 7 of this document outlines the general requirements for the confidence development test program.

2.17 RELIABILITY PROGRAM CONTROL

The prime contractor shall establish and maintain a reliability control program for managing and evaluating the reliability engineering program. The control aspect of the reliability program shall consist of:

a. Measuring the performance of each specified reliability task.

b. Evaluating the measured performance in relation to the established reliability performance standards.

c. Developing and instituting any corrective action necessary.

d. Revising the original plans as required, for better reliability control, in order to assure the highest level of reliability.

2.17.1 The reliability control phase of the program shall require separate, defined controls for each and every task in the reliability program. The reliability control methods and techniques shall be detailed in the contractor's reliability program plan.

2.17.2 The reliability program shall be controlled by the contractor using documented management policies and procedures for reliability program operations, milestones schedules, and the PERT network. The reliability program shall be closely integrated with carefully developed and applied information systems which shall continuously and accurately display current status.

2.18 MILESTONES SCHEDULES

Milestone schedules shall be used as a method of reliability program control. The milestone schedules shall be composed of the major events listed in this document and as required in the contract.

2.18.1 Three confidence level milestones shall be established for the research and development hardware during application approval testing (see glossary). These confidence levels shall represent increasing assurance that reliability goals are being achieved and shall define approval points for research and development hardware.

2.18.2 Three control level milestones shall be established for production hardware during operational assurance testing (see glossary). These control levels will allow comparison of the operation of launch vehicle equipment to confidence level criteria and shall provide for positive identification of continued satisfactory operation.

2.19 RELIABILITY PERT NETWORK

The reliability PERT network shall be established and maintained by the contractor for control of the Reliability Program and for furnishing management information as required in the contract. The reliability PERT network should consider the following network routes:

a. The reliability design review route for all parts, components, subsystems, systems and vehicles.

b. The qualification and reliability tests route for the non-flight hardware.

c. The operational assurance test route for the flight hardware.

2.19.1 The overall network shall show how the events are interdependent throughout the contract schedule from the contract "go-ahead" stage to the launching of the vehicle. The contractor's reliability organization will use the PERT program for reliability program planning, evaluation, and control. The reliability group shall furnish information to the PERT network which will consist of events, activities, estimated times and schedule dates based on the reliability work.

2.19.2 The contractor will provide the reliability group with the latest reliability PERT network charts, denoting the critical path, and PERT output forms depicting the events, activities, estimated time, expected dates, latest dates, slack time and schedule dates.

2.19.3 By use of the PERT management tool, the reliability group shall identify future problem areas so that appropriate action may be taken in order to resolve the problem and thus achieve a stated objective.

2.20 PROGRESS REPORTS

Technical progress reports shall be submitted as set forth in the contract requirements. Section 4 of this document, outlines the reliability information required in these reports in order to assist the cognizant MSFC project systems office to evaluate the progress of the contractor.

2.21 FINANCIAL MANAGEMENT REPORTS

Financial management reports shall be submitted by the contractor in accordance to the contract requirements. The contractor shall furnish reliability management type information such as fund allocation, funds expended, balance, and estimates to complete the various phases of the reliability program.

2.22 RELIABILITY DOCUMENTATION

Reliability specifications, analyses, lists, and a program plan shall be furnished according to the contract requirements. In addition, the contractor shall submit to the cognizant MSFC project system office, or its designated representative, for information or approval as required, test procedures, test reports, and other related documents. Section 3 of this document outlines the reliability documentation requirements and the documents required by the cognizant MSFC project system office for approval, review, or for informational purposes.

2.23 OPERATION TIME MEASUREMENTS

The prime contractor and the major subcontractors shall consider and provide for operation time measurements on all critical flight and ground equipment. Operation time measurement instruments, operation time meters, and elapsed time indicators shall be considered for continuously monitoring the amount of operating time or the number of operations placed on time-critical flight and ground support equipment.

2.23.1 The reliability engineering group shall coordinate with the contractor's design groups responsible for the development of these critical items, and assist the design groups in establishing the limits of life expectation.

2.23.2 The reliability group shall be responsible for compiling necessary documentation demonstrating compliance with the operation time requirements, and shall also be responsible for the information compatibility from an over-all systems viewpoint.

2.23.3 Prescribed preventive maintenance and unit replacement schedules shall be recommended in order to avoid wearout failures. Routine equipment checks shall also be required depending on the operation time measurment requirements of all critical flight and ground support equipment.

2.24 RELIABILITY AUDIT

The contractor shall audit the adequacy of the reliability engineering and control program. The audit shall consist of reviewing the reliability program internal working procedures, tests, evaluation methods, design reviews, failure analysis, reporting methods; etc. The audit shall be performed on a timely basis, in each area of reliability, and by an impartial group selected by the contractor's reliability policy board.

2.24.1 The audit group shall evaluate the established reliability requirements and standards of operations. Particular consideration shall be given to the auditing of the reliability control and monitoring methods and techniques. Where appropriate, the reliability audits may be a coordinated effort with the quality control program audits. Sufficient audits shall be performed on a random, unannounced basis in order to be effective in revealing manufacturing, reliability, or quality deficiencies requiring corrections.

2.24.2 Reliability audit reports shall be prepared and submitted to the reliability policy board and to the reliability representative located at the contractor's plant. The report shall include recommendations for corrections of reliability deficiencies. Corrective and follow-up action shall be taken by the contractor's reliability group to correct the reported deficient areas.

2.24.3 Quarterly summaries of reliability program performance audits, corrective and preventive actions taken, and results of reviews of deficient areas shall be prepared and distributed to the contractor's top management, to the cognizant MSFC project systems office, and to its designated representatives as information type documents.

SECTION 3: RELIABILITY DOCUMENTATION REQUIREMENTS

3.1 GENERAL

Objective evidence of reliability and quality conformance including management procedures and records of inspection and test results, shall be made readily available to the cognizant MSFC project systems office and its designated representatives. The prime contractor and his major subcontractor's shall develop and provide all documentation specified herein. Depending upon requirements specified by the cognizant MSFC project systems office, contracts may provide for departures from the documentation specified herein. Where this is done, the contract requirements shall be followed. All documentation will be available to the cognizant MSFC project systems office and its designated representative for approval, review, or as information type documents. The reliability program documentation requirements herein shall not be construed as requiring a duplication of effort to requirements set forth in the NASA Quality Publication NPC 200-2.

3.2 RELIABILITY REPORTING SYSTEM

The prime contractor and his major subcontractors shall document and maintain adequate records of all test data, inspection reports, failure reports, analysis and other information pertinent to the assessment of reliability requirements. The reliability reporting system shall be simple and inexpensive, but as comprehensive as the amount of required reliability informmation and data demands. The reliability engineering group shall be responsible for the establishment of the reliability data flow and the determination for the adequacy of the reliability follow-up systems within the contractor's facilities.

3.2.1 The reliability documentation and reporting system shall provide periodic reports to the cognizant MSFC project systems office and to its designated representatives in order to permit a continuous accounting of reliability progress and problems throughout the development program. The prime contractor's reliability engineering group shall set up the mechanism for updating reliability information regarding reliability data and failure data reporting.

3.2.2 The reliability group shall coordinate with the participating contractor organizations to prepare reliability documents in order to assure a sound and effective coverage of the reliability engineering program. The reliability group shall also analyze and be responsible for all reliability data and establish the reliability reporting system at the beginning of the program so that valuable experience shall not be wasted or lost.

3.3 APPROVAL DOCUMENTS

The cognizant MSFC project systems office's approval will be granted in writing within the time specified in the contract. The contractor shall not implement documents in this category until such approval is granted. Neither approval nor waiver of such approval shall relieve the contractor of his obligation to meet requirements of the contract.

3.3.1 The following documents shall be prepared by the contractor's reliability engineering group and shall be submitted to the cognizant MSFC project systems office for approval.

a. Reliability Program Plan

b. Environmental Design Criteria

c. Reliability Test Proposals

3.3.2 The following documents shall require inputs from the prime contractor's reliability engineering group prior to being released for approval.

a. Launch Vehicle Model Specifications

b. Ground Support Equipment Model Specifications

c. General Test Plan

d. Data Submittal Documents.

3.4 REVIEW DOCUMENTS

Documents in this category shall be received by the cognizant MSFC project systems office or its designated representative a minimum of two weeks prior to the intended or required use by the contractor. If the contractor has not been notified of disapproval within the two-week period, he may proceed. However, subsequent changes in such documents may be required by the cognizant MSFC project systems office.

3.4.1 The following documents shall be prepared by the contractor's reliability engineering group and shall be submitted to the cognizant MSFC project systems office for review.

a. Reliability Specifications

b. Approved Supplier List

c. Reliability Test Procedures

d. Reliability Test Specifications (or Criteria)

e. Approved Parts, Component, and Subsystem List - If not assigned to the Contractor's quality assurance group.

f. Qualification Status List - This list shall also be coordinated with the MSFC Quality Assurance Division and the MSFC Reliability Office.

3.4.2 The following documents shall require inputs by the contractor's reliability engineering group prior to being released for review.

a. System Test Plans

b. System Test Procedures

c. Procurement Specifications.

3.5 INFORMATION TYPE DOCUMENTS

All documents in this category shall be submitted for the purpose of determining current reliability program status, reliability problem areas, progress, and future planning.

3.5.1 The following documents shall be prepared by the contractor's reliability engineering group and shall be submitted to the cognizant MSFC project systems office or its designated representatives as information type documents.

a. Reliability Mathematical Apportionment, Prediction, and Assessment Reports.

b. Vehicle or Stage System Reliability Design Reports.

c. Weekly Technical Progress Reports.

d. Failure Mode and Effect Analysis Reports.

e. Failure Cause Analysis Reports

f. Reliability Design Review Reports.

3.5.2 The following documents require inputs from the contractor's reliability engineering group prior to being released as information type documents.

a. Subcontractor and Supplier Survey Reports.

b. Corrective Action and Follow-up Reports.

c. Supplier Rating Reports.

d. Monthly Technical Progress Reports.

e. Reliability Quarterly Audit Summary Reports.

3.6 INTERNAL WORKING PROCEDURES

Internal working procedures shall be prepared and documented in order to control the integrity of the reliability data, and to assure that the reliability and failure information will be interpreted properly. All reliability and failure information shall be located in a reliability central file and shall be easily accessible. Reliability reports and summaries suitable for all levels of management and engineering shall be issued on a periodic basis. Reliability program status reports shall be distributed periodically in accordance to the contract requirements.

3.7 SUPPLEMENTAL DATA DOCUMENTS

Supplemental data documents shall be prepared by the prime contractor's reliability engineering group. These documents shall be used as working type documents to carry out the reliability program. Due to the frequent revisions required for these documents, they shall be issued separately from other data submittal type documents. Objective evidence of reliability engineering conformance including contractor's management and reliability policies, procedures, records of performance, test procedures, test data, test results, reliability stress analysis, etc., shall be made readily available to the cognizant MSFC project systems office and its designated representatives.

3.7.1 The following working documents shall be prepared by the contractor's reliability engineering group.

a. Reliability Design Guide.

b. Reliability Control Procedures.

c. Subcontractor and Supplier Survey and Rating Questionnaire.

d. Reliability Process Specifications.

e. Reliability Test Program Summary Book.

f. Reliability Test Training Manual.

g. Laboratory Evaluation Reports.

h. Reliability Pre-Test Analysis Reports.

i. Test Facilities Survey Questionnaire.

3.7.2 The reliability group shall coordinate with the contractor's other organizations, responsible for specific input or function, in order to prepare the documents listed below.

a. Reliability Training and Indoctrination Documents.

b. Application Approval Test Requirements.

c. Reliability Stress Analysis Reports.

d. Criteria Application Manual.

e. Design Review Program Procedures.

f. Design Review Check Lists.

3.8 RELIABILITY CONTROL PROCEDURES

The prime contractor's reliability engineering group shall prepare and maintain reliability procedures to be used in the reliability control of the contractor's development program. These procedures shall be outlined in the contractor's policies and procedures manual, design manuals, drawing requirement manuals, and in other documents used by the contractor's organization which may affect reliability.

SECTION 4: TECHNICAL PROGRESS REPORTS

4.1 WEEKLY REPORTS

A letter report shall be submitted to the reliability representative located in the contractor's plant. The local representative will forward teletype copies of this report to the cognizant MSFC project system office and to the MSFC Reliability Office. The reports by the contractor shall be submitted on applicable areas of effort such as testing, status, new problems, special information, etc.

4.2 MONTHLY PROGRESS REPORTS

Included in the Monthly Progress Report, as set forth in the contract requirements, will be a reliability section which reviews the work performed during the report period. Included shall be plans and schedules of work, schedule changes, technical difficulties, etc. that will assist the cognizant MSFC project system office in evaluating the progress of the contractor. Technical progress and significant accomplishments together with problem areas, decisions, actions, changes and their effects on the program shall be emphasized.

SECTION 5: RELIABILITY DESIGN REVIEW REQUIREMENTS

5.1 GENERAL

The reliability design review program shall be the control applied to assure that the design will meet the specified functional and reliability goals. This program shall assure that no weakness exists which will affect reliability. The design review shall be a progressive evaluation of a design, shall start with preliminary data, and shall be a continued program at pre-planned stages of design and hardware development. The design reviews shall confirm, with the contractor and the cognizant MSFC project systems office, that basis exists for proceeding to the next milestone. In the initial stages of system design conception, the design review board shall review the proposed configuration with respect to the reliability of its major assemblies and components. Surveys shall be conducted of different types of assemblies to determine their relative merits with regard to performance, weight, reliability, cost, etc. Reliability design review shall be considered as an essential activity of the reliability program. It shall not be considered as a duplication of the effort of the design engineer. The design review board shall evaluate the performance objectives with the techniques of reliability design review, performed independently of the original designer, in order to assure a more effective system design.

5.2 SYSTEM DESIGN ANALYSIS

The contractor's design analysis group shall conduct detailed analysis of the vehicle or stage system configuration. Analytical studies shall be made to determine whether redundancy concepts have been considered. Consideration shall be given to the use of items at derated outputs, the establishment of safety factors in marginal cases, and the use of parallel systems where possible.

5.2.1 System design analysis shall be conducted to insure that the design is sufficiently flexible to accommodate later modifications that may be required to increase the system design reliability. The analysis shall also insure that modified designs or alternate items purposed are available as back-up in the event of difficulties in the program.

5.2.2 Where new designs are purposed for use, the design analysis shall ascertain that the recommended new items are significantly better than the previous items used in the system. New designs, or design changes, shall be reviewed to see that the modes of failure have been eliminated by component or part modification or elimination.

5.2.3 Potential failure modes introduced by design changes shall be estimated by design analysis and judgement. The contractor's reliability

engineering group shall evaluate all design changes. The design analysis shall also be coordinated with human engineering consultants in order to ascertain that the design takes into account human factors, ease of operation, and maintenance.

5.3 DESIGN ANALYSIS GROUP

Design analysis by reliability engineering, human engineering, manufacturing, quality control, value analysis specialists, and safety specialists shall be conducted during the period where the design concept, value, and safety is being formulated, and prior to the formal design review. These specialty groups and departments will evaluate the design data from their various points of view, discuss problem areas with the design group, obtain additional data when necessary, and prepare their questions, recommendations, objections or approval for presentation at the design review board meetings.

5.4 DESIGN REVIEW BOARD

The contractor shall set up a design review board, with the reliability manager as chairman, and consisting of the following suggested personnel, each with action authority, and with additional specialists or consultants as circumstances may dictate:

a. Reliability manager - including reliability engineering specialists.

b. Personnel responsible for the design being reviewed; design engineers, design supervision and the design manager or chief.

c. Systems engineering manager, human factors engineers and the system test engineering manager.

d. Quality control manager.

e. Manufacturing and production specialists.

f. Logistics manager.

g. Purchasing representatives.

h. Manufacturing and production engineering supervision.

5.4.1 Design review board members shall participate in all design review meetings arranged by the design review board chairman. They shall review all aspects of design, including effect on cost and schedule, and identify problem areas affecting quality, manufacturing, operations, maintenance, man-machine integration, and reliability. The design review board shall define required actions to resolve the problem areas identified. In all cases, design review board approval of the design shall be required.

5.4.2 The design review shall be conducted by contractor personnel who will specialize in design reviews. The design reviews shall provide a means of assuring that adequate consideration has been given to reliability during the early design. In order to have an effective reliability design review program, the contractor shall prepare written policy procedures requiring design analysis and reviews to be held. Written design guides for the designer shall be prepared which tell how to design reliable equipment and systems.

5.4.3 The design review chairman shall be responsible for arranging meetings of the design review board. He shall also establish and distribute the meeting agenda, including material appropriate to the applicable design review stage, for the design being reviewed. He shall conduct design review board meetings in an expeditious manner and prepare and distribute minutes of design review board meetings. The design review board chairman shall prepare board decision reports for submittal to program management relative to redirection of the program; corrective action required, etc. The reliability manager shall be responsible for follow-up on recommendations and shall prepare and submit reports to the chief engineer and top management reflecting the corrective action taken or reasons for no action.

5.5 SCHEDULED DESIGN REVIEWS

In order that the responsible design engineers may make optimum use of their time, and to avoid duplicate explanation to various staff specialists, a series of formal design review meetings shall be scheduled. All interested groups or individuals of the design review meeting shall be notified at least two weeks in advance of the meeting date, in order that attendees may come prepared to effectively discuss the design concept or application. The reliability engineering group working under the direction of the reliability manager shall establish a list of the designs to be reviewed. The reliability group shall coordinate with the departments concerned to determine completion status of design material required for evaluation by the design review board.

5.5.1 Responsible departments shall prepare the detailed information appropriate to the applicable design review stage. Sufficient copies to all design review board members shall be submitted to the design review board chairman within one week before the board convenes. Personnel responsible for such information shall be prepared to make oral presentations to the convened board and to answer related questions.

5.5.2 Design reviews shall be scheduled and conducted in three sequential stages, preliminary design review, major design review, and application approval, or final, design review. When necessary, special design reviews shall be scheduled by the design review board chairman.

5.6 PRELIMINARY DESIGN REVIEW

The preliminary design review shall be a broad evaluation of the design approach and techniques that will be used in the design. It shall be scheduled as soon after inception of design as is feasible using preliminary data and criteria. The purpose of the preliminary review shall be to evaluate and approve the design approach, determine potential problem areas, and provide a basis for further design reviews.

5.6.1 The data required for the preliminary design reviews shall consist of; schematic layouts or charts of the system or equipment being reviewed, environmental and performance criteria, preliminary mission failure mode analysis, system reliability mathematical apportionment (including the major system elements), principles of operation and maintainability criteria. Also, consideration shall be given to the methods of mechanical packaging, maintenance and check-out provisions, and human engineering factors. The design review board shall objectively evaluate the decisions as to what methods and techniques will be used. Close consideration shall be given to determine that the design philosophy is compatible with the manufacturing and tooling facilities that will be available at the time production is scheduled.

5.6.2 The design engineer shall be the final authority with regard to ultimate design decisions. The final decisions regarding the approaches and techniques that will be used in the design, for this particular review, shall be closely coordinated with the design group leader. The validity of the design approach shall insure maximum reliability determination. Corrective action, further study, or additional considerations, shall be indicated when the design approach does not indicate potential achievement of reliability goals.

5.7 MAJOR DESIGN REVIEW

The major design review shall be conducted prior to production design release. This review shall include an evaluation of engineering test results, an evaluation of manufacturing plans covering fabrication and quality requirements, and will ascertain that all design changes required have been incorporated, prior to the production release of the design. This design review shall also serve the purpose of introducing the design to the manufacturing and production specialists. In addition, a detailed evaluation shall be made of all aspects of the design, including handling, packaging, and installation requirements. Consideration shall be given to insure complete compatiblility with the ground support equipment and the stage interface requirements.

5.7.1 During the major design review, the following items or data shall be carefully examined:

a. Specifications - accurately describing and outlining the design criteria, and detailed layouts defining physical interfaces and characteristics.

b. Detailed Analysis - accurately outlining and describing function of parameters and tolerances.

c. Mathematical apportionment and prediction reports covering equipment reliability and a statement of the environments expected.

d. Completed check lists in all areas.

e. Failure mode and human engineering analyses.

f. Test operations and maintenance plans for the equipment during development, manufacturing, and operations.

g. Completed quality implementation plans.

h. Component and part selection and application review reports - to determine that high quality reliable components are being employed and that the components and parts are being applied well within their rating.

5.7.2 Reviews shall also be made in the critical circuit areas to determine that factors such as ambient environment, component and part operating requirements, and expected life are taken into consideration when derating the components or parts.

5.8 APPLICATION APPROVAL DESIGN REVIEW

The application approval, or final, design review shall be conducted prior to launch approval, utilizing test and analyses data generated during the Confidence Development Test Program. This review shall stress preventive action review, hardware evaluation, and provide a detailed reliability analysis assessment. It also provides final and conclusive acceptance of the design, and records reflecting the results of tests, quality, manufacturing, and logistic operations conducted to assure a reliable application in the contracted program. The items and data required for the application approval design reviews shall consist of:

a. Completed layouts, drawings, and details as determined by the reliability design review board.

b. Completed check lists in all areas and the evaluation of the completed test specifications and test data.

c. Completed tooling, manufacturing, and handling plans and resulting data.

d. Completed quality implementation plans and resulting data.

e. All pertinent component and system specifications.

f. Failure mode and effect analysis reports.

g. Mathematical predictions and production reports - including completed detailed reliability analysis and assessment reports.

h. Completed procurement specifications and maintenance plans.

i. System integration and human engineering analyses.

5.9 SPECIAL DESIGN REVIEWS

Special design reviews shall be conducted at the request of the design review board members to evaluate changes, problem areas resulting from tests or usage data, or as a result of the procuring agency's request. Special design reviews may also be conducted to review the contractor's, or his suppliers, designs not included in the regular formal design review schedules; changes in design or design application; quality, manufacturing, test or operations problems affecting design; and other stage or associated contractor interface designs. Special design reviews will be devoted to a single facet of the design rather than an overall evaluation. Written justification shall be required to substantiate special design review recommendations. These special design reviews are in addition to the normally programmed reviews and shall not replace or supersede them.

5.10 DESIGN REVIEW CONTROLS

Design evaluation and reliability demonstration of components, or assemblies, shall be completed prior to approval for beginning the system's testing. Preliminary design reviews shall be completed prior to conducting major design reviews. The design review board may approve the final design as submitted, require correction of problem areas before approval is granted, or refuse approval and reschedule another design review. The need for resolution of problem areas or for refusing approval of design shall be based on substantiating, objective documentation. The design review program shall be outlined in the contractor's reliability program plan indicating the control methods as well as the review techniques and procedures.

5.10.1 Standard reliability review forms shall be used in order to facilitate reliability control. These forms shall include parts list, parts application and data sheets, stress analysis forms, parts control lists, and physical evaluation check lists. Particular emphasis shall be given to reliability control activities and to continuous monitoring of reliability achievement. Reliability control activities shall consist essentially of final reviews of equipment designs; reliability surveillance

of engineering testing of parts, assemblies, and major components; investigation of early failure problems; and collecting and analyzing all pertinent failure and operating-time data.

5.10.2 Problems which the reliability design review board cannot resolve shall be referred to the chief engineer or top management. In these instances, the review board chairman shall provide all of the necessary data, including clear definitions of the problem areas. The chief engineer shall take such action as necessary to resolve the problem and reschedule the design for review and approval by the review board. In all instances, final authority rests with the chief engineer. Design approval may be withheld for lack of sufficient data to evaluate the design, interface problems, material consideration, etc. A review must be scheduled to cover areas of improvement required.

5.11 DESIGN EVALUATION

The design review shall be properly carried out in order to provide assurance that adequate considerations have been given to reliability during the early design. The design review procedures shall be a continuing one and its importance in the development phase shall be emphasized. Check lists and forms shall be used which question or establish the existence of the more important environmental prediction and dynamic design features; the details of packaging and its influence on mechanical, thermal, and electrical stresses; workmanship features; and maintainability features. All major design changes resulting from reliability reviews shall have been considered by the time the design is released for production. All critical component and part evaluations, mock up studies, and development-hardware environmental evaluations shall have been completed at this time and the results analyzed for their effect on design changes.

5.12 RELIABILITY GROUP'S RESPONSIBILITIES

The contractor's reliability engineering group shall establish the requirements for the design reviews and coordinate the preparation of procedures to outline and accurately describe the methods and responsibilities of the review participants. The reliability group shall also:

a. Coordinate the establishment of positive schedule dates for all design reviews and direct their accomplishments.

b. Prepare reports and recommendations for the program management predicted upon design reviews.

c. Prepare and disseminate a design review program document describing the criteria and documentation required for each design review.

d. Coordinate the development of check lists covering all facets of the review with the organizations responsible for the specific input or function.

e. Coordinate with the design review group in analyzing failure modes of each system, and assure that design action is taken to provide the means to eliminate all critical failure modes with respect to system reliability, or crew safety.

5.13 DESIGN CHANGES

Each engineering design change shall be reviewed and analyzed by the reliability engineer for effects on reliability prior to release. Reliability engineering approval shall be required of each changed document to assure that this analysis has been accomplished. If the change is such as to warrant a formal design review, it shall be the responsiblity of the reliability engineer to arrange for such action before approving the release.

5.14 DESIGN REVIEW REPORTS

The results of each design review shall be documented in a separate report. This report shall contain design review data, including review board conclusions and/or recommendations, and shall be made available for reliability review conferences. Design review reports shall also be made available to the cognizant MSFC project systems office or its designated representatives upon request. The chairman of the design review board shall be responsible for the preparation of these reports and for documenting all design review board activities. These reports shall be submitted also to the contractor's chief engineer or top management and will summarize the data submitted to the board for design review. These reports shall reflect Board dispositions, corrective action taken, and Board approvals.

SECTION 6: RELIABILITY FAILURE MODE AND EFFECT ANALYSIS

6.1 GENERAL

The prime contractor shall conduct failure mode and effect analysis on all components, subsystems, systems, stage systems, vehicle systems, ground support equipment, and elements thereof. These analyses shall be generated and up-dated by engineers of the reliability organization as aids to the design organization. They shall provide designers with information which identifies effects of all possible failures of a given design without regard for probabilities.

6.2 RELIABILITY GROUPS RESPONSIBILITIES

The prime contractor's reliability engineering organization shall be responsible for developing and maintaining reliability methods and techniques to be applied in the failure mode and effect analysis program. This group shall coordinate with the design review group in analyzing failure modes of each system, and assuring that design action is taken to provide the means to eliminate all critical failure modes with respect to system reliability, or crew safety. The reliability group shall prepare and maintain an environmental design criteria document based on the environmental criteria established by the responsible organizations, inclusive of adequate design margins, to assure inherent design reliability. These data will provide the requirements for both design and test of all hardware and will be the basis of design review, reliability prediction, and reliability assessment. The group responsible for conducting failure mode and effect analysis for reliability shall also:

a. Establish the failure reporting requirements for the reliability program and coordinate the implementation of these requirements with the participating contractor organizations and the cognizant MSFC project systems office.

b. Analyze each reported failure and determine the extent of future preventive action. Coordinate with the applicable organization and apprise them of the latest actions to prevent failure recurrences.

c. Provide reliability liaison for all tests, fabrication, and supplier activities required to maintain adequate failure analysis and reporting.

d. Coordinate with manufacturing and quality control to assure implementation of the reliability aspects of the in-house failure reporting system and to determine their compatibility with reliability assessment requirements.

6.3 FAILURE MODE ANALYSIS

The failure mode analysis shall consist of a detailed analysis of the vehicle or stage system, system, subsystem, component, and ground support equipment design and operations. The failure mode analysis shall identify potential failure causes and failure modes. The result of failure referenced to performance and safety shall be analyzed as well as the effect of failure on mission success and operations. Failure modes shall be evaluated in terms of probability of occurrence, event, time, and criticality. The detailed analysis shall also provide for failure detection methods as pertaining to the GSE design and operation, or in reference to the abort-sensing system design and operation.

6.3.1 Prediction analysis techniques shall be used with the failure mode analysis to provide feed-back to the mathematical apportionment and prediction models and shall consist of both the reliability and design considerations. Included in the design area shall be system and subsystem functional operations, utilization of failed-safe or redundancy, and establishment of parameters for time, stress, and environment. Parts and component selection, and prediction analysis shall be included in the failure mode analysis.

6.3.2 The failure mode analysis shall examine the potential failures before they actually occur, and determine all failure modes and their effects. The analysis shall serve the purpose of also determining system failure interactions and coordinate systems, provide abort sensing and checkout criteria, support design in the design review, and provide reliability recommendations early in the development program.

6.4 FAILURE EFFECT ANALYSIS

The failure effect analysis shall describe how the equipment in the launch vehicle or stage system can fail, and the resulting effects of this failure on the stage system, or the vehicle mission. The objective of this analysis shall be to identify and remove all first order failure modes from the dynamic components of all systems, regardless of the occurrance probability, thus raising the inherent reliability. It shall also be the objective of this particular analysis to reduce all critical failure modes to a third order.

6.5 FAILURE MODE AND EFFECT ANALYSIS FORMAT

The format used for listing the failure mode and failure effects analysis, and the manners in which components of a system can fail shall be included in the reliability program plan. The format shall list the system phase, the component or item in the system being analyzed, all failure modes identified, and the failure effect on system, other systems, or the mission.

6.6 FAILURE MODE AND EFFECT ANALYSIS REPORTS

The prime contractor's reliability engineering group shall prepare the failure mode and effect analysis reports to be used in the reliability design reviews. These reports shall be submitted for integration with the applicable system design reports.

6.6.1 A failure mode and effect analysis report shall be prepared for each of the launch vehicle or stage systems and the individual systems, subsystems, and components. This report shall begin during the design phase and shall present examination of the modes and effects of system and component failures during various phases of the launch vehicle or stage mission.

6.6.2 A critical ground support equipment failure mode and effect analysis report shall be prepared and maintained during the design phase. This report will present the modes and effects of mechanical, electro-mechanical, and electronic equipment failures, and shall form the basis for establishment of special safety features for critical ground support equipment.

6.6.3 System design reports shall be prepared by the contractor's reliability engineering group for all applicable system designs. The report shall include failure mode and effect analyses of the systems, failure cause analysis, and design review check lists.

6.7 FAILURE CAUSE ANALYSIS

The prime contractor's reliability group shall conduct a failure cause analysis for the purpose of obtaining a high reliability standard through pre-hardware evaluation of potential causes of failure modes. The failure modes which were identified in the failure mode and effect analysis for each component in a system shall be examined for potential failure causes and for reasons why the causes should not occur. As a result of these examinations, preventive actions shall be recommended where appropriate. The failure cause analysis shall also identify the potential weaknesses in the design and determine why the weaknesses should be eliminated.

6.7.1 The failure cause analysis format shall include a listing of the failure mode, the potential failure causes, prevention evaluation, and the probability factor expressed as a probability of failure.

6.7.2 A failure cause analysis report shall be prepared for each of the launch vehicle or stage systems and the associated ground support equipment. This report shall be included in the system design report and shall present the potential cause or causes of component and system failure modes and the efforts taken to reduce, or eliminate, the failure potential.

6.8 CRITICALITY RANKING

The prime contractor shall rank the equipment or components of airborne systems and ground support equipment systems according to the failure effect in order to identify the hardware for criticality ranking. Criticality categories shall be used as a criteria for automatic checkout and monitoring frequency. A criticality table shall be generated for all airborne and ground support equipment systems to be used in establishing equipment checkout requirements.

6.9 EMERGENCY DETECTION SYSTEM

The failure mode and effect analysis shall be used to classify all mission failures as either deferred, critical, or catastrophic, depending upon the time between the failure event and a subsequent crew hazard. These identifications shall be the fundamental criteria for selecting parametric monitoring of the launch vehicle or stage system emergency detection system. The reliability group shall provide an emergency detection system evaluation list for use by the responsible contractor's design groups. This list will be revised periodically to reflect the latest configurations.

6.10 RELIABILITY DESIGN GUIDE

The contractor's reliability engineering group shall prepare and maintain a reliability electro-mechanical stress analysis manual, to be used by the design groups, as guides for equipment reliability. This manual shall contain failure data and procedures for its use. Also, the reliability engineering group, in coordination with the design groups, shall prepare stress analysis reports for the airborne systems and the associated ground support equipment.

6.10.1 An airborne systems electronic stress analysis report shall be prepared and maintained during the design phase. This report shall examine the failure potential of electronic equipment and provide suggestions to eliminate the failure potential; such as use of different components, broader derating factors, or environmental protection. The purpose of the report shall be to assure that the equipment inherent reliability will be statistically acceptable to man-rating standards.

6.10.2 A reliability stress analysis report, for ground support equipment, shall be prepared and maintained during the design phase. This report shall examine the failure potential of electrical, electronic, and electro-mechanical equipment and will provide suggestions to eliminate failure potentials. The purpose of this report shall be to assure that the equipment will meet or exceed the minimum MTBF requirements listed in the ground support equipment model specifications.

SECTION 7: CONFIDENCE DEVELOPMENT TEST PROGRAM

7.1 GENERAL

The confidence development test program shall be designed to reveal all areas of weakness early in the program and provide for prompt, corrective action at a reasonable cost. Breadboard testing and analysis shall be considered in order to determine how effectively the design has been carried out. The test program shall include all testing proposed for the vehicle or stage system development. Great care shall be taken to use the pertinent test data, make the correct interpretation of the results, and apply the most appropriate statistical methods for reliability estimation. The contractor's reliability group shall review all test plans and schedules to determine whether environmental effects and production-process consideration are incorporated sufficiently early in the program.

7.2 QUALIFICATION AND RELIABILITY TESTING CRITERIA

The prime contractor shall provide a test program planned in sufficient detail to fully qualify and evaluate all systems, sub-systems and equipment prior to production in quantity. The reliability program shall include means of auditing and monitoring the test program.

7.2.1 Time schedules shall be set for the preparation of written procedures and the starting of the test program. Test procedures shall be distributed in advance of the start of tests, and all testing shall be time-phased to insure completion before initial production.

7.2.2 Sub-contractor and supplier facilities shall be surveyed in order to evaluate their capability and availability for conducting tests. The approved facilities shall be scheduled so as not to hinder the progress of the overall test program.

7.3 RELIABILITY GROUP'S RESPONSIBILITIES

The prime contractor's reliability engineering group shall establish and maintain a Confidence Development Test Program to integrate all levels of testing, and determine the required testing for each system, component or module that is considered significant to the system reliability. This group shall prepare all test requirement data for procurement specifications and approve specifications for adequacy of testing, based on the integrated test plan. Reliability engineers shall coordinate with the design engineer during preparation of specifications and provide inputs and recommendations concurrently with specification development.

7.3.1 The reliability engineering group shall approve all in-house and supplier test procedures to assure conformance with reliability requirements, and to assure development of data that is acceptable for reliability assessment. This group shall also coordinate the integration of the Confidence Development Test Program with the General Test Plan. The contractor's reliability group shall review and approve the General Test Plan prior to release.

7.3.2 The reliability group shall coordinate with the test operations organization to assure that the Battleship stage, All-Systems, static firing, and vehicle acceptance test data are compatible with reliability assessment requirements. This group shall coordinate the generation, development, and transmission of reliability test data from all contractor areas to implement reliability assessment.

7.3.3 The prime contractor's reliability engineering group shall analyze each reported test failure and determine the extent of future preventive action.

7.4 TEST PLANNING AND ANALYSIS

Test plans and test schedules shall be reviewed early in the development program to insure that a balanced and integrated test program has been established. Non-destructive test methods shall be investigated, and failure analyses shall be conducted to see whether the test methods are pertinent and sufficient for assurance of reliability. Consideration shall be given to effective testing methods so that the true behavior of the equipment will be established.

7.4.1 The contractor's reliability engineering group shall prepare reliability test plans described in detail in the contractor's "General Test Plan". Reliability test plans shall be submitted to the cognizant MSFC project systems office or its designated representative for approval.

7.4.2 Detailed test procedures shall be prepared by the contractor. Reliability test procedures shall be submitted to the cognizant MSFC project systems office, the MSFC design divisions concerned, and to the MSFC reliability representative located at the contractor's plant. Reliability test procedures shall be subject to review.

7.5 PART AND COMPONENT APPLICATION, REVIEW, AND STANDARDIZATION

The contractor shall establish and maintain a parts and component application, review, and standardization program in order to encourage the use of reputable parts and properly evaluate those new items which may be included in the vehicle or stage systems. The application data shall be used to assign a failure rate to each part or component. These failure rates shall be used in predicting the reliability of the complete systems or equipment.

7.5.1 A formal application review shall be conducted when the system designs or circuits are approximately 90% complete. Continuous contact shall be maintained between the parts and component specialists and the circuit or systems engineers. The reliability group shall prepare a list of recommended parts and components to be used in breadboard and prototype design and development. Requirements for an effective program shall be:

a. A parts and component application group working in close harmony with engineering, purchasing, and quality control.

b. Qualified specialists, within this group, on the commonly used parts and components.

c. A sign-off, by the contractor's reliability and quality assurance specialists, shall be required on all part and component control drawings.

d. The contractor's quality assurance and reliability group shall act as consultants to the design groups concerning the application of parts components.

7.5.2 Analysis shall be prepared on all parts and components that fail and corrective action shall be taken contingent on the failure reports from laboratory or field use. Data obtained from field and laboratory tests shall be coordinated with the parts and component manufacturers so that they may improve the product reliability. These reports shall also be submitted to the cognizant MSFC project system office or its designated representative for review.

7.6 RESEARCH AND DEVELOPMENT TEST DATA

Performance test data of early designs shall be reviewed and evaluated to determine adequacy of the designed system's operation at the anticipated environments. In addition to the test data from earlier testing programs, such as tests on basic materials, parts, and components, the early engineering tests on initial designs shall be reviewed and analyzed.

7.6.1 Adequate performance and qualification testing shall be accomplished prior to release of hardware designs to production. Reliability analyses shall determine the critical parts, components, and systems, where these tests should be expanded. Test data and test results from these tests shall be evaluated by the reliability group in order that they may determine the inherent reliability of the critical items.

7.6.2 Engineering evaluation test data shall be analyzed for use in the mathematical apportionment models. Test results shall be analyzed by the reliability group to make redesign or rework recommendations in order to increase the reliability level. Test results shall also be analyzed in order to identify major modes of failure and degredation in performance caused by the environments.

7.6.3 Breadboard testing data and results shall be analyzed by the reliability group to provide detailed data for predicting the reliability level attained. Breadboard test results shall also be evaluated to determine the critical or sensitive areas in a design and for establishing test monitoring points on prototype and production equipment.

7.7 FLIGHT HARDWARE TEST REQUIREMENTS

Proper planning shall be initiated early in the design phase of the test program to insure sufficient samples for reliability testing. Vibration testing of actual flight hardware shall be kept to a minimum, and then, only when properly justified and approved in writing in accordance to the conditions specified in the MSFC Reliability Policy Board Directive No. 1.

7.8 EXPERIMENTAL EVALUATION TESTS

These tests shall be performed on breadboards, mock-ups, and first items produced. Test results shall be evaluated to verify fulfillment of the basic parameter requirements, determine parameter limits and best design approach; resolve design difficulties affecting reliability, and to verify component and system parameter stability. Test data and test results from these tests shall be analyzed to be used for hardware selection by comparison and for preliminary verification of parameter stability under stress conditions.

7.9 APPLICATION APPROVAL TESTS

Application approval tests, for R&D hardware, shall be planned and conducted to verify suitability of the design for its ultimate use, and provide the data required to demonstrate reliability at the required confidence level. Evaluation and trade-off studies of required number and cost of test specimens versus confidence shall be considered in the formulation of detail test plans. To prevent unnecessary test costs, the required level of detailed testing will be considered by a careful evaluation of the required confidence levels as they relate to the component, major element, system and stage.

7.9.1 Qualification tests shall be performed prior to reliability tests and in accordance to the requirements of this document including the requirements set forth in the NASA Quality Publication NPC 200-2. The application approval test shall be a combination of design evaluation,

or qualification tests, and reliability demonstration tests. The purpose of these tests shall be to demonstrate through analysis and test that the launch vehicle and ground support equipment hardware will perform the required function with a high degree of reliability. Evaluation will be broad, and the environmental exposure shall be considered.

a. Qualification tests shall be performed to demonstrate that the design is inherently capable of meeting the established requirements under the various combination of service environments that may be applicable. The qualification test shall be conducted on a sample size approved by the MSFC.

b. Requalification may be required when inspection, tests, or operational data indicate the inadequacy of a qualified article or when the design has been changed. Requalification shall be accomplished only after necessary corrective action has been implemented.

7.9.2 Reliability demonstration tests shall be a continuation of the qualification tests to determine failure points, safety margins, and life expentancy under the environmental conditions required for manufacturing, system storage, transportation, and operation. Reliability demonstration test results shall be analyzed in order to provide data on failure modes and to indicate possible design improvements. Reliability tests shall be conducted on a sample size as approved by the MSFC. The reliability test samples may also include those which were used in the qualification tests.

a. Reliability test proposals shall be submitted for review and approval prior to the start of testing. Proposals shall include test conditions, environmental conditions, hardware to be tested, instrumentation, special facilities, and time schedules.

b. Failure and analysis of reliability demonstration test results shall be reported. Analysis shall be based on ability to correlate laboratory conditions with actual damage potential under field and induced environments. Results of test shall have maximum dissimination among the cognizant contractor organizations, affected sub-contractors, NASA, and other government agencies.

c. The contractor's reliability group shall take effective steps to insure that corrective action is completed on the deficient items by the cognizant design and manufacturing organizations. This effort shall be coordinated with the quality organization.

7.9.3 System Test Plans shall be established under the contractor's Confidence Development Test Program and designed to evaluate the application of subsystems and systems selected for use. The system test program will establish reliability factors, safety margins, conformance to design

criteria, and information necessary to evaluate system compatibility under operational conditions. System tests shall be designed to locate significant failure modes, determine the effects of various stress levels, determine the effects of combination of stresses and drift of design parameters, and to determine the effects of combinations and sequences of environments and of stress levels.

a. The contractor shall conduct system evaluation in accordance with the approved system test procedures. The system shall be evaluated to determine the effects of natural and induced environments under conditions of storage, handling, transportation, and operation. Special emphasis shall be placed on reliability operation and human engineering problems during the system tests.

b. System revaluation tests shall have a purpose of revaluating changes to parts, materials, processes, or sources of supply as they may effect the reliability of systems or subsystems. They will be conducted throughout the development program as they are required.

7.9.4 Ultimate Stress Tests shall be conducted while the specimens are exposed to selected environmental combinations. The selection of the most critical environments will be based on the results from prior demonstration testing. The test results shall provide data for determining wear out characteristics and obscure failure modes. Continuous correlation of stress levels used in tests with those stress levels experienced in actual service shall provide assurance that the safety margins established have been obtained.

7.9.5 Vehicle or stage test data will be correlated with data obtained from application approval testing on parts, components, and systems in order to provide the verification and assurance that Confidence Level No. 3 has been achieved. The stage program from which the stage test data will be obtained shall include structual static testing, structual dynamic testing, operation testing, battleship static firing, and non propulsive stage tests.

7.10 OPERATIONAL ASSURANCE TEST

Operation assurance testing shall be performed on production equipment prior to use in a flight vehicle. Acceptance, in-process, and stage checkout shall be the segments of testing which provide the data to support the application approval results. Operational assurance tests include functional cycling under nominal environmental stresses, combined systems tests, and ultimate vehicle static firing. The data from the operational assurance tests shall be analyzed in order to continuely evaluate component, system and stage reliability during all phases of testing of production flight equipment and to assure operational readiness of each flight vehicle prior to shipment.

7.11 APPROVED PARTS, COMPONENTS, AND SUBSYSTEM LISTS

Approved parts, components, and subsystem lists shall be individually prepared in loose leaf folder form on a format approved by the Marshall Space Flight Center. These lists shall contain documentation of all physical, functional, and environmental characteristics necessary to describe each item. Certification (verified by the contractor's reliability engineering group) shall be included to show that each item has met application approval requirements, as dictated for the usage of the item. A list of approved suppliers for each item shall also be included. These lists shall be submitted to the cognizant MSFC project systems office and its designated representatives for review.

7.12 QUALIFICATION STATUS LISTS

The contractor shall prepare and maintain a list showing the planned and completed qualification status of each part, component, subsystem, system, and higher level of assembly. The Qualification Status list shall be coordinated with the MSFC Quality Assurance Division and the MSFC Reliability Office. The requirements for preparing, maintaining, and submitting this list shall be in accordance to the requirements set forth in the NASA Quality Publication NPC 200-2.

7.13 CORRECTIVE ACTION AND FOLLOW-UP REPORT

This report shall indicate the corrective and preventive action taken or in process to correct existing deficiencies and minimize or eliminate future failures. The report shall be reviewed to determine the adequacy of the corrective and preventive actions proposed or taken and shall summarize the rework of all affected articles at the contractor's facilities, at test sites, and at operating sites. The report shall be available to the cognizant MSFC project systems office or its designated representative at all times.

7.14 RELIABILITY PROCESS SPECIFICATIONS

The contractor's reliability engineering group shall prepare specifications of this type as supplementary engineering instructions to establish and assure uniformity of manufacturing and test methods. Reliability procedures that are essential to the fabrication and test of a product shall also be prepared.

7.15 RELIABILITY TEST TRAINING MANUAL

A reliability test training manual shall be prepared to provide the necessary explanatory information to familiarize the test engineer with the objectives, description, implementation, and the intended result of the Confidence Development Test Program as it relates to reliability.

7.16 LABORATORY EVALUATION

The prime contractor's reliability group shall survey the sub-contractors and suppliers' test laboratories and prepare laboratory evaluation reports. The reports shall highlight the deficiencies as well as the capabilities of each laboratory. Laboratories that are unacceptable for reliability testing shall be so noted in the reports.

7.17 APPLICATION APPROVAL TEST REQUIREMENTS

A document outlining methods and requirements associated with the Confidence Development Test Program peculiar to suppliers shall be prepared and maintained throughout the development program. All procurement specifications containing test requirements shall prescribe this manual as required material to be followed by the sub-contractors and suppliers. Copies of this document shall be delivered with each procurement specification, and the manual shall contain methods of performing required tests, type and quality of data required, format, required data reduction, monitoring provisions, failure reporting procedures, corrective action requirements, and re-test requirements.

7.18 RELIABILITY PRE-TEST ANALYSIS REPORTS

Reliability pre-test analysis reports shall be prepared and maintained for the purpose of assuring that valid test programs are being prepared. The reports shall be prepared from information and detailed reports supplied by the reliability test engineers. Detailed answers shall be provided pertaining to environmental criteria, operational considerations, duty cycle, failure analysis, previous history, and statistical considerations.

7.19 TEST FACILITIES SURVEY QUESTIONNAIRE

The prime contractor's reliability engineering group shall prepare and maintain test facilities survey questionnaires. The information derived from these questionnaires shall be such as to help the reliability test engineer to evaluate the capability, confidence, and availability of test laboratory facilities. The facility surveys shall include government and commercial laboratories, supplier test facilities, and laboratory facilities of the major sub-contractors.

7.20 CRITERIA APPLICATION MANUAL

A criteria application manual shall be prepared and maintained throughout the application approval test program. This document shall outline the basic and environmental tests that the parts, components, and systems of the launch vehicle are required to complete without failure.

In addition to the test descriptions for each environment, a brief summary of the general environmental requirements and design modules shall be provided to furnish the background needed to understand the reliability tests described. This document shall be used along with the General Test Plan and the Pre-Test Analysis report as a basis for preparing the reliability test requirements in procurement specifications.

7.21 STATISTICAL SYSTEM TESTS - PLANNING AND ANALYSIS

System test plans shall be evaluated to determine that the most efficient statistical methods are used, that the test criteria are valid, and that sample sizes are suitable for the requirements of the program. The contractor's reliability engineering group shall consider the use of competent statistical techniques to obtain system reliability estimated with confidence limits, for test planning, and data analysis. Statistical analysis shall be considered to reduce the component test sample size, prevent wasteful testing and also possible misinterpretation of design or test information. Statistical experimentation shall be performed to provide estimates of functional and evnironmental effects and variations in component's behavior from both separate and with-in system tests.

SECTION 8: RELIABILITY MATHEMATICAL MODEL REQUIREMENTS

8.1 GENERAL

The prime contractor's reliability group shall make optimum use of all data in the statistical and mathematical activities that are undertaken. The data shall be analyzed to see whether they follow any useful mathematical pattern. Mathematical analyses shall be used to obtain reliability estimates, establish growth curves, and to audit the program at specific phases of development. Reliability mathematical apportionment, prediction, and assessment shall be used with the design reviews and failure mode and effect analyses for establishing the system reliability with confidence.

8.2 RELIABILITY GROUP'S RESPONSIBILITIES

The prime contractor's reliability engineering group shall analyze the stage system and sub-systems in order to establish apportioned reliability goals to the component level. This group shall also evaluate the system designs prior to release of engineering data in order to determine the predicted reliability. Also, the contractor's reliability group shall:

a. Conduct studies to validate specified reliability requirements, establish pre-planned assessment control points; and improve reliability apportionments, predictions, and assessment methods.

b. Coordinate with the MSFC reliability representative to assure that methods and procedures utilized to predict and assess the achieved reliability are acceptable to all participating organizations.

c. Coordinate with participating contractor's design organizations concerning the apportioned reliability goals and predicted reliability design values. Design revision shall be recommended as required to eliminate system weaknesses and to upgrade reliability.

8.3 APPORTIONMENT MODEL

The contractor's reliability engineering group shall develop a reliability mathematical model to apportion, or allocate, the stage system inherent reliability goal requirements into subsystems and component goals. The apportionment reliability values used in this mathematical model shall equal or exceed the stage system inherent design reliability goals specified in the launch vehicle model specifications or in the technical work statement of the contract. When the apportionment component reliability values are recombined, their reliability interrelationship shall be such as to satisfy the system inherent reliability goal requirements.

8.3.1 In making the reliability apportionment, consideration shall be given to the degrading effects of complexity, time, and environment. Reliability apportionment shall also serve the purpose of:

a. Indicating the relative phase of development of the components.

b. Providing means by which test schedules can be reviewed (for all levels of testing) and to provide evaluation of the amount of information and assurance to be derived from the test program.

c. Providing means by which test data may be correlated to the stage system inherent reliability goal requirements.

d. Providing analytical design predictions.

8.3.2 The apportionment model shall be constructed by accepted analytical procedures and graphically illustrated by a reliability block diagram. A series of blocks - arranged in echelons, shall be used to illustrate the sequential breakdown of the stage system; to the subsystems level and down to the component level. The sources of data to be considered for the apportionment model shall include:

a. Schematic diagrams and preliminary design studies.

b. Studies and reports on estimates of severity of stress; such as stress analysis, MTBF data, prototype test data, etc.

c. Reliability proposals and recommendations - including suppliers and other contractors. Also, past programs shall be considered for historical test data or system evaluations.

d. Design engineering reports.

e. Reliability conferences and survey reports.

f. Revaluation reports on part and component MTBF data.

8.3.3 A reliability apportionment report shall be prepared covering derivation and use of the inherent reliability mathematical models and a detailed apportionment of the launch vehicle or stage system reliability to the component level. This report shall also contain apportionment methods, and shall correlate reliability goals and apportionment to the launch vehicle or stage system model and equipment specification requirements. The report shall be up-dated to contain all current data. It shall be issued quarterly throughout the program as an information type document.

8.4 MATHEMATICAL PREDICTION MODEL

The prime contractor shall develop a reliability mathematical prediction model to be used as a prime tool for stage and system development. The prediction model shall be based on previous experience with similar items under similar applications. Mathematical techniques shall be used to derive unbiased estimates for component and system reliability prediction. Through the use of statistics and failure rate data, a direct evaluation of the minimum reliability shall be derived to determine the effects of variation on component parameters, for given mission operating times, under different environmental and installation conditions.

8.4.1 Methods and techniques shall be used to simulate component success and failure conditions, or predict component output parameter frequency distribution, during product development and demonstration. The reliability prediction model shall also be used to:

a. Determine the expected reliability goals (with confidence) for each component, system, combined system, and mission phase.

b. Reallocate the apportioned reliability goals of the major subsystems and components.

c. Correlate the predicted reliability with the failure mode and effect analyses in order to isolate possible weak areas.

d. Specify the numerical reliability goals to be attained during testing; to specify test sample size, number of tests required, and the number of allowable failures during each test.

8.4.2 The predicted reliability shall be used to generate Reliability-Confidence growth curves and to specify the numberical confidence program status points. Sources of data to be evaluated for use in the prediction model shall include:

a. Functional block and operational flow diagrams.

b. Time Bar graphs of system design and development functions.

c. Previous failure rate experience and current part, component and system literature.

d. Statistical Analyses of mission environments and time parameters.

e. Similar parts and component application studies.

f. Revaluation of the apportionment model data and the apportioned reliability goals.

8.4.3 The contractor shall prepare a reliability prediction report indicating in detail the mathematical prediction model and techniques used. The report shall include resulting data and up-grading procedures. Periodic revisions shall be a continuing task during the execution of the contract. The reliability prediction reports shall be issued quarterly throughout the program as information type documents.

8.5 MATHEMATICAL ASSESSMENT MODEL

The contractor shall develop a reliability assessment model indicating the achieved or attained reliability, with a confidence factor of 0.90, for the individual systems and subsystems. The assessment model shall be used to evaluate the reliability of the systems at periodic phases of the program, and shall also serve the purpose of evaluating phase and mission attained reliability at the appropriate confidence and control levels (see glossary). The assessment model shall be used as an analytical method to assure that the design of the stage system, subsystems, and ground support equipment will allow evaluation and detection of reliability degradation and also provide man-rating capability for the launch vehicle missions.

8.5.1 The reliability assessment model shall also be used in conjunction with the detailed specifications of mission objectives and the failure mode and effect analysis to provide means for monitoring of progress and defining the reliability goals. The reliability assessment shall be used as an analytical method for reliability operations and as a method for assuring review and correction of reliability problems.

8.5.2 Confidence development and control level statistical analyses shall be performed as audit points for the reliability assessment model. The confidence development analysis shall be used to periodically evaluate the research and development hardware achieved reliability with an appropriate confidence. It shall also be used for determining the reliability safety margins of the R & D components, systems, and stages.

a. A control level analysis shall be conducted for periodically evaluating production hardware reliability and quality during production. This analysis shall also indicate the operational readiness of each flight vehicle or stage system.

b. A functional analysis shall be conducted with the mathematical assessment model to evaluate the phase and mission achieved reliability with confidence limits. The analysis shall also evaluate the system and stage reliability design criteria.

c. An operational analysis shall be conducted to statistically evaluate reliable life, replacement schedules, logistics programs, item life characteristics, and instantaneous failure rates.

8.5.3 The mathematical assessment model shall include a statistical demonstration analysis to determine if pre-flight reliability goals have been attained for the launch vehicle, or stage system, including the ground support equipment. This analysis shall also determine the status of actual flight reliability as compared with the inherent reliability and the mission reliability goals. Launch operations test data, acceptance test data, and flight evaluation reports shall be analyzed in order to make an assessment of the actual reliability of the launch vehicle and stage systems. The actual reliability shall be compared with the apportioned and predicted reliabilities.

8.5.4 A reliability assessment report shall be prepared and distributed quarterly throughout the contract program. This report shall contain the mathematical models used in the reliability assessment and a detailed reliability assessment of the achieved reliability at each audit point. This report shall cover all reliability assessments based on tests or equipment operation data. It shall be issued quarterly throughout the program as an information type document.

8.6 AUDIT POINTS

For reliability assessment purposes, the contractor shall establish three audit points to periodically evaluate the achieved reliability at the appropriate confidence level. The audit points shall correspond to the confidence level points used in the Confidence Development Test Program. The first audit point shall indicate the component and system achieved reliability with a confidence factor of 50%.

8.6.1 The second audit point shall represent the achieved reliability of the systems and subsystems at a confidence level of 70%.

8.6.2 The third audit point shall represent the achieved reliability of the launch vehicle and stage systems with a confidence level of 90%. Data evaluated at this point of the program shall provide verification and assurance that Confidence Level No. 3 (see glossary) has been achieved.

SECTION 9: DATA CENTER

9.1 GENERAL

The prime contractor shall provide a data center for acquisition, processing, and retrieval of launch vehicle or stage system data. The data center will provide a single source for all information related to product evaluation and improvement, and for any information indicative of success of application of similar or related parts or equipment by other agencies. Timely reviews or progress, status, data, and reports shall be essential to the successful implementation of corrective action and management of the reliability program. Accordingly, a reliability monitoring, program review, documentaion, reporting, and data processing system shall be established to provide NASA and the contractor's functional organizations and management with significant information and guidance upon which reliability decisions can be formulated.

9.2 COMPATIBILITY

The design of the Data Center will be such as is compatible with government and contractor data systems having similar objectives and complexity. The initial results of the Data Center will be closely monitored by MSFC to ensure that the desired effectiveness is being built into the Data Center. It shall be designed to function not only for reliability data handling and processing, but also for information necessary for design, development, manufacturing, and quality control.

9.3 CAPABILITY

The Data Center shall have the capability to provide the data and information to generate the following documents, reports, and listings;

a. Parts Lists - Listing the frequency of usage and identification of parts occurring in sub-assemblies, assemblies, and the complete stage system to aid in determining priority of parts qualification, reliability testing, and related information.

b. Qualified Parts List.

c. Limited Life items and change of status of these items.

d. Correlation of environmental data with test data for comparison with design and specification requirements.

e. Data on mode and cause of equipment failure while in the development and manufacturing stages, comparisons with field failure reports.

f. Document all corrective actions and follow-up.

g. Generate a continuous review of all areas of the launch vehicle system so that defects and failures may be grouped and problem areas pinpointed or predicted.

h. Generate a complete technical review of a given item at anytime during its development, manufacture, and operation.

i. Summarizing data on deviating materials.

j. Inputs from field failure reports.

9.4 RELIABILITY EFFORT

The reliability engineering group shall furnish technical reliability guidance to the contractor's data center. The contractor's reliability manager shall be kept informed of reliability program progress by continuously monitoring and periodically reviewing all reliability activities. The source of information for this effort shall be the data and reports generated by the contractor's documentation and reporting system. From these and other sources, the reliability manager shall determine the following:

a. The attainment of reliability and safety objectives.

b. The adequacy of the program plan as it progresses.

c. The performance of all work affecting reliability in accordance with the program plan.

d. The effectiveness of reorientation.

e. The adequacy of control measures.

9.4.1 Formal determinations of progress shall be made periodically and the results shall be published in a reliability report, with implemented or recommended remedial action, as applicable. These reports shall be submitted to the cognizant MSFC project systems office or its designated representative for review purposes as required.

9.4.2 Reliability progress charts, including those showing achieved reliability versus reliability growth objectives, shall be continuously maintained and displayed.

SECTION 10: SUBCONTRACTOR AND SUPPLIER RELIABILITY PROGRAM

10.1 GENERAL

Supplier reliability programs shall be clearly defined in the procurement specifications in accordance to the requirements of this document including the requirements as set forth in NASA Quality Publication NPC 200-2. Quantative reliability requirements; expressed as mean-time or cycle-to-failure, or in terms of probability, shall be defined reliability requirements incorporated in the appropriate section of each procurement specification. Other requirements shall include simplicity, circuit standardization and use of qualified piece parts, redundancy and fail-safe principals, human factors considerations to minimize or eliminate human errors, and maintenance concepts to lessen "down time".

10.2 PROCUREMENT SPECIFICATION REVIEW

The contractor's reliability organization shall prepare and maintain a series of general reliability specifications defining various elements of supplier reliability effort to supplement procurement specifications. Procurement specifications shall be reviewed by the contractor's quality and reliability organizations prior to release of the specification for procurement. All procurement specifications shall be available, for review, to the reliability and/or quality MSFC plant representatives.

10.2.1 The acceptance criteria for each procured unit shall be clearly documented in the procurement specification. The supplier's responsibility for compliance with contractual requirements, as defined in the procurement specification and supplementary directives, will be assured by constant design surveillance, and by reliability and quality assurance personnel.

10.2.2 The contractor's reliability group shall coordinate with the contractor's quality control group to assure that the receiving inspection tests are in accord with the reliability test plan.

10.3 SUPPLIER RELIABILITY SURVEY

The prime contractor's reliability organization shall establish the reliability aspects of sub-contractor and supplier survey requirements, and coordinate the implementation of these requirements with the quality control group in the selection of suppliers. The reliability aspects of supplier performance shall be monitored by the prime contractor's reliability group. Supplier reliability survey reports shall be available to the cognizant MSFC project systems office upon request.

10.4 SUBCONTRACTOR AND SUPPLIER RELIABILITY RATING

The prime contractor's reliability group will furnish reliability rating reports on all subcontractor and major suppliers to objectively evaluate their reliability capabilities. Consideration will be given to the supplier's reliability program, test facilities, test program, reliability management and organization, and suppliers prior reliability programs and experience. These reports shall be made available to the MSFC project systems office upon request.

SECTION 11: RELIABILITY TRAINING PROGRAM

11.1 GENERAL

Considerable importance shall be placed on the reliability training, indoctrination, and motivation of all employees whose work influences the reliabilility of the products to be delivered. This indoctrination and training program shall be a continuing education process.

11.2 EMPLOYEE INDOCTRINATION

A series of programs on reliability requirements and practices shall be presented to all employees assigned to work on the project. These programs shall be oriented toward developing and teaching an understanding that all personnel in some way affect the reliability of the project. The required programs shall be directed toward the historical background of reliability, the magnitude of the reliability problem, what reliability encompasses, and the scope of the reliability program.

11.3 SPECIAL RELIABILITY ENGINEERING COURSES

Reliability training programs dealing with the specific reliability and design standards pertaining to the engineering aspects of the project shall be considered. Reliability engineering studies shall consider intensive, formal courses covering specific technical aspects of the subject, and including such courses as computer methods of design analyses, systems and components analyses, system effectiveness evaluation techniques, reliability predictions, malfunction reporting and corrective action requirements, reliability aspects in purchasing, and management tools for reliability.

11.4 TRAINING AIDS

The actual training aids to be used in a particular course of instructions will take into account the facilities in which the learning will be taking place, and the various techniques of instruction being developed in relation to new definitions of learning.

11.4.1 The media of closed circuit television shall be considered as a major training aid for indoctrination lessons. Television shall also be considered for use where a number of highly technical classes must be taught and there is a shortage of qualified instructors.

11.4.2 In addition to television, the more recent self-instructional aids, or teaching machines, shall be utilized as the tasks demand. The use of these special devices will be integrated with reliability training

by experts on the reliability training staff who have special qualifications in programming techniques of self-instructional systems, advanced training aids, and audio-visual learning systems.

11.5 SUBCONTRACTOR TRAINING AND INDOCTRINATION

All subcontractors and suppliers shall be briefed on the stage system reliability requirements and the latest methods of reliability achievement, with particular emphasis placed on the critical nature of manned missions.

11.5.1 Where applicable, each supplier or subcontractor will be required by contract or purchase order to establish and maintain a reliability training program similar to the one outlined for the prime contractor.

11.5.2 The prime contractor's personnel shall periodically visit the suppliers to discuss, review, and assist in the overall task assignment of indoctrinating all personnel connected with the prime contract.

11.5.3 In those instances where more formalized detail indoctrination on special problems is called for, the prime contractor's reliability engineering group shall visit the supplier's facility to assist in maintaining required reliability standards.

SECTION 12: CONTROL OF GOVERNMENT FURNISHED EQUIPMENT (GFE)

12.1 INSPECTION OF GFE

Upon receipt, the contractor shall inspect Government furnished property and equipment in accordance to the NASA Quality Publication NPC 200-2. The contractor shall also provide protection, periodic inspections, and controls to insure that quality and reliability is maintained, that storage conditions are adequate, and that damage or deterioration does not occur in handling or storage.

12.2 DEFECTIVE GOVERNMENT FURNISHED EQUIPMENT (GFE)

The contractor shall advise the cognizant MSFC project systems office, or its designated representative, of any Government furnished property or equipment found damaged, malfunctioning, or unsuitable for its intended use, in accordance to the Quality Publication NPC 200-2. The contractor shall report reliability problems due to any deficient or damaged government furnished equipment and shall recommend, to the cognizant MSFC project systems office, the degree of improvement, or corrective action required, to make the GFE compatible with the rest of the equipment in the system.

12.3 GFE DATA AND INFORMATION

The cognizant MSFC project systems office, or the MSFC design divisions, shall furnish to the contractor all reliability values, data, and information required by the contractor on Government furnished equipment. Where such reliability information on GFE is not available, the procuring agency will make provisions for the contractor to obtain it.

APPENDIX A

GLOSSARY OF TERMS

The following definitions apply to terms used in this document.

Acceptance Tests - Tests to determine conformance to design or specifications as a basis for acceptance. When specially designed, they may apply to parts, equipments or systems.

Achieved Reliability - The reliability demonstrated at a designated point in time during equipment operation. It consists of inherent reliability with any degradation that occurs in manufacture, shipping, handling, storage, maintenance, and/or use.

Application Approval Tests - The qualification and reliability demonstration tests conducted on parts, components, subsystems, and systems for verifying the suitability of the design for its ultimate utilization and for assessing the reliability of the manufactured product. Depending on the type of reliability program being conducted, these tests may also include the Battleship and All-Systems tests.

Assurance Tests - The quality tests conducted on all items of equipment to ensure that the high standards of quality control are maintained. These tests consist of: Source and Receiving Inspection, In-Process Inspection, and Acceptance Tests.

Checkout Equipment - Electric, electronic and electro-mechanical equipment both automatic and manual which is required to perform the launch vehicle and stage system checkout.

Combined Systems Tests - Tests designed to evaluate the application of subsystems and systems selected for use in the stage system. These tests will establish information necessary to evaluate system compatibility under operational conditions.

Component - A component is defined as an article which is normally a combination of parts, sub-assemblies, or assemblies mounted together as a self-contained element to perform a design function.

Confidence Development Test Program - The test program encompassing all testing planned for the launch vehicle, stage system or elements thereof. This includes experimental evaluation testing (R&D), application approval testing, operational assurance testing, and launch operations.

Confidence Levels - Milestones established for R&D hardware control points during application approval testing. These confidence levels shall represent increasing assurance that reliability goals are being achieved and define approval points for hardware development. Also used with the reliability mathematical models in performing analytical analysis of the achieved reliability, with appropriate confidence, in order to periodically evaluate the research and development hardware.

Confidence Level No. 1 - Attainment of this confidence level constitutes approval for initial static firing operations and start of systems test. Represents a demonstration of reliability with a confidence of 50 per cent. Established upon successful completion of the experimental evaluation tests, the qualification and design evaluation tests, and the reliability demonstration tests. Preliminary design reviews should be completed at this time.

Confidence Level No. 2 - Attainment of this confidence level constitutes approval for fabrication and installation of R&D hardware and equipment in the flight vehicle or flight stages. Represents a demonstration of reliability with a confidence of 70 per cent. Established upon successful completion of ultimate stress tests together with satisfactory system evaluation test experience. Stage, Battleship and All-Systems tests should be started on attainment of this level. The major design reviews should be completed by this time.

Confidence Level No. 3 - Attainment of this level constitutes approval for starting the application approval design review, system sequential tests and evaluations, and combined system tests. Represents a demonstration of reliability with a confidence of 90 per cent upon successful completion of the vehicle or stage system checkout (Battleship and All-Systems test included). This is the final phase of the confidence development test program and confirms all previous testing. Constitutes approval for starting launch operations after successful completion of the vehicle checkout operations.

Contractor - The individual(s) or concern(s) who enter into a prime contract with the government.

Control Levels - Milestones established for production hardware control points during the operational assurance testing. These control levels shall allow the comparison of the operation of flight stage equipment to confidence level criteria and provide a positive identification of continued satisfactory operation.

Control Level A - Production hardware has successfully completed in-process testing, source and receiving inspection tests, and acceptance tests. Provides a positive identification of continued satisfactory operation and is achieved upon completion of satisfactory acceptance testing.

Control Level B - Provides a positive identification of continued satisfactory operation throughout individual and integrated system testing. Includes combined systems operation and testing prior to static firing. This level is achieved at completion of all component and system checkout and test and constitutes approval for starting static firing tests, combined systems checkout, and vehicle or stage checkout.

Control Level C - Maintains a positive identification of continued satisfactory operation throughout the static firing test program, combined systems checkout, transportation, and vehicle or stage checkout operations. This control level is achieved at completion of prelaunch vehicle or stage checkout. Constitutes approval for start of vehicle checkout operations and start of launch operations. Should be compared with Confidence Level No. 3.

Critical Path - The particular sequence of activities in a PERT network that comprise the most rigorous time constraint in the accomplishment of the end event. The path with the smallest amount of positive slack or largest amount of negative slack.

Contract - The prime contract executed by the government and the prime contractor which, in addition to the terms and conditions thereof, includes by reference or otherwise, specifications, drawings, exhibits, and other data necessary to its proper performance.

Designated Representative - A representative of the MSFC installation stationed at the contractor's plant whom reliability monitoring functions have been delegated.

Failure Cause Analysis - A descriptive list of the cause, or causes, for the component failure modes identified in the failure mode and effect analysis.

Failure Mode - The physical description of the manner in which equipment malfunctions.

Failure Mode Analysis - A detailed and extensive program to isolate all known or potential failure modes and to identify these failure modes with the appropriate materials, production processes, production controls, environments and/or design.

Failure Mode Effect Analysis - An orderly and qualitative listing of the manner in which components of a system can fail, the effects of the failures on the vehicle's ability to complete the mission, the order and classification of the failures (first order, second order, etc.) and the sequence of operation of the system in which the failures could occur.

First Order Failure - Mission failures caused by a malfunction of a single component. Second and higher order failures require the failure of two or more components or parts to cause mission failure.

Inherent Reliability - The reliability potential in the design as determined prior to manufacturing, handling, transportation, maintenance, storage, and use. The inherent reliability can be changed only by redesign.

Launch Operations - The phase of operations beginning with start of the launch countdown, and ending at lift-off.

Meantime Between Failures (MTBF) - The total measured operating time of a population of equipments divided by the total number of failures within the population during the measured period of time.

Mission Phase - One of the distinct sequences of the over-all vehicle mission such as countdown, first stage boost, first stage separation, second stage boost, second stage separation, etc.

Part - An article that is not operationally useful by itself but is an element of a sub-assembly, an assembly or a component, and is of such construction that it is practically or economically not amendable to further disassembly for maintenance purposes.

Procedure - An outline in detail of the manner or method of proceeding in a test or checkout of an assembly, subsystem, system or composite vehicle and stage system.

Procurement Specification - Establishes the design, performance, environmental, and test requirements for the procured parts and equipment.

Quality Control - A management function to control the quality of articles to conform to quality standards.