SURVEYOR SPACECRAFT LABORATORY

RELIABILITY PROGRAM

October 1961

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DEPARTMENT 22-54
Ref. No. 2254.2/120

ABSTRACT

This report outlines the Reliability Program established to fulfill the reliability requirements of J.P.L. Specification 30240 and initially discussed in Volumes III and IX of the Hughes "Project Surveyor" Proposal 60H-13005/6565 ED 6122 R submitted in December of 1960.

This program has been refined from the basic proposal into certain specific areas of responsibility which are being implemented as programmed in the Project Surveyor Management Control Plan. The major areas include:

(a) Establish a reliability philosophy, model and specification.

(b) Develop analytical system and subsystem equations for reliability analysis and assessment.

(c) Design Review participation for reliability and failure mode analysis.

(d) Subcontractor reliability evaluation and surveillance.

(e) A reliability assurance test program.

(f) Data analysis, failure reporting and follow-up control during system and spacecraft assurance evaluation.

(g) Establish spacecraft standard parts, processes and materials specifications.

(h) Provide project management with a prediction of spacecraft reliability prior to each mission.

(i) Reliability training and indoctrination.

(j) Provide reliability coordination with the customer.

Scientific payload considerations have not been given a high priority relative to the basic spacecraft since HAC does not currently have responsibilities for instrument procurement or payload management.

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A. Reliability Model

B. HAC Specification 224600 & 224601

C. Reliability Assurance Test Program

D. Components Parts Program

E. HAC Preferred Parts and Materials Lists

I. INTRODUCTION

The reliable operation of the Surveyor spacecraft and scientific equipment is a major requirement for mission success. Each launching is an irreversible process and once initiated must survive the varied environments from the spacecraft launch to final mission operation. This reliability is defined as the probability that the spacecraft system will be capable of achieving all mission objectives in the environments and for the periods of operation specified for each Surveyor mission.

In order to fulfill this responsibility the Surveyor reliability program has been developed to ultimately provide project management with a probability of mission success prior to each spacecraft launch.

The program has the following major divisions.

- ANALYSIS
- DESIGN REVIEW
- CONTROL

II. RELIABILITY ANALYSIS

The reliability information obtained for Surveyor equipment will be analyzed continually during the Surveyor program. The information derived from the analyses will be utilized directly for providing the following:

- Management Visibility
- Design Trade-off
- Reliability Test Planning
- Reliability Improvement

For a project involving a complex system, such as the Surveyor, it is important to present to management the status of reliability in such a form that all pertinent information is given in a minimum number of words and figures. The specific information to be generated depends on the management level to which the information is presented. For overall visibility a single reliability estimate on the minimum reliability would suffice. Therefore, at scheduled points in the development program, reliability information for such management visibility will be developed.

The generation of the above mentioned reliability information for management is generally required in most government equipment development projects. Quite often, the reliability analysis encompasses nothing more than the above. One of the reasons for so limiting the reliability analysis is that quite often the equipment operating time and the environmental conditions will vary from mission to mission. Furthermore, if the equipment can be repaired and maintained, as in aircraft application, a low reliability may not be very detrimental. Hence, for such cases, it is reasonable to consider broad equipment reliability levels rather than specific reliability values. This approach led to the development of a number of engineering disciplines such as safety margins, parts derating and design reviews. All of these disciplines will be imposed on the Surveyor development. However, because of the specific Surveyor spacecraft usage, it was clear at the start of development that more precise quantitative reliability analyses would be desirable and possible. It was also clear that the Surveyor spacecraft reliability must be high even though the launch booster reliability may be low. In fact, the inverse relationship holds, i.e., the spacecraft reliability should be increased for a decrease of booster reliability. The predetermined use condition for the spacecraft greatly facilitates the study of trade-offs between reliability and other design parameters. For system constraints such as cost, weight and volume, where the sum of the values of the constraining factors of the subsystems must be kept within a certain limit, the trade-off criterion may be determined readily by means of the method of Lagrange

multipliers. For this class of constraints the criterion for achieving maximum reliability is simply that the rate of change of reliability with respect to a parameter, e.g., weight, should be identical for all subsystems. Such trade-off studies have already led to the use of redundant equipments in many areas in the spacecraft. Since the spacecraft will perform many different functions and the relative importance of each function differs from the others, reliability emphasis must be placed on the more important functions. Such considerations will be given in the reliability analyses. This design trade-off requirement dictates the need for a continuous reliability analysis that penetrates into the details of the designs. The present analysis method differs from the common engineering disciplines for reliability primarily in its use of quantitative rather than qualitative reliability measures.

The reliability information derived from all equipment operations and tests will be analyzed. Particular attention will be directed toward the investigation of failures to uncover the causes of failure. The resultant information will be utilized directly for improving the reliability of the spacecraft equipment.

III. DESIGN

The inherent reliability of the Surveyor spacecraft must be provided from the basic design formulation. This requires early and rigorous adherence to proven reliable design practices, failure modes analysis, redundancy studies, etc., which can be utilized to insure that the ultimate product meets the reliability requirement defined in the System Reliability Specification, HAC No. 224600 (Appendix B). Updated reliability predictions will include continual design information as obtained by design analysis in each review.

Reliability design responsibilities in the Surveyor program include the following:

(a) Provide reliability design requirements based upon a realistic analysis of mission requirements and environments. HAC Specification 224600, Revision A (Appendix B).

(b) Provide a Reliability Specification for subcontractor reliability design requirements. HAC Specification 224601 has been prepared and released (Appendix B).

(c) Determine the best standard parts, materials and processes, and by review and approval of drawings insure that only those suitable for lunar environments are utilized. A detailed program outline for component and material approval is provided as Appendix E.

(d) Design Reviews take place at scheduled points in the program. These reviews, basically three in sequence; design concept, circuit review and packaging review; have been established for the Surveyor program. Each such review will be attended by reliability engineers cognizant of that design and capable of challenging the reliability status of the design. A report of each review will be made and the questionable areas will be spelled out to insure analysis and appropriate follow-up. Information thus attained will be useful in updating the reliability predictions, system model and subsystem design requirements.

(e) Subcontractor Design Reviews will be attended by reliability engineers to maintain close surveillance over vendor programs and insure that appropriate reliable designs are being generated, reviewed and evaluated to insure that reliability requirements are being met.

IV. CONTROL

The requirements imposed upon the Surveyor require that very well-defined closed loop controls be implemented to insure that potential problem areas be highlighted, that management visibility be provided, and that corrective follow-up be maintained where critical reliability concepts or design problems exist.

The control of reliability for Surveyor is therefore being implemented in the following manner.

(a) Insure that all equipment utilizes only those qualified for Surveyor environment. HAC Preferred Parts List for Surveyor is utilized in flight assured equipment. A Process and Materials Manual will be available shortly to supplement this area.

(b) A reliability assurance test program has been implemented to provide, through statistical design of testing, a level of confidence in equipment reliability. This program is a major task and provides one of the basic tools for updating the reliability prediction and system model. This program is detailed in Appendix C.

(c) Data analysis will provide control information during the major phases of the Surveyor program. Data collected and analyzed will include significant failure data from first identifiable prototypes (development), type approval units, flight assured units and the reliability assurance test results mentioned in (d) above. Variables data will be collected as a normal function of the test program and will be evaluated for significant possible failure modes.

At discrete intervals the results of data analysis will be reported to project management to indicate the reliability status, highlight critical problems and provide reliability probability of mission success prior to spacecraft launch.

(d) Failure reporting has been established as a firm requirement since a test failure at any level represents a critical problem. A failure report format has been established and will be utilized starting with the first identifiable unit, Form I - attached. A similar requirement has been placed upon all subcontractors. The reliability section will have the responsibility for implementing the Failure Review Board consisting of the cognizant unit engineer, the chief engineer and reliability engineer. The reliability member of this board will have the initiative for follow-up for corrective action following board analysis and corrective action determination.

(e) Reliability training and information concerning space applications is being directed to the critical design areas through close working contact of the area reliability representatives, the design areas and the Surveyor Reliability Section. A series of seminars

on reliability techniques has been presented and additional reports and information will be provided.

(f) Reliability representatives have been assigned to each design area to work directly with the designers in insuring that the basic reliability requirements are considered in each design. These engineers provide first level screening for reliability for design reviews, vendor procurement and surveillance and will be the major control in their areas for failure follow-up. In certain areas they are also providing the major control effort for the Reliability Assurance Test Program, Item (b) above.

(g) Reliability engineers will participate in post flight data analysis to analysis failures, assess real time operation of spacecraft equipment for mission evaluation and be responsible for failure follow-up and insure that corrective action is accomplished where required.

FAILURE REPORT

SERIAL NO. **0001**

PROJECT **PROJECT SURVEYOR**

CASE NO.:

DATE:

EQUIPMENT (NAME) (P/N) (S/N)

LOCATION:

TEST SPECIFICATION:

OPERATING TIME INFO.:

HIGHER ASS'Y: (NAME) (P/N) (S/N)

ON-OFF CYCLES:

DESCRIPTION (TEST CONDITIONS, DIFFICULTIES, SYMPTOMS, ETC.)

REPORTED BY:

DATE

FAILURE VERIFICATION AND ANALYSIS

REWORK ACTION NECESSARY:

ANALYZED BY:

DATE

REWORK ACTION:

ITEM, REPLACED, REPAIRED, SERVICED OR ADJUSTED (TO BE FILLED IN BEFORE ISSUING NEW ITEMS)

ITEM	NAME/CKT REF	MFG & HAC PART NO.	PROJECT QUALIFIED	HOW ITEM FAILED

IF FAILED ITEM (S) WAS NOT QUALIFIED FOR PROJECT USE EXPLAINED:

REWORK BY: DATE

INSPECTED BY: DATE

RETEST RESULTS

TESTED BY:

DATE

ADDITIONAL INFORMATION (RELATED CASES AND/OR MEMOS)

DISTRIBUTION:

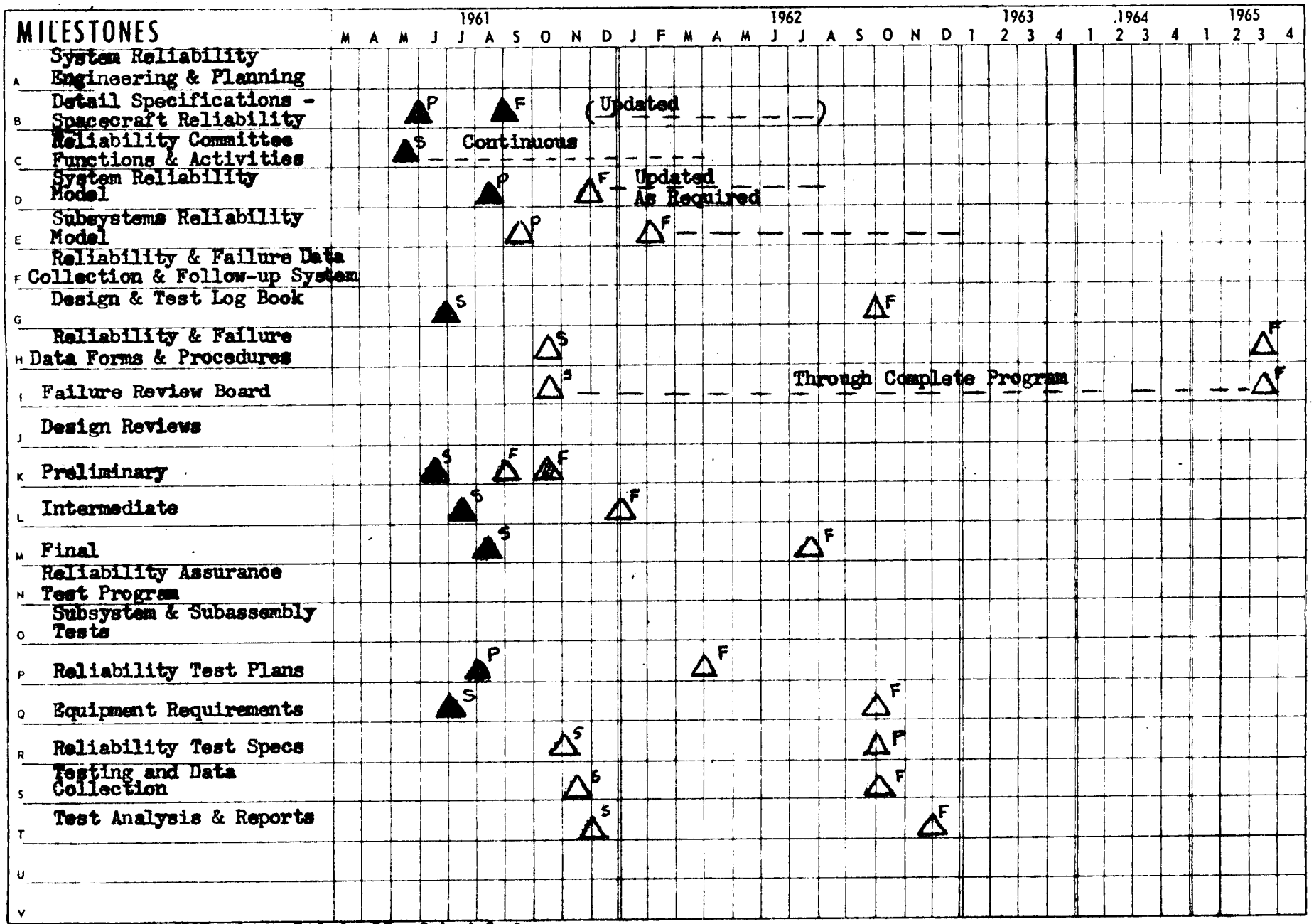
COPY 1 REL. SECTION
COPY 2 CONTROL ITEM STORE
COPY 3 EQUIPMENT ENGR.
COPY 4 TEST ENGR.
COPY 5 REL. SECTION

COPY

V. SCHEDULES AND MILESTONES

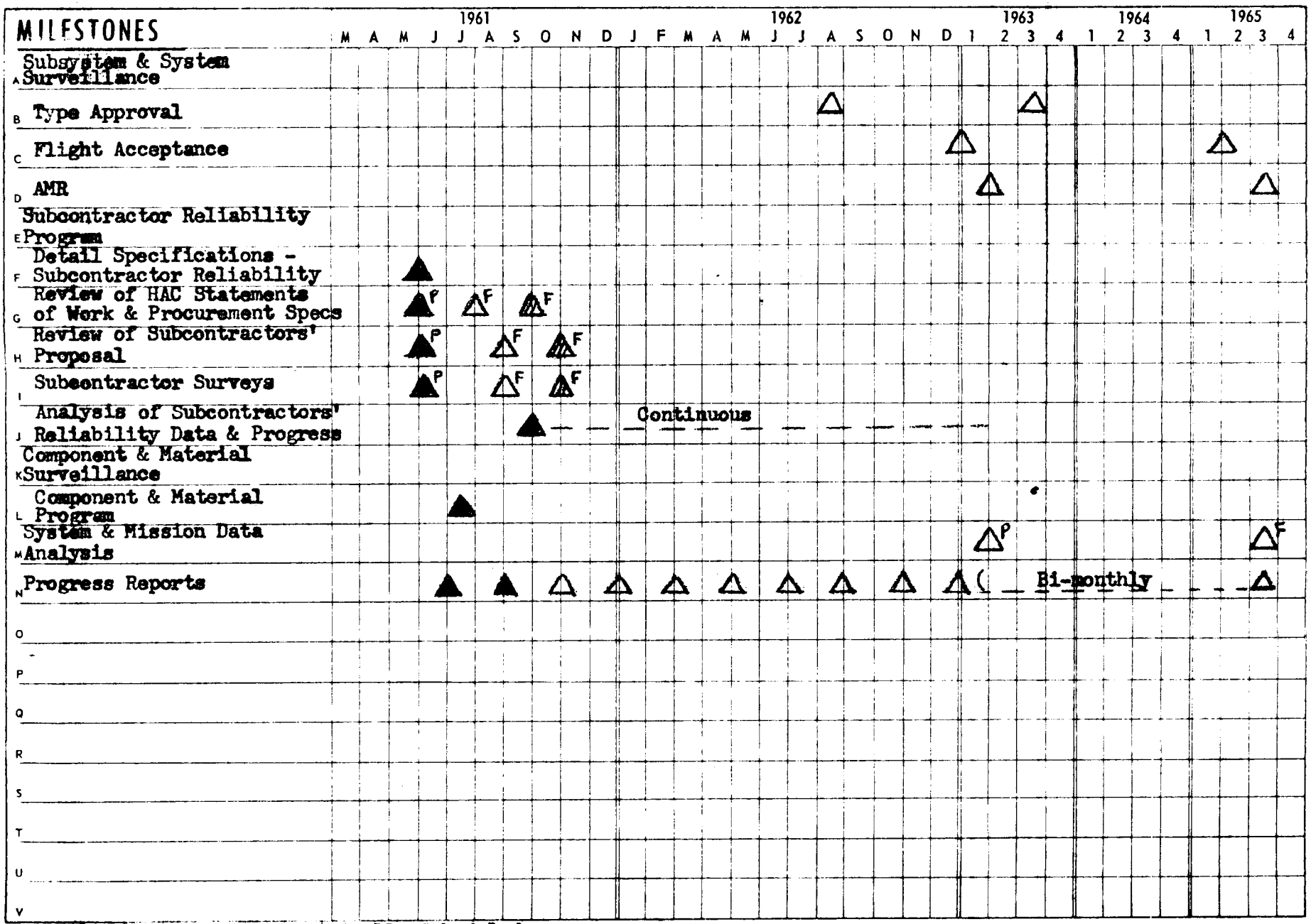
The basic Reliability milestones have been presented to J.P.L. in the monthly Project Surveyor Management Control Report. The current section for Reliability is presented again herein as Charts 1, 2, and 3. In addition, the basic breakdown indicating broad area time spans is also shown as Chart 4. Since the schedules represent key items in the control of reliability and are closely keyed to outputs from other areas, i.e., design review schedules, drawing release schedules, and test hardware availability, some flexibility must exist. However, more important than meeting a date will be the insistence from Reliability that the item presented meet the reliability requirements or that the review, release or delivery be delayed until appropriate action has been taken.

RELIABILITY PROGRAM



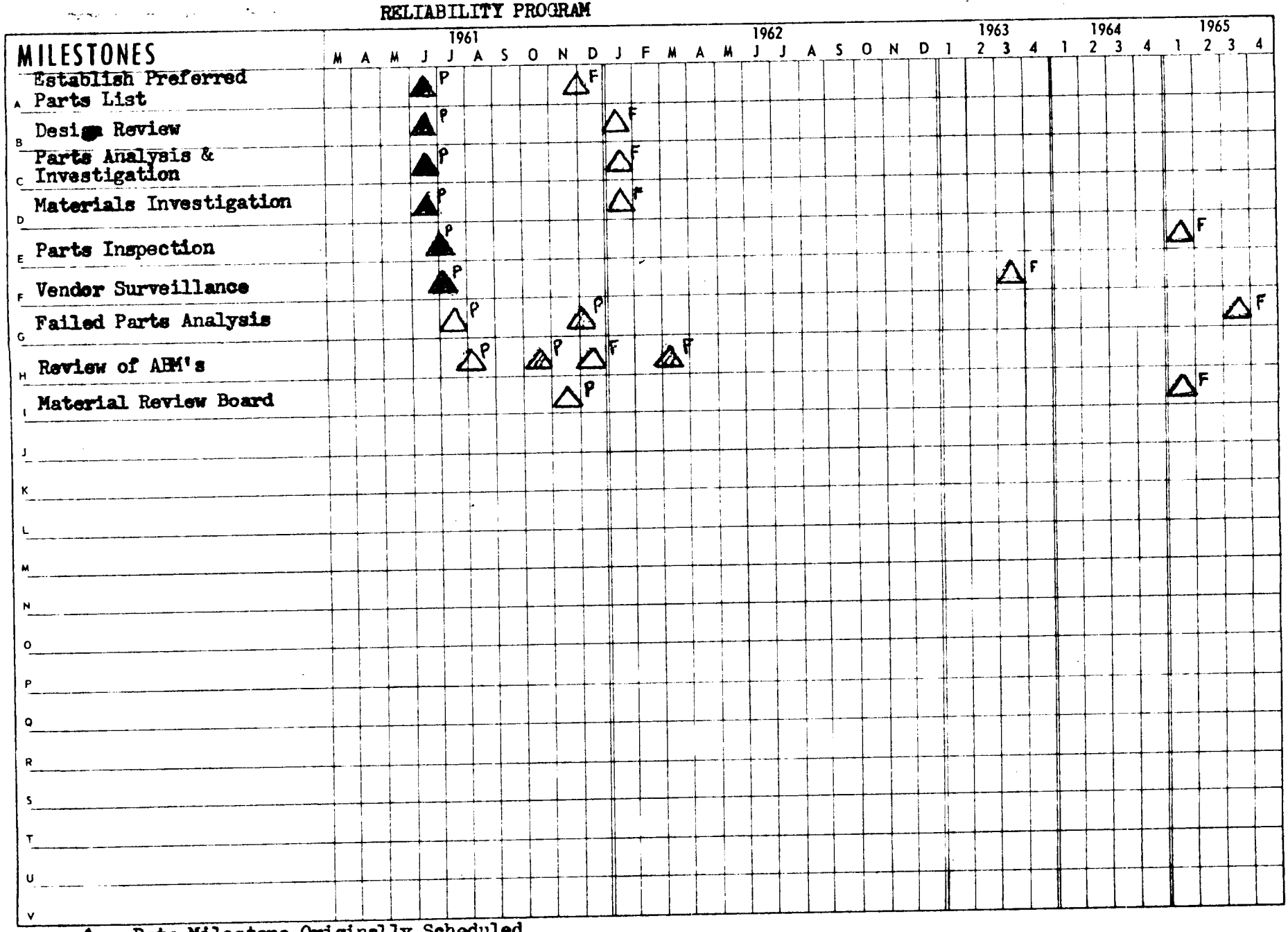
△ - Date Milestone Originally Scheduled
▲ - Estimated Milestone Reschedule Date
▲ - Milestone Completed

RELIABILITY PROGRAM



△ - Date Milestone Originally Scheduled
△ - Estimated Milestone Reschedule Date
▲ - Milestone Completed

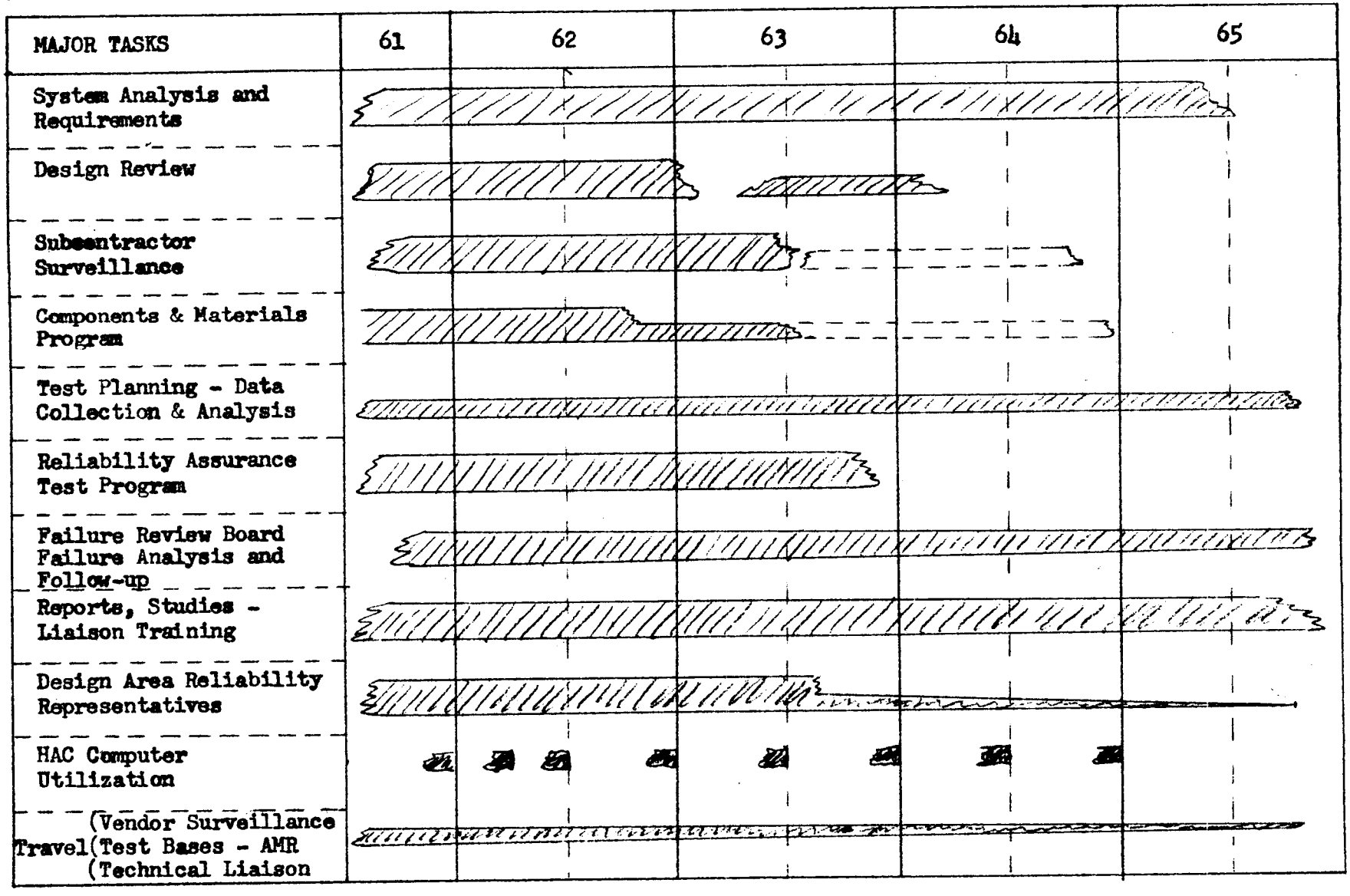
RELIABILITY PROGRAM



△ - Date Milestone Originally Scheduled
△ - Estimated Milestone Reschedule Date
▲ - Milestone Completed

SURVEYOR RELIABILITY PROGRAM

MAJOR TASK SCHEDULE



APPENDIX

A. Reliability Model

B. HAC Specification 224600 & 224601

C. Reliability Assurance Test Program

D. Components Parts Program

E. HAC Preferred Parts and Materials Lists

APPENDIX A

TABLE

CROSS INDEX OF EQUIPMENT RELIABILITY

EQUIPMENT BLOCKS / ASSEMBLIES ACTIVITIES	FLIGHT CONTROL GROUP	PROPULSION GROUP	ELECTRICAL POWER GROUP	ELECTRONICS GROUP
ESSENTIAL POWER DISTRIBUTION (E)				R_{01} ESSENTIAL POWER SWITCHES AND POWER FORM CONVERTERS
RECEIVER "A"				R_{02} RECEIVER A
OMNI-DIRECTIONAL ANTENNA A				R_{04} ANTENNA A
TRANSMITTER "A"				R_{05} TRANSMITTER A
DIRECTIONAL ANTENNA				R_{06} DIRECTIONAL ANTENNA ELIGIBLE TRANSMITTER
TRANSMITTER "B"				R_{07} TRANSMITTER B
OMNI-DIRECTIONAL ANTENNA "B"				R_{08} ANTENNA B
RECEIVER "B"				R_{09} RECEIVER B
CENTRAL COMMAND PROCESSOR				R_{12} CENTRAL DATA PROCESSOR AND CENTRAL SIGNAL DISTRIBUTION
CENTRAL SIGNAL PROCESSOR				R_{12} SIGNAL PROCESSING CIRCUITRY
SOLAR POWER CONVERTER			R_{13} SOLAR CELLS AND CONVERTER	
RADIOISOTOPE THERMOELECTRIC CONVERTER			R_{14} RTG	
BATTERY BANK AND ASSOCIATED CIRCUITRY #1			R_{15} BATTERY #1	R_{15} BATTERY #1 AND ASSOCIATED CIRCUITRY
BATTERY BANK AND ASSOCIATED CIRCUITRY #2			R_{16} BATTERY #2	R_{16} BATTERY #2 AND ASSOCIATED CIRCUITRY
VOLTAGE REGULATION				R_{17} POWER REGULATOR
THERMAL CONTROL EXTERNAL CONTROL ACTIVITY				
STRUCTURAL SUPPORT				
VISUAL SURVEILLANCE TV CAMERA #1				TV CAMERA #1
VISUAL SURVEILLANCE TV CAMERA #2				R_{20} TELEVISION CAMERA #2 AND CONTROL
VISUAL SURVEILLANCE TV CAMERA #3				RELEVANT AND CONTROL
SUBSURFACE SAMPLER ASSEMBLY				R_{024} SURFACE SAMPLER ELECTRONICS
GEOPHYSICAL SUBSYSTEM "A1"				P_{031} GEOPHYSICAL "A1" ELECTRONICS
GEOPHYSICAL SUBSYSTEM "A2"				P_{032} GEOPHYSICAL "A2" ELECTRONICS
GEOPHYSICAL SUBSYSTEM "B"				P_{033} GEOPHYSICAL "B" ELECTRONICS
X-RAY EQUIPMENT-SPECTROMETER				P_{034} X-RAY EQUIPMENT ELECTRONICS
ORGANIC ANALYSIS EQUIPMENT				P_{035} ORGANIC ANALYSIS EQUIPMENT ELECTRONICS
SEISMIC MEASUREMENT				P_{036} SEISMIC INSTRUMENT ELECTRONICS
MAGNETIC FIELD MEASUREMENT EQUIPMENT				P_{037} MAGNETIC FIELD MEASUREMENT EQUIPMENT ELECTRONICS
SOLAR WIND MEASUREMENT EQUIPMENT				P_{038} SOLAR WIND MEASUREMENT EQUIPMENT ELECTRONICS
GRAVITY MEASUREMENT				P_{039} GRAVITY MEASUREMENT ELECTRONICS
SOLAR WIND ION ANALYZER				P_{040} SOLAR WIND ION ANALYZER ELECTRONICS
SURFACE SAMPLER & LANDING SURVEILLANCE EQUIPMENT				P_{041} SURFACE SAMPLER AND CONTROL
EQUIP # 2 PLASMA PROBE & MAGNETOMETER				
ACOUSTICAL EQUIPMENT (SEISMIC)				P_{042} ACOUSTICAL EQUIPMENT
SOIL TRANSFER CLUSTER				
SUBSURFACE SAMPLER				
TRANSMITTER AND GRAVIMETER STATION EQUIPMENT				
TAPE RECORDER				P_{044} TAPE RECORDER ELECTRONICS
X-RAY EQUIPMENT-DIFFRACTOMETER				P_{045} X-RAY EQUIPMENT ELECTRONICS
PERCUSSIVE ACOUSTICAL SENSOR				P_{046} ACOUSTIC SENSOR ELECTRONICS
SUBSURFACE LOGGING SONDE				P_{050} SUBSURFACE SEISMICAL SUBSYSTEM ELECTRONICS
RESISTIVITY MEASUREMENT				P_{051} RESISTIVITY MEASUREMENT EQUIPMENT ELECTRONICS
SOIL MECHANICS				P_{052} SOIL MECHANICS EQUIPMENT ELECTRONICS
PENETROMETRIC MEASUREMENT				P_{053} PENETROMETRIC ELECTRONICS
SYSTEM OR GROUP * RELIABILITY 80 MILES	R_A NOT APPLICABLE	R_B NOT APPLICABLE	R_C = 0.995-.91	R_D = 0.990-.990
SYSTEM OR GROUP ** RELIABILITY-ONE MONTH	R_A NOT APPLICABLE	R_B NOT APPLICABLE	R_C = 0.950-0.990	R_D = 0.780-0.990

* EQUIPMENT RELIABILITY FOR RETURNING MISSILE [illegible] DATA SOURCE.
** EQUIPMENT RELIABILITY FOR MISSILE [illegible]
*** ELECTRONICS RELIABILITY INCLUDES DATA [illegible] DEEP INTERSTELLAR CONVERTER

II

N'

LITY AND DESIGN RESPONSIBILITY, LUNAR OPERATION PHASE

VEHICLE GROUP	ENGR MECHANICS & THERMAL CONTROL GROUP	MECHANICS GROUP	SCIENTIFIC INSTRUMENT GROUP	EQUIPMENT BLOCK RELIABILITY: 180 HOURS	EQUIPMENT BLOCK RELIABILITY: 1 MONTH
HARNESS AND INTERCONNECTIONS				R_1 =	0.98-1	0.92-0.98
-CONNECTIONS				R_2 =	0.97-1	0.93-0.99
		R_{64} OMNI-DIRECTIONAL ANTENNA BOOM AND LANYARD		R_4 =	1	1
				R_5 =	0.97-1	0.93-0.99
		R_{66} DIRECTIONAL ANTENNA DRIVE MECHANISM INCLUDING TRIM TABLE, CAMERA STOWE AND LANYARD DEVICE		R_6 =	0.995-0.999	0.995-0.999
				R_7 =	0.97-1	0.93-0.99
		R_{68} OMNI-DIRECTIONAL ANTENNA BOOM AND LANYARD		R_8 =	1	1
				R_9 =	0.97-1	0.93-0.99
				R_{11} =	0.96-0.999	0.85-0.95
				R_{12} =	0.99-1	0.96-0.999
		R_{613} SOLAR PANEL DRIVE MECHANISM		R_{13} =	0.98-1	0.95-0.995
				R_{14} =	0.96-0.999	0.87-0.97
				R_{15} =	0.94-0.998	0.84-0.98
				R_{16} =	0.94-0.998	0.89-0.98
				R_{17} =	0.99-1	0.95-0.995
	R_{618} RADIATION SURFACE THERMAL SHELL AND RTG THERMAL ENERGY TRANSFER DEVICE			R_{18} =	1	1
		R_{621} VEHICLE ANCHORING MECHANISM & WELL		R_{22} =	1	1
R_{625}		R_{626} "TV CAMERA" MANIPULATION DEVICES AND OPTICS		R_{26} =	0.96-0.999	0.96-0.999
R_{627}		R_{627} "TV CAMERA #2" MANIPULATION DEVICES AND OPTICS		R_{27} =	0.96-0.999	0.96-0.999
R_{628}		R_{628} "TV CAMERA #3" MANIPULATION DEVICES AND OPTICS		R_{28} =	0.96-0.999	0.96-0.999
R_{629}		R_{629} "SUBSURFACE CAMERA" DEVICES MECHANISMS SAMPLE MANIPULATION EQUIPMENT AND PULVERIZER		R_{29} =	0.96-0.999	0.96-0.999
R_{631}	R_{631}	R_{631} GEOPHYSICAL SUBSYSTEM "A1" MANIPULATION DEVICES	R_{431} GEOPHYSICAL INSTRUMENT "A1"	R_{31} =	0.95-0.995	0.75-0.85
R_{632}		R_{632} GEOPHYSICAL SUBSYSTEM "A2" MANIPULATION DEVICES	R_{432} GEOPHYSICAL INSTRUMENT "A2"	R_{32} =	0.95-0.995	0.75-0.85
R_{633}		R_{633} GEOPHYSICAL SUBSYSTEM "B" MANIPULATION DEVICES	R_{433} GEOPHYSICAL INSTRUMENT "B"	R_{33} =	0.95-0.995	0.75-0.85
R_{634}	THERMAL CONTROL	R_{634}	R_{434} SPECTROGRAPH	R_{34} =	0.95-0.995	0.95-0.995
R_{635}	THERMAL CONTROL	R_{635}	R_{435} GAS CHROMATOGRAPH	R_{35} =	0.95-0.995	0.95-0.995
R_{636}	THERMAL CONTROL		R_{436} SEISMOMETER	R_{36} =	0.95-0.995	0.75-0.85
R_{637}	THERMAL CONTROL		R_{437} MAGNETOMETER	R_{37} =	0.95-1	0.85-0.95
R_{638}	THERMAL CONTROL		R_{438} RADIATION INSTRUMENT	R_{38} =	0.95-0.995	0.75-0.85
R_{639}	THERMAL CONTROL	R_{639}	R_{439} GRAVIMETER	R_{39} =	0.95-0.995	0.85-0.95
R_{640}	THERMAL CONTROL	R_{640} BOOM	R_{440} [illegible] VALVE	R_{40} =	0.95-0.995	0.75-0.85
		R_{641} "TV CAMERA #4" DEVICES		R_{41} =	0.96-0.999	0.96-0.999
		R_{642} BOOM #2 AND RESTRAINT DEVICE		R_{42} =	1	1
		R_{643} [illegible] MANIPULATION DEVICES	R_{443} ACOUSTIC SENSOR	R_{43}	0.96-1	0.96-0.999
		R_{644} SOIL TRANSFER EQUIPMENT		R_{44}	0.98-1	0.98-1
		R_{645} [illegible] EQUIPMENT		R_{45}	0.98-1	0.98-1
		R_{646} SEISMOMETER MANIPULATION DEVICE		R_{46} =	1	1
				R_{47} =	0.98-1	0.92-1
	R_{648} THERMAL CONTROL		R_{448} DIFFRACTOMETER	R_{48} =	0.95-0.995	0.95-0.995
		R_{649} ACOUSTIC SENSOR LOCATION & MANIPULATION DEVICE	R_{449} ACOUSTIC [illegible]	R_{49} =	0.95-0.995	0.95-0.995
			R_{450} SUBSURFACE INSTRUMENTS	R_{50} =	0.97-0.999	0.97-0.999
		R_{651} RESISTIVITY EQUIPMENT MANIPULATION DEVICE	R_{451} RESISTIVITY INSTRUMENTS	R_{51} =	0.99-1	0.99-1
		R_{652} SOIL MECHANICS MANIPULATION DEVICE	R_{452} SOIL MECHANICS INSTRUMENTS	R_{52} =	0.99-1	0.99-1
		R_{653} [illegible] EQUIPMENT MANIPULATION DEVICE	R_{453} PENETROMETER INSTRUMENT	R_{53} =	0.96-0.999	0.96-0.999
MASTER INTERCONNECTIONS					
[illegible]	$R_F \approx 1$	R_G = 0.985-0.996	R_H = 0.95-0.995	R_{Σ} = 0.75-0.90	0.64-0.82
[illegible]	R_F = .998-∞	R_G = 0.99[illegible]-∞	R_H = 0.80-0.95		

Spacecraft Reliability
System, Equipment Groups and Subassemblies

SUNNYVALE LABORATORY
LOCKHEED AIRCRAFT COMPANY
AEROSPACE DEVELOPMENT DIVISION

226600

B 50

SURVEYOR LABORATORY

HUGHES AIRCRAFT COMPANY

AEROSPACE ENGINEERING DIVISION

DETAIL SPECIFICATION

Spacecraft Reliability

System, Equipment Groups and Subassemblies

PREPARED	DATE	REVISIONS						NUMBER	
		LETTER	DATE	AUTH. DOC.	APPROVALS				
F.M. RESCHETAR								224600	
APPROVED	8 May 61	A	4-24-61						
APPROVED	11 Aug 61	B	8-11-61	Prod Flt Mod				REVISION B	MODEL SC
APPROVED	10 Nov 61							PAGE 1 OF 26 PAGES	
APPROVED								CUSTOMER CONCURRENCE	

1.0 SCOPE

1.1 Objectives: This specification establishes reliability objectives for the design of the Surveyor Spacecraft and its equipment groups and subassemblies. Reliability objectives are suggested for the scientific instruments for compatibility with the reliability objectives of the HAC equipment.

2.0 APPLICABLE DOCUMENTS

2.1 The following applicable documents shall form a part of this specification to the extent specified herein:

Hughes Aircraft Company Specifications

224500 Spacecraft Mission Objectives and Design Criteria

Hughes Aircraft Company IDC

2254.2/38 Control Item List - Reliability Functional Designation Cross Index

3.0 REQUIREMENTS

3.1 Design Description

3.1.1 Reliability Block Diagram

(See Figure 1)

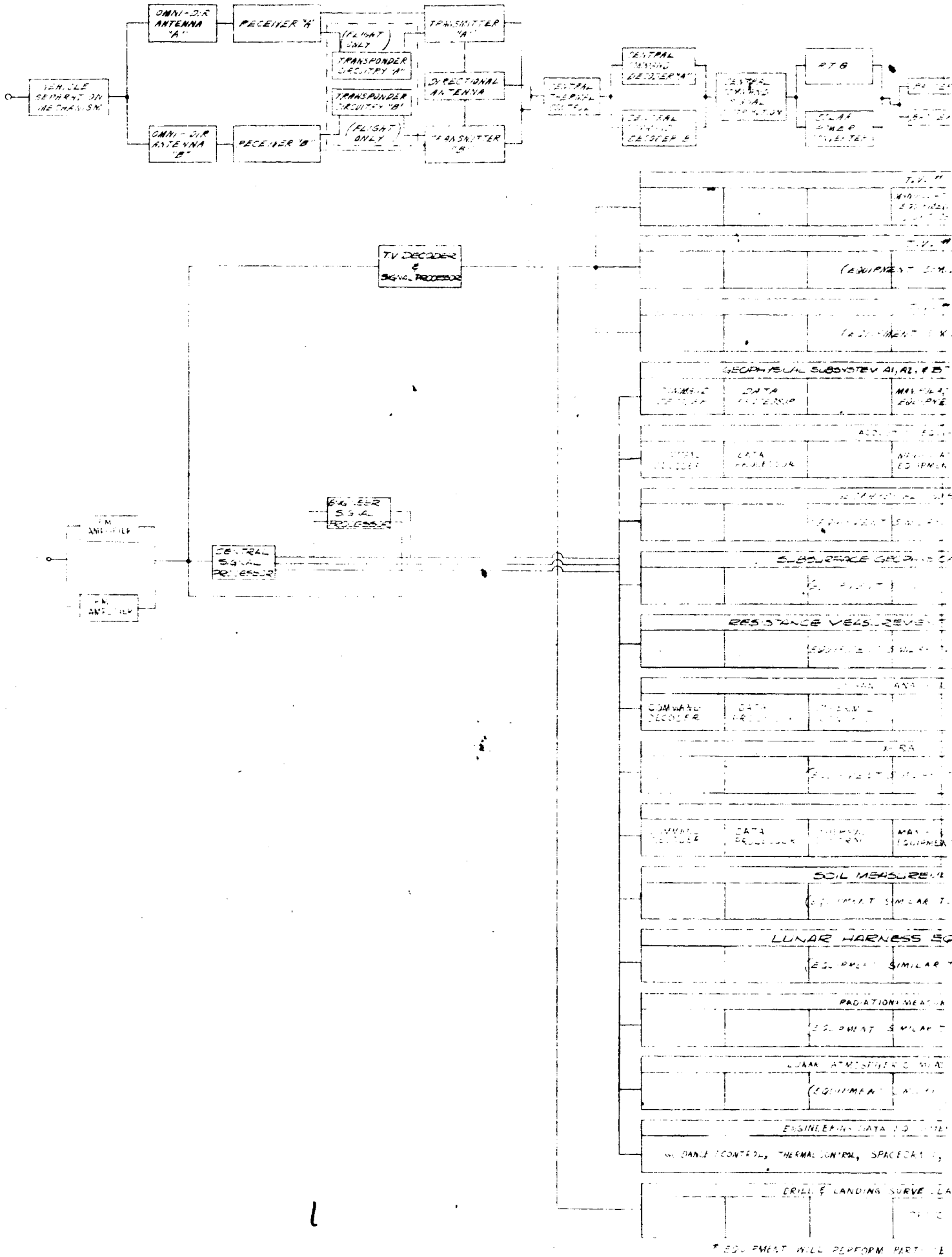
3.2 Operational Conditions

3.2.1 Environmental Conditions: The expected environmental conditions for the spacecraft and its subassemblies are described in the specification on external environments and specifications covering thermal control; and shock and vibration isolation and damping.

3.2.2 Use Cycles: The frequencies and durations of use of the spacecraft and its subassemblies are given in specifications on detailed equipment designs and mission operations.

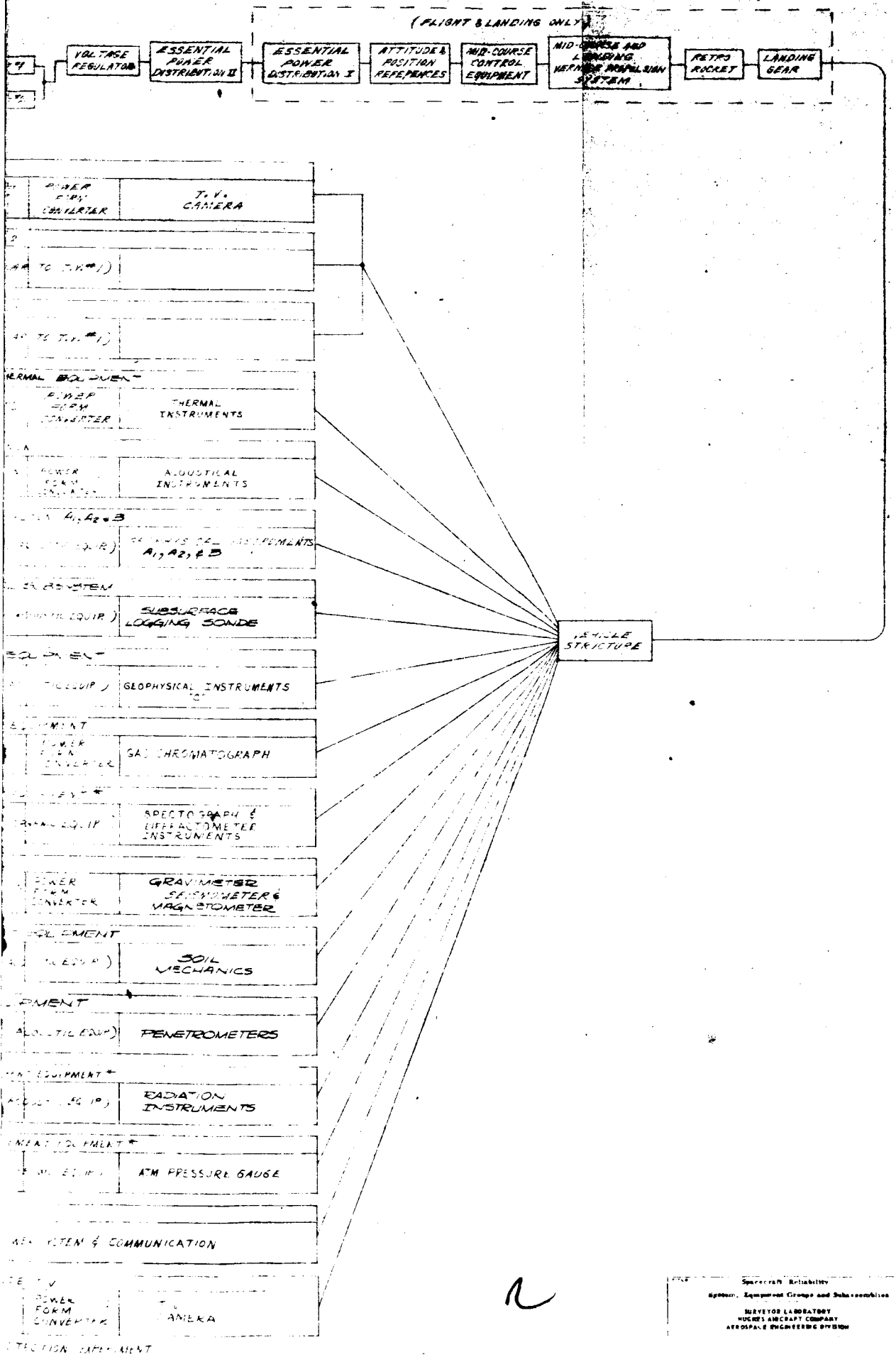
3.3 Reliability Objectives: Reliability objectives are specified in the following sections.

FIGURE 1 [illegible] RELIABILITY B[illegible]



* EQUIPMENT WILL PERFORM PART [illegible]

OCK DIAGRAM



Spacecraft Reliability
System, Equipment Groups and Subassemblies
SURVEYOR LABORATORY
HUGHES AIRCRAFT COMPANY
AEROSPACE ENGINEERING DIVISION
224600

3.3 Reliability Objectives (Cont'd)

3.3.1 Surveyor System

EQUIPMENT \ PHASE / RELIABILITY SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Surveyor System	R_S	0.75 - 0.90	0.93 - 0.99	0.64 - 0.82
Flight Control Group	R_A	0.89 - 0.95	(Not Applicable)	
Propulsion Group	R_B	0.85 - 0.94	(Not Applicable)	
Electric Power Group	R_C	0.995 - 0.999	0.995 - ≈ 1 *	0.95 - 0.99
Electronic Group	R_D	0.95 - 0.99	0.95 - 0.99	0.78 - 0.93
Vehicle Group	R_E	0.98 - 0.995	0.999 - ≈ 1	0.995 - ≈ 1
Engineering Mechanics and Thermal Control Group	R_F	≈ 1	≈ 1	0.998 - ≈ 1
Mechanics Group	R_G	0.99 - 0.999	0.985 - 0.996	0.999 - ≈ 1
Scientific Instrument Group **	R_H	≈ 1	0.95 - 0.995	0.8 - 0.95

*Wherever $\simeq 1$ appears in this document, it indicates a reliability requirement ≥ 0.9999.

**Reliability objectives are suggested for these instruments for compatibility with the overall Surveyor system reliability.

3.3.2 Flight Control Group

EQUIPMENT \ PHASE / RELIABILITY / SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Flight Control Group	R_A	0.89 - 0.95	(Not Applicable)	
Attitude Reference Sensors (Sun Sensors, Earth Sensors, Gyros and Star Tracker)	R_{A19}	0.92 - 0.98		
Control Equipment (Accelerometers, Control Electronics and Gas Jets)	R_{A20}	0.95 - 0.995		
Actuator, Roll Vernier	R_{A21}	0.99 - ≈ 1		
Retro Rocket Burn-out Sensor	R_{A22}	≈ 1		

3.3.3 Propulsion Group

EQUIPMENT \ PHASE / RELIABILITY SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Propulsion Group	R_B	0.85 - 0.94	(Not Applicable)	
Vernier Engine System	R_{B21}	0.86 - 0.96		
Retro Rocket	R_{B22}	0.96 - 0.99		

3.3.4 Electrical Power Group

EQUIPMENT / PHASE / RELIABILITY SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Electrical Power Group	R_C	0.995 - 0.999	0.995 - ≈ 1	0.95 - 0.99
Solar Cells and Solar Panel Structure	R_{C13}	0.98 - ≈ 1	0.98 - ≈ 1	0.95 - 0.995
R.T.G.	R_{C14}	0.96 - 0.999	0.96 - ≈ 1	0.87 - 0.97
Battery No. 1	R_{C15}	0.94 - 0.998	0.94 - 0.998	0.90 - 0.98
Battery No. 2	R_{C16}	0.94 - 0.998	0.94 - 0.998	0.90 - 0.98

3.3.5 Electronics Group

EQUIPMENT \ PHASE / RELIABILITY SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Electronics Group	R_D	0.95 - 0.99	0.96 - 0.99	0.78 - 0.93
Essential Power Switches and Power Form Converters	R_{D1}	0.98 - 0.995	0.98 - ≈1	0.92 - 0.98
Receiver "A"	R_{D2}	0.97 - ≈1	0.97 - ≈1	0.93 - 0.99
Transponder Circuitry "A"	R_{D3}	0.99 - ≈1	(Not Applicable)	
Diplexer "A"	R_{D4}	≈ 1	≈1	≈1
Transmitter "A"	R_{D5}	0.97 - ≈0.999	0.97 - ≈0.999	0.93 - 0.99
Directional Antenna	R_{D6}	≈ 1	≈1	≈1
Transmitter "B"	R_{D7}	0.97 - ≈0.999	0.97 - ≈0.999	0.93 - 0.99
Diplexer "B"	R_{D8}	≈1	≈1	≈1
Transponder Circuitry "B"	R_{D9}	0.99 - ≈1	(Not Applicable)	
Receiver "B"	R_{D10}	0.97 - ≈1	0.97 - ≈1	0.93 - 0.99
Central Decoders No. 1 and No. 2, and Central Command Signal Distribution	R_{D11}	0.96 - 0.999	0.96 - 0.999	0.85 - 0.95

3.3.5 Electronics Group (Cont'd)

EQUIPMENT / PHASE / RELIABILITY SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Signal Processing Circuitry	R_{D12}	0.995 - 0.999	0.99 - ≈1.999	0.96 - 0.995
Battery No. 1 Charge, Discharge and Overload Circuitry	R_{D15}	0.99 - ≈1	0.99 - ≈1	0.95 - 0.995
Battery No. 2 Charge, Discharge and Overload Circuitry	R_{D16}	0.99 - ≈1	0.99 - ≈1	0.95 - 0.995
28 Volt Regulator	R_{D17}	0.99 - ≈1	0.99 - ≈1	0.95 - 0.995
Radar (Altitude Marking Radar, Radar Altimeter, and Doppler Velocity Sensing Radar)	R_{D19}	0.99 - ≈1	(Not Applicable)	
T.V. Camera No.1 Television and Control Circuitry	R_{D26}	≈1	0.97 - ≈1	0.97 - ≈1
T.V. Camera No. 2 Television and Control Circuitry	R_{D27}	≈1	0.97 - ≈1	0.97 - ≈1
T.V. Camera No.3 Television and Control Circuitry	R_{D28}	≈1	0.97 - ≈1	0.97 - ≈1

3 3.5 Electronics Group (Cont'd)

EQUIPMENT / PHASE / RELIABILITY SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION 80 HOURS	LUNAR OPERATION ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Subsurface Sampler and Processor Electronics	R_{D29}	≈1	0.99 - ≈1	0.99 - ≈1
Geophysical Subsystem A_1 Electronics	R_{D31}	≈1	0.99 - ≈1	0.95 - 0.995
Geophysical Subsystem A_2 Electronics	R_{D32}	≈1	0.99 - ≈1	0.95 - 0.995
Geophysical Subsystem B Electronics	R_{D33}	≈1	0.99 - ≈1	0.95 - 0.995
X-Ray Equipment Electronics	R_{D34}	≈1	0.99 - ≈1	0.99 - ≈1
Organic Analysis Equipment Electronics	R_{D35}	≈1	0.99 - ≈1	0.99 - ≈1
Seismic Measurement Electronics	R_{D36}	≈1	0.99 - ≈1	0.95 - 0.995
Magnetic Field Measurement Equipment Electronics	R_{D37}	≈1	0.99 - ≈1	0.95 - 0.995
Incident Radiation Measurement Equipment Electronics	R_{D38}	≈1	0.99 - ≈1	0.95 - 0.995

3.3.5 Electronics Group (Cont'd)

EQUIPMENT	PHASE / RELIABILITY / SYMBOL	FLIGHT AND LANDING Minimum-Desired	LUNAR OPERATION 80 HOURS Minimum-Desired	LUNAR OPERATION ONE MONTH Minimum-Desired
Gravity Measurement Equipment Electronics	R D39	≃ 1	0.99 - ≃ 1	0.95 - 0.995
Lunar Atmosphere Measurement Equipment Electronics	R D40	≃ 1	0.99 - ≃ 1	0.95 - 0.995
T.V. Camera No. 4 Television, Strobe, and Controlling Circuitry	R D41	≃ 1	0.97 - 1	0.97 - ≃ 1
Acoustic Source Electronics	R D43	≃ 1	≃ 1	≃ 1
Tape Recorder	R D47	0.99 - ≃ 1	0.98 - ≃ 1	0.92 - ≃ 1
Surface Acoustical Sensor Electronics	R D49	≃ 1	≃ 1	≃ 1
Subsurface Geophysical Subsystem Electronics	R D50	≃ 1	0.97 - 0.995	0.97 - 0.995
Resistivity Measurement Equipment Electronics	R D51	≃ 1	0.99 - ≃ 1	0.99 - ≃ 1
Soil Mechanics Equipment Electronics	R D52	≃ 1	0.99 - ≃ 1	0.99 - ≃ 1
Penetrometer Equipment Electronics	R D53	≃ 1	0.99 - ≃ 1	0.99 - ≃ 1

Note: Electronics for the experiments includes command decoder data processor and power form converter

3.3.6 Vehicle Group

EQUIPMENT \ PHASE / RELIABILITY SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Vehicle Group	R_E	0.98 - 0.995	0.999 - ≈ 1	0.995 - ≈ 1
Harness and Interconnections	R_E'	≈ 1	≈ 1	≈ 1
Retro Rocket Separation Mechanism	R_{E22}	0.99 - 0.998	(Not Applicable)	
Vehicle Structure	R_{E23}	0.995 - $\simeq 1$	≈ 1	≈ 1
Vehicle Separation Mechanism	R_{E24}	0.99 - 0.998	(Not Applicable)	
Landing Gear (3) (Includes Unfolding Mechanism and Crushable Blocks)	R_{E25}	0.995 - $\simeq 1$	≈ 1	≈ 1

R_E' includes R_{E1}, R_{E2}, ... R_{E17}, R_{E19}, R_{E20}, R_{E21}, R_{E22}, R_{E24} and

R_{E26}, R_{E27}, ... R_{E48}

3.3.7 Engineering Mechanics and Thermal Control Group

PHASE / RELIABILITY / SYMBOL / EQUIPMENT		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Engr. Mech. and Thermal Control Group	R_F	≈ 1	≈ 1	0.998 - ≈ 1
Radiation Surfaces Thermal Shell and RTG Thermal Transfer Device	R_{F18}	≈ 1	≈ 1	≈ 1
Landing Gear Dampers	R_{F25}	≈ 1	≈ 1	≈ 1
Thermal Control Heaters	$R_{F'}$	≈ 1	≈ 1	≈ 1

$R_{F'} = R_{F34}, R_{F35}, R_{F36}, R_{F39}, R_{F40}$

3.3.8 Mechanics Group

EQUIPMENT	SYMBOL	FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Mechanics Group	R_G	0.99 - 0.999	0.985 - 0.996	0.999 - ≈1
Omni-Directional "A" Antenna Boom and Lanyard	R_{G4}	≈1	≈1	≈1
Directional Antenna Drive Mechanism (Including Turn-Table, Launch Stops, and Landing Locks)	R_{G6}	≈1	0.995 - 0.999	0.995 - 0.999
Omni-Directional "B" Antenna Boom and Lanyard	R_{G8}	≈1	≈1	≈1
Solar Panel Drive Mechanism	R_{G13}	0.995 - 0.999	0.995 - 0.999	0.99 - 0.998
Vehicle Anchoring Mechanism	R_{G23}	0.995 - ≈1	≈1	≈1
TV No. 1 Camera Manipulation Devices and Optics	R_{G26}	≈1	0.98 - ≈1	0.98 - ≈1
TV No. 2 Camera Manipulation Devices and Optics	R_{G27}	≈1	0.98 - ≈1	0.98 - ≈1
TV No. 3 Camera Manipulation Devices and Optics	R_{G28}	≈1	0.98 - ≈1	0.98 - ≈1

3.3.8 Mechanics Group (Cont'd)

EQUIPMENT	SYMBOL	FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Subsurface Sampler Drive Mechanism, Sample Handling Equipment and Pulverizer	R_{G29}	≈1	0.96 - 0.999	0.96 - 0.999
Geo. Subsystem A1 Manipulation Devices	R_{G31}	≈1	≈1	≈1
Geo. Subsystem A2 Manipulation Devices	R_{G32}	≈1	≈1	≈1
Geo. Subsystem B Manipulation Devices	R_{G33}	≈1	≈1	≈1
Pressure Gage Boom	R_{G40}	≈1	≈1	≈1
Subsurface Surveillance (T.V. Camera No. 4) Optics	R_{G41}	≈1	0.99 - 0.998	0.99 - 0.998
Plasma and Magnetometer Boom	R_{G42}	≈1	≈1	≈1
Acoustic Source Location and Manipulation Devices	R_{G43}	≈1	≈1	≈1
Soil Transfer Cluster	R_{G44}	≈1	0.98 - ≈1	0.98 - ≈1

3.3.8 Mechanics Group (Cont'd)

EQUIPMENT \ PHASE / RELIABILITY / SYMBOL		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Subsurface Sampler and Geo. Probe Location and Manipulation Devices	R_{G45}	≈ 1	0.98 - ≈1	0.98 - ≈1
Seismic and Gravity Measurement Equip. Manipulation Devices	R_{G46}	≈ 1	≈1	≈1
Surface Acoustic Sensor Location and Manipulation Devices	R_{G49}	≈1	≈1	≈1
Resistivity Measurement Equipment Manipulation Device	R G51	≈1	≈1	≈1
Soil Mechanics Manipulation Device	R G52	≈1	≈1	≈1
Penetrometer Equipment Manipulation Device	R G53	≈1	≈1	≈1

3.3.9 Scientific Instruments Group

PHASE / RELIABILITY / SYMBOL / EQUIPMENT		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
Scientific Instruments Group	R_H	≈1	0.95 - 0.995	0.8 - 0.95
Geo. Equip. - Set A1	R_{H31}	≈1	0.95 - 0.995	0.75 - 0.85
Geo. Equip. - Set A2	R_{H32}	≈1	0.95 - 0.995	0.75 - 0.85
Geo. Equip. - Set B	R_{H33}	≈1	0.95 - 0.995	0.75 - 0.85
X-Ray Spectrograph	R_{H34}	≈1	0.95 - 0.995	0.95 - 0.995
Gas Chromatograph	R_{H35}	≈1	0.95 - 0.995	0.95 - 0.995
Seismometer	R_{H36}	≈1	0.95 - 0.995	0.75 - 0.85
Magnetometer	R_{H37}	≈1	0.96 - 0.999	0.85 - 0.95
Radiation Instrument	R_{H38}	≈1	0.95 - 0.999	0.75 - 0.85
Gravimeter	R_{H39}	≈1	0.96 - 0.999	0.85 - 0.95
Atmospheric Pressure Gauge	R_{H40}	≈1	0.95 - 0.995	0.75 - 0.85
Acoustic Source	R_{H43}	≈1	0.99 - ≈1	0.96 - 0.999

3.3.9 Scientific Instruments Group (Cont'd)

PHASE / RELIABILITY / SYMBOL / EQUIPMENT		FLIGHT AND LANDING	LUNAR OPERATION	
			80 HOURS	ONE MONTH
		Minimum-Desired	Minimum-Desired	Minimum-Desired
X-Ray Diffractometer	R_{H48}	≈ 1	0.95 - 0.995	0.95 - 0.995
Surface Acoustical Sensor	R_{H49}	≈ 1	0.96 - 0.999	0.85 - 0.95
Resistivity Instruments	R_{H51}	≃ 1	0.96 - 0.999	0.96 - 0.999
Soil Mechanics	R_{H52}	≃ 1	0.96 - 0.999	0.96 - 0.999
Penetrometers	R_{H53}	≃ 1	0.96 - 0.999	0.96 - 0.999

3.4 Total Operating Life: The nominal operating Life of the Spacecraft shall be three months, excluding test and checkout time. The detailed life requirements are given in the specifications for the individual equipments.

4.0 SUPPLEMENTARY

4.1 Cross References

4.1.1 Cross Index for Equipment Reliability and Design Responsibility, Flight and Landing Phase. (See Table I, Page 22).

4.1.2 Cross Index for Equipment Reliability and Design Responsibility, Lunar Operation Phase. (See Table II, Page 23).

4.2 Definitions

4.2.1 Reliability (R): The reliability of an item is the probability that it will perform the function for which it was designed for the specified period of time when used in the manner and for the purpose intended. In addition to parts count and part failure rates, failure modes and effects must be considered in estimating reliability. Equations given in the Reliability Formulas section may be used when applicable in making reliability calculations.

4.2.2 Minimum Reliability: Minimum reliability is the minimum inherent reliability to be achieved in the design and shall be considered as the point of 20% consumer's risk in developing reliability demonstration plans.

4.2.3 Desired Reliability: Desired reliability is the inherent reliability achievable within the state-of-the art, weight, cost and time limits of the development program. It is anticipated that extensive trade-off actions will be necessary in order to achieve the desired reliability. This reliability shall be considered as the point of 20% producer's risk in developing reliability demonstration plans.

4.3 Reliability Formulas

4.3.1 Reliability of One-Shot Devices: The term "one-shot device" refers to any device whose failure or success depends only on a specific outcome. A device whose failure is a function of time is also considered a one-shot device if the required operating time is determined. As a direct application of the definition of reliability, the following equation is used for calculating reliability (R):

TAB

CROSS INDEX OF EQUIPMENT RE

EQUIPMENT BLOCKS / RESPONSIBLE ACTIVITIES	FLIGHT CONTROL GROUP	PROPULSION GROUP	ELECTRICAL POWER GROUP	ELECTRONICS GROUP
ESSENTIAL POWER DISTRIBUTION (II)				R_{D} ESSENTIAL POWER SWITCHES AND POWER FORM CONVERTERS
RECEIVER A				$R_{}$ RECEIVER A
OMNI-DIRECTIONAL ANTENNA A				R_{CA} ANTENNA A
TRANSMITTER 'A'				R_{DA} TRANSMITTER A
DIRECTIONAL ANTENNA				R_{CB} DIRECTIONAL ANTENNA
TRANSMITTER 'B'				R_{DB} TRANSMITTER
OMNI-DIRECTIONAL ANTENNA 'B'				R_{CB} ANTENNA B
RECEIVER 'B'				R_{DB} RECEIVER B
CONTROL COMMAND PROCESSOR				$R_{}$ CONTROL COMMAND PROCESSOR
CENTRAL SIGNAL PROCESSOR				$R_{}$ CENTRAL SIGNAL PROCESSOR
SOLAR POWER CONVERTER			$R_{}$ SOLAR CELLS AND [illegible]	
RADIOISOTOPE THERMOELECTRIC CONVERTER			$R_{}$ RTG	
BATTERY BANK AND ASSOCIATED CIRCUITRY #1			BATTERY #1	$R_{}$ BATTERY #1 CHARGE, DISCHARGE AND OVERLOAD CIRCUITRY
BATTERY BANK AND ASSOCIATED CIRCUITRY #2			BATTERY #2	R_{DIL} BATTERY #2 CHARGE, DISCHARGE AND OVERLOAD CIRCUITRY
CHARGE REGULATION				R_{CD} 28 VOLT REGULATOR
[illegible]				
STRUCTURAL EXPERT				
VISUAL SURVEILLANCE TV CAMERA #1				$R_{}$ TV CAMERA #1 TELEVISION AND CONTROL MONITOR
VISUAL SURVEILLANCE TV CAMERA #2				$R_{}$ TV CAMERA #2 TELEVISION AND CONTROL MONITOR
VISUAL SURVEILLANCE TV CAMERA #3				$R_{}$ TV CAMERA #3 TELEVISION AND CONTROL MONITOR
SUBSURFACE SAMPLING ASSEMBLY				R_{DD} SURFACE SAMPLER ELECTRONICS ***
GEOPHYSICAL SUBSYSTEM 'A'				R_{DF} GEOPHYSICAL SUBSYSTEM 'A' ELECTRONICS ***
GEOPHYSICAL SUBSYSTEM 'B'				R_{DGA} GEOPHYSICAL SUBSYSTEM 'B' ELECTRONICS ***
X-RAY EQUIPMENT-SPECTROMETER				$R_{}$ X-RAY EQUIPMENT ELECTRONICS ***
ORGANIC ANALYSIS EQUIPMENT				R_{DH} ORGANIC ANALYSIS EQUIPMENT ELECTRONICS ***
SEISMIC MEASUREMENT				$R_{}$ SEISMIC MEASUREMENT ELECTRONICS ***
MAGNETIC FIELD MEASUREMENT EQUIPMENT				$R_{}$ MAGNETIC FIELD MEASUREMENT EQUIPMENT ELECTRONICS ***
RADIATION MEASUREMENT EQUIPMENT				R_{CH} RADIATION MEASUREMENT EQUIPMENT ELECTRONICS ***
GRAVITY MEASUREMENT				R_{CJ} GRAVITY MEASUREMENT ELECTRONICS ***
[illegible]				R_{DG} ATMOSPHERE POWER ELECTRONICS ***
SURFACE SAMPLER & LANDING SURVEILLANCE EQUIPMENT				R_{CE} TV CAMERA #4 TELEVISION STROBE AND CONTROL CIRCUITRY
EQUIP # 2 PLASMA PROBE & MAGNETOMETER				
ACOUSTICAL EQUIPMENT				R_{DB} ACOUSTICAL SOURCE
SOIL TRANSFER CONTAINER				
SUBSURFACE SAMPLER				
PENETROMETER AND GRAY METER STATION EQUIPMENT				
TAPE RECORDER				R_{DAT} TAPE RECORDER ELECTRONICS
X-RAY EQUIPMENT-DIFFRACTOMETER				R_{DH} X-RAY EQUIPMENT ELECTRONICS
SURFACE ACOUSTICAL SENSOR				R_{DF} ACOUSTIC SENSOR ELECTRONICS
SUBSURFACE LOGGING SONDE				R_{DG} SUBSURFACE GEOPHYSICAL SUBSYSTEM ELECTRONICS
RESISTIVITY MEASUREMENT				R_{DG} RESISTIVITY MEASUREMENT EQUIPMENT ELECTRONICS
SOIL MECHANICS				R_{DG} SOIL MECHANICS EQUIPMENT ELECTRONICS
PENETROMETRIC MEASUREMENT				R_{DG} PENETROMETRIC ELECTRONICS
SYSTEM OR GROUP ** RELIABILITY 80 HOURS	R_A NOT APPLICABLE	R_B NOT APPLICABLE	R_C 0.995 - 1	R_D 0.990 - 1.000
SYSTEM OR GROUP ** RELIABILITY-DURATION	R_A NOT APPLICABLE	R_B NOT APPLICABLE	R_C 0.950 - 0.990	R_D 0.780 - 0.950

* EQUIPMENT RELIABILITY [illegible]

** EQUIPMENT RELIABILITY FOR [illegible]

*** [illegible] SEE POWER CONVERTER

C II

ILITY AND DESIGN RESPONSIBILITY, LUNAR OPERATION PHASE

VEHICLE GROUP	ENGR MECHANICS & THERMAL CONTROL GROUP	MECHANICS GROUP	SCIENTIFIC INSTRUMENT GROUP	EQUIPMENT BLOCK RELIABILITY		
					240 HOURS	1 MONTH
HARNESS AND INTERCONNECTIONS				R_1 =	0.98-1	0.92-0.98
INTERCONNECTIONS				R_2 =	0.97-1	0.93-0.99
INTERCONNECTIONS		R_{64} OMNI-DIRECTIONAL ANTENNA BOOM AND LANYARD		R_3 =	1	1
INTERCONNECTIONS				R_4 =	0.97-1	0.93-0.99
INTERCONNECTIONS		R_{66} DIRECTIONAL ANTENNA		R_5 =	0.998-0.999	0.998-0.999
INTERCONNECTIONS				R_6 =	0.97-1	0.93-0.99
		R_{68} OMNI-DIRECTIONAL ANTENNA BOOM AND LANYARD		R_7 =	1	1
				R_8 =	0.97-1	0.93-0.99
				R_9 =	0.96-0.999	0.85-0.95
INTERCONNECTIONS				R_{10} =	0.99-1	0.96-0.999
		R_{613} SOLAR PANEL DRIVE MECHANISM		R_{11} =	0.98-1	0.95-0.995
				R_{12} =	0.96-0.999	0.87-0.97
				R_{13} =	0.94-0.998	0.89-0.99
				R_{14} =	0.94-0.998	0.89-0.99
				R_{15} =	0.99-1	0.95-0.995
	R_{F18} RADIATION SURFACE THERMAL SHELL AND ETC THERMAL ENERGY TRANSFER DEVICE			R_{16} =	1	1
		R_{623} VEHICLE ANCHORING MECHANISM FUSEL		R_{23} =	1	1
	R_{F26}	R_{626} TV CAMERA #1 MANIPULATION DEVICES AND OPTICS		R_{24} =	0.96-0.999	0.96-0.999
	R_{F27}	R_{627} TV CAMERA #2 MANIPULATION DEVICES AND OPTICS		R_{25} =	0.96-0.999	0.96-0.999
	R_{F28}	R_{628} TV CAMERA #3 MANIPULATION DEVICES AND OPTICS		R_{26} =	0.96-0.999	0.96-0.999
	R_{F29}	R_{629} SUBSURFACE PENETRATOR MECHANISMS SAMPLE HANDLING EQUIPMENT AND PULVERIZER		R_{27} =	0.96-0.999	0.96-0.999
	R_{F31}	R_{631} GEOPHYSICAL SUBSYSTEM "A" MANIPULATION DEVICES	R_{H31} GEOPHYSICAL INSTRUMENT "A"	R_{31} =	0.95-0.995	0.75-0.85
	R_{F32}	R_{632} GEOPHYSICAL SUBSYSTEM "A2" MANIPULATION DEVICES	R_{H32} GEOPHYSICAL INSTRUMENT "A2"	R_{32} =	0.95-0.995	0.75-0.85
	R_{F33}	R_{633} GEOPHYSICAL SUBSYSTEM "B" MANIPULATION DEVICES	R_{H33} GEOPHYSICAL INSTRUMENT "B"	R_{33} =	0.95-0.995	0.75-0.85
	R_{F34} THERMAL CONTROL	R_{634}	R_{H34} SPECTROGRAPH	R_{34} =	0.95-0.995	0.75-0.995
	R_{F35} THERMAL CONTROL	R_{635}	R_{H35} GAS CHROMATOGRAPH	R_{35} =	0.95-0.995	0.95-0.995
	R_{F36} THERMAL CONTROL	R_{636}	R_{H36} SEISMOMETER	R_{36} =	0.95-0.995	0.75-0.85
	R_{F37} THERMAL CONTROL		R_{H37} MAGNETOMETER	R_{37} =	0.96-0.999	0.85-0.95
	R_{F38} THERMAL CONTROL		R_{H38} RADIATION INSTRUMENTS	R_{38} =	0.95-0.995	0.75-0.85
	R_{F39} THERMAL CONTROL	R_{639}	R_{H39} SPECTROMETER	R_{39} =	0.96-0.999	0.85-0.95
	R_{F40} THERMAL CONTROL	R_{640} [illegible]	R_{H40} [illegible] VALVE	R_{40} =	0.95-0.995	0.75-0.85
		R_{66} TV CAMERA #4 OPTICS		R_{41}	0.96-0.999	0.96-0.999
		R_{642} BOOM #2 AND RESTRAINT DEVICE		R_{42} =	1	1
		R_{643} ACOUSTIC SENSOR LOCATION MANIPULATION DEVICES	R_{H43} ACOUSTIC SENSOR	R_{43} =	0.99-1	0.96-0.999
		R_{644} SOIL TRANSFER EQUIPMENT		R_{44} =	0.98-1	0.98-1
		R_{645} [illegible]		R_{45} =	0.98-1	0.98-1
		R_{646} 16 SEISMOMETER AND MAGNETOMETER MANIPULATION DEVICE		R_{46} =	1	1
	R_{F48} THERMAL CONTROL		R_{H48} DIFFRACTOMETER	R_{47} =	0.98-1	0.92-1
		R_{649} ACOUSTIC SENSOR LOCATION MANIPULATION DEVICE	R_{H49} ACOUSTIC [illegible]	R_{48} =	0.96-0.999	0.95-0.995
				R_{49} =	0.96-1	0.85-0.95
			R_{H50} SUBSURFACE INSTRUMENTS	R_{50} =	0.97-0.998	0.97-0.998
		R_{651} RESISTIVITY MEASUREMENT EQUIPMENT MANIPULATION DEVICE	R_{H51} RESISTIVITY INSTRUMENTS	R_{51} =	0.99-1	0.99-1
		R_{652} SOIL MECHANICS MANIPULATION DEVICE	R_{H52} SOIL MECHANICS INSTRUMENTS	R_{52} =	0.99-1	0.99-1
		R_{653} PENETROMETER EQUIPMENT MANIPULATION DEVICE	R_{H53} PENETROMETER INSTRUMENT	R_{53} =	0.96-0.999	0.96-0.999
INTERCONNECTIONS				R_{54} =	0.99-0.999	0.64-0.82
[illegible] - 1	R_F = 1	R_G = 0.983-0.996	R_H = 0.96-0.995			
[illegible] - 1	R_F = 0.998-1	R_G = [illegible] - 1	R_H = 0.80-0.95			

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$$R = \frac{\text{number of successful trials}}{\text{total number of trials}} \quad (1)$$

Furthermore, the reliability of a group of independent devices is given by the "product rule":

$$R = \prod_i R_i \quad (2)$$

where R_i = reliability of the ith device.

4.3.2 Reliability of Time and On-Off Cycle Dependent Devices - One of the most fundamental and important equipment failure characteristics is the Poisson distribution which describes random failures. For the required operating time of 1 to 3 months, the Surveyor will be designed to have no wearout failures, except in isolated instances such as the batteries. Therefore, most of the failures will occur at random and follow the Poisson characteristic.

To account for all the stresses besides the mission operating time (on-off cycling and storage effects), the exponential law which characterizes a Poisson distribution can be expressed as follows:

$$R = e^{-\left(\frac{s}{m_s} + \frac{t}{m_t} + \frac{c}{m_c}\right)} = e^{-(\alpha_s s + \alpha_t t + \alpha_c c)} \quad (3)$$

where m_s = mean time between failures during storage (in hours)

m_t = mean time between failures during operation (in hours)

m_c = mean cycles between failures during the mission (in cycles)

s = storage time in hours

t = operating time in hours

c = power on-off cycles

α_s = $\frac{1}{m_s}$ = failure rate during storage (per hours)

$$a_t = \frac{1}{m_t} = \text{failure rate during operation (per hours)}$$

$$a_c = \frac{1}{m_c} = \text{failure rate during the mission (per cycle)}$$

By application of the "product rule," Equation (2), it can be shown that

$$a = \sum_i a_i$$

where a_i = failure rate of the ith element.

4.3.3 Reliability of Redundant Equipment with Standby Equipment Energized - Reliability can be enhanced by the addition of standby equipments. However, before adding another piece of equipment, it is important to know how much gain can be derived from such an arrangement. If the equipments are completely redundant, i.e., the function fails only if all equipments fail, then the following equation is used:

$$R = 1 - \prod_i (1-R_i) \tag{4}$$

where R_i = reliability of the ith redundant equipment.

If switch systems are used with the redundant equipment, the reliability of the switch system must be included in the over-all calculation.

4.3.4 Over-all Effective Reliability - If a piece of equipment is used to carry out several distinct functions, the failure to perform a minor function should not be considered as a total failure of the equipment. In order that the reliability of completing the important functions will not be masked by the reliability of an unimportant function, a method for calculating the over-all effective reliability of the equipment is needed. The following equation shall be used for such purpose:

$$R = \sum_i W_i R_i \tag{5}$$

where R_i = reliability of the ith distinct function

W_i = importance weighting factor for the ith function

(note: $\sum_i W_i = 1$)

SURVEYOR LABORATORY

HUGHES AIRCRAFT COMPANY

AEROSPACE ENGINEERING DIVISION

Reliability Assurance Program

for Developmental and Limited Production Equipment

PREPARED	DATE	REVISIONS						NUMBER
H. McCormick	5/18/61	LETTER	DATE	AUTH. DOC.	APPROVALS			224601
APPROVED								
APPROVED	5/20/61							REVISION / MODEL
APPROVED								PAGE 1 OF 11 PAGES
APPROVED								CUSTOMER CONCURRENCE

1.0 SCOPE

1.1 Scope: This specification details the minimum reliability assurance program requirements that must be followed by sub-contractors during the development and fabrication of equipment.

1.2 Objectives: The broad objectives of the reliability program are to assure the achievement of the quantitative reliability specified in the detail specification through the establishment of adequate reliability control and to verify the attainment of this reliability through analysis, design documentation, history with similar equipment and accumulated test data.

1.3 Supporting Areas: The requirements specified herein also establish the minimum areas to be considered by the sub-contractor to assure the adequacy of his program.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification:

STANDARDS

Military

MIL-STD-441 Reliability of Military Electronic Equipment

2.2 In the event there is a conflict between the detailed product specification, the work statement, this specification and/or specifications referenced in 2.1 the following order of precedence shall apply:

a. Work Statement

b. Detailed Product Specification

c. This Specification

d. Referenced Specifications

3.0 REQUIREMENTS

3.1 General Requirements

3.1.1 Reliability Requirements: It shall be the responsibility of the subcontractor to achieve and verify the quantitative reliability specified in the detail specification.

3.1.2 Approach: In order to assure positive control of equipment reliability, the subcontractor shall establish and maintain an adequate reliability program. A draft of the proposed program with task definitions, milestones, manpower assignments, analysis techniques and reliability test schedule shall be submitted to Hughes Aircraft Company for approval as scheduled in the purchase order.

3.1.3 Documentation: Progress in implementing the reliability program shall be documented to the extent necessary to demonstrate positive control and to allow ready monitoring by Hughes Aircraft Company.

3.1.4 Reliability Design Techniques: Emphasis is to be placed on following high reliability design practices and concentrating reliability efforts during the design phase. Specific techniques to be stressed are simplicity, redundancy, utilization of standard parts, environmental control, design reviews, and the use of proven equipments and design techniques. Whenever practicable parts from the Hughes Aircraft Company Standard Parts List approved for the project are to be used. Approval for all non-standard parts shall be required.

3.1.5 Environmental Considerations: The equipment shall provide the specified reliability under the environmental conditions to which it will be subjected as specified in the detail equipment specification. Particular attention shall be given to the determination of those realistic combinations of service condition that could most significantly affect the reliability of the equipment.

3.1.6 Subcontract Requirements: When incorporated into the contract this specification shall be applicable to all equipment for which reliability requirements have been established. Prime subcontractors are responsible for determining the applicable portions of this specification to be included in their respective subcontracts and purchase orders, subject to the right of disapproval by Hughes Aircraft Company.

3.1.7 Reliability Organization: A single group shall be designated the responsibility for the overall reliability function to cover engineering, testing, manufacturing, quality control and purchasing.

3.2 Specific Requirements

3.2.1 Reliability Prediction and Analysis

3.2.1.1 The subcontractor shall analyze the number and type of component parts needed to perform the specified equipment functions. Using part failure rates, derating curves, stress analyses, redundancy formulas or other suitable data, the contractor shall estimate the inherent reliability to be realized by the equipment.

3.2.1.2 The subcontractor shall conduct trade-off studies such as reliability versus weight, power consumption, cost, etc., and indicate the incorporation of the results in his design.

3.2.1.3 The results of these analyses shall be forwarded to Hughes Aircraft Company as scheduled in the purchase order. The data sources, analysis techniques, and assumptions with appropriate justification shall accompany the analyses.

3.2.2 Achieved Reliability

3.2.2.1 At a minimum of three points, to be defined in the Reliability Program Plan, the subcontractor shall estimate the operational reliability of the equipment. These estimates shall be based, in so far as possible, on test data and shall account for environmental effects, manufacturing variations, storage effects, transportation effects and maintenance requirements.

3.2.2.2 Statistical confidence limits and expected reliability growth shall accompany each estimate of operational reliability.

3.2.2.3 In those cases where the estimated operational reliability is less than desired the subcontractor shall indicate action such as improvements in the basic design, material selection, production processes and quality control that will be taken to increase the reliability to the desired level.

3.2.3 Failure Reports

3.2.3.1 A failure report shall be initiated for each failure. The failure report shall be used as a basis for failure analyses. The format of the report shall be similar to HAC Form 9261 - CC - EN) and shall contain the minimum information required on HAC Form 9261 - CC-EN.

3.2.3.2 The internal use and distribution shall be at the discretion of the subcontractor; however, the following rules shall apply:

a. A positive control, such as requiring a failure report as a requisition for a replacement part, shall be used to assure complete reporting.

b. One copy shall remain attached to the article until its eventual disposition by scrap or return to a serviceable condition.

c. A completed copy shall be sent by air mail or other expeditious means, within 5 working days after failure is discovered, to Hughes Aircraft Company.

3.2.4 Failure Analyses

3.2.4.1 A failure analysis shall be conducted on each failure establishing the mode of failure, cause of failure, and planned corrective action.

3.2.4.2 Each failure analysis shall be reported and the following rules shall apply:

a. A positive control shall be established to ascertain that each failure is analyzed.

b. The investigation of each failure shall be performed by specialists experienced in failure analysis and acquainted with the materials, processes and techniques used in the manufacture.

c. All steps taken to determine the cause of failure shall be documented thoroughly, using photographs or sketches with specific measurements where applicable and parts dissected to whatever degree necessary to establish ultimate failure cause.

d. A failure analysis shall be completed and forwarded to Hughes Aircraft Company within 30 days of the occurrence of each failure.

3.2.5 Control of Parts, Materials and Processes

3.2.5.1 The subcontractor shall analyze and document the selection and application of the parts, materials and processes used in the equipment.

3.2.5.2 The subcontractor shall prepare and maintain a list of the selected parts, materials and processes. Each part, material or process for which the subcontractor does not have a high engineering confidence will be identified on this list as "Critical". Items shown as "Critical" will be subjected to limited qualification and/or special reliability tests to assure their reliability.

3.2.5.3 By successive changes to the preliminary list, a final list of parts, materials and processes will be developed. The final list will reflect the resolution of the tests recommended for "Critical" items on prior lists.

3.2.6 Fabrication Control: The subcontractor shall establish a program for assuring reliability through the control of fabrication processes. Controls established will include, but not be limited to:

a. Parts and Materials

1. Lot purchase plans for maximum control of quality.

2. Special reliability tests on parts and materials intended for "Critical" application.

3. Receipt accountability.

4. Incoming inspection tests for all parts and materials.

5. Identification of parts and materials requiring special handling, packaging and stockage.

6. Segregated and controlled storage; controlled issuance.

b. Processes

1. Written specification for each process.

2. Satisfactory test results for this process.

3. Certification of the process based upon 1 and 2.

4. Quality control check system.

5. Certification of skilled operations (i.e., welders, etc.)

3.2.7 Reports

3.2.7.1 Progress Reports: When progress reports are required as a contract item a section on reliability shall be included. The subcontractor shall state his efforts and his accomplishments in achieving reliable operation of the basic equipment. Estimates of equipment reliability status shall be included.

3.2.7.2 Interim Engineering Reports: When interim engineering reports are required as a contract item, a separate reliability appendix shall

be included in each such report. Emphasis shall be placed on the following areas as a minimum.

a. Reliability achieved and expected reliability growth.

b. Reliability program effectiveness.

c. Analysis of each failure and corrective action status.

d. All trade-off data of performance, reliability, weight and cost.

e. All critical problems.

f. Corrective action taken since last period on each problem.

g. All test results including conditions of test.

If interim engineering reports are not required, a special reliability report shall be submitted quarterly or at such other periods as specified in the contract.

3.2.8 Final Engineering Report: When a final engineering report is required as a contract item, a separate appendix shall be included in the report to summarize the results of the reliability program. The final report shall include the data required by the Phase II report (MIL-STD-441) and shall document the following:

a. Achieved reliability: The achieved reliability of the final design of the equipment under the operational conditions stated and based in so far as possible on testing of the final prototype models. The subcontractor shall also state the statistical confidence he places in his estimates and fully describes any condition that limits the reliability of the equipment.

b. Reliability improvement: The measures taken by the manufacturer to increase the reliability of the equipment and the improvement in reliability attained by the measures taken. Recommendations shall also be included as to possible future improvement in the reliability of the equipment.

3.3 Supporting Efforts: In addition to the requirements delineated in paragraphs 3.1 and 3.2 the subcontractor shall consider, establish standard procedures as required, and report his action on each of the following areas of supporting effort required to achieve the specified reliability. The following shall be regarded as the minimum additional areas necessary for consideration. The subcontractor shall also include additional areas where evidence exists that this will be necessary for an overall adequate support program.

a. Reliability testing facilities.

b. Reliability analysis techniques.

c. Reliability design reviews

d. Maintainability

e. Quality control

f. Handling, packaging and shipping considerations

g. Reliability verification techniques including reliability tests

4.0 RELIABILITY ASSURANCE PROVISIONS

4.1 General Procedures: Equipment shall be subjected to one of the following procedures, as specified in the procurement document, to verify that the design is capable of meeting the specified reliability requirements.

4.2 Minimum Verification

4.2.1 Verification that the design meets the reliability requirements shall be based upon the design documentation, the reliability program specified in paragraph 3 of this specification and the results of the quality assurance tests delineated in the detail specification.

4.2.2 If in the opinion of either the contractor or Hughes Aircraft Company additional verification is required such test will be negotiated between Hughes Aircraft Company and the contractor.

4.2.3 Hughes Aircraft Company reserves the right to conduct additional tests as are deemed necessary to verify the reliability of the equipment being purchased but in no case to impose more stringent requirements than those called for in the detail specification. Failure of the equipment to pass these tests shall be cause to reject the equipment under terms of the purchase order.

4.3 Reliability Demonstration

4.3.1 Demonstration of equipment reliability shall include the provisions of 4.1 plus additional testing specifically designated for the purposes of demonstrating equipment reliability.

4.3.2 Reliability demonstration tests shall be conducted on equipment representative of the final configuration. Changes in either equipment design or manufacturing process shall necessitate re-verification of equipment reliability.

4.3.3 Reliability test procedures, test levels and number of equipments to be tested are to be prepared by the subcontractor and submitted to Hughes Aircraft Company for approval 90 days before such testing is scheduled.

4.3.4 The number of items tested and the test levels imposed shall be such as to demonstrate with 80% confidence that the equipment meets the minimum reliability specified in the detail specification.

5.0 NOTES

5.1 Intended Use: This specification is intended to provide requirements and procedures pertaining to a reliability program to be applied to research and development contracts for individual equipments.

5.2 Definitions

5.2.1 Reliability: Reliability is the probability of performing without failure a specified function under given conditions for a specified period of time.

5.2.2 Inherent Reliability: Inherent reliability of a device is the reliability potential present in the design.

5.2.3 Achieved Reliability: Achieved reliability of a device is the reliability demonstrated by the physical item under actual or simulated conditions of use.

5.2.4 Manufacturing: Manufacturing as used herein includes the manufacture of prototype and pilot-production articles as well as manufacture of the final article. This use of the term recognizes the growth of reliability during initial manufacture and the close relationship between production and development activities in achieving reliability.

5.2.5 Milestone: (In the programming sense.) A significant and frequently critical event having qualitative and/or quantitative aspects which, when completed indicates the accomplishment of a step in progress toward a predetermined goal.

APPENDIX C

Reliability Assurance Test Program

A planned and scheduled reliability assurance testing program has been designed to provide valid measurements on achievable reliability. Selected items of basic spacecraft equipment have been scheduled to undergo testing as early as possible to provide for feedback of data to assist in evaluating design reliability prior to launching of each spacecraft. Quantities and programs have been subject to economic and schedule restraints as well as test feasibility.

The quantitative reliability objectives established for the basic bus are reflected in requirements in appropriate detail equipment specifications. These requirements provide two of the four parameters necessary to define the individual test plans. The assumed risk of accepting equipment when its reliability is below the specified minimum and the risk of rejecting equipment when its reliability is at least as good as a specified value provide the two remaining parameters.

Project Management must be given an estimate of spacecraft reliability prior to shipment to AMR. One input to this will include that each equipment type to be tested undergo sequential time-sample testing (see Sequential Life Tests in the Exponential Case by B. Epstein and M. Sobel, The Annals of Mathematical Statistics, Vol. 26, No. 1, March 1955). Combinations and sequences of appropriate mission environments have also been planned at stress/time levels to provide quantitative assurance at appropriate confidence levels that equipment is satisfactory. For example, each test plan includes hard vacuum (10^{-7} mm mercury) operation of the equipment for a period equal to three times its expected space life, but in no case more than 450 hours. Recent studies (1 and 2) indicate that the effects of the combined thermal/hard vacuum environments on the materials selected for Surveyor can be evaluated within the planned exposure time.

1. Electronic Component Application Consideration for Space Vehicles, Hughes Aircraft Special Research Study No. 424, 15 May 1961.

2. Equipment Design Consideration for Space Environment, by Lehr, Tronolone and Horton, STL Report STL/TR-60-000-09224, September 1960.

Reliability verification or demonstration requirements have been imposed upon subcontractors who submit program plans to the Surveyor Reliability Section for review and approval.

A summary of the test plans appears as Table 2. This defines the item and sample size for reliability assurance testing, the expected mission environmental and operating profile, the duration of reliability test and the acceptance criteria. The use of this table can best be shown by

observing the entries for the Transmitter, Part Number 231800 (Table 2).

Two will be selected for reliability test; the expected mission operational requirement is 14 hours in transit and continuous thereafter. For greater reliability, it is planned that one will be operated until it fails, then the other transmitter will be used.

Vibration testing will include simulation of phase A, B and C (Fig. 3) with the equipment operating during phase C. Equipment temperature will be cycled between 0° and 50°F during the vibration test. Included in this test will be the appropriate number of shocks D - J (Fig. 3) A hard vacuum soak of 450 hours during which time the transmitter will be operating and the temperature cycled between 0° - 125°F is included in the test plan.

The operational test cycle will be based on 80 hours providing adequate assurance of the transit reliability without increasing the test time prohibitively. However, since the transmitter is operated approximately 14 times during the transit phase, each cycle of 80 hours will include 14 on-off cycles with suitable cooling time between cycles. The reliability calculations will be based on a continuous function. The sequential plan will assure a risk of accepting equipment with a reliability of .97 no more than 20% of the time and a producer's risk of 20% at the desired value of reliability (.996). This plan will require operating the two transmitters a maximum of 10,667 hours for a decision and the test program is expected to last 10 months.

The Reliability Assurance Test Schedule, Figure 1, is a composite of the hardware items which will undergo extensive evaluation testing. For each item, this schedule shows major tasks to be accomplished prior to the start of testing, the expected duration of testing and the target date for achieving an estimate of the probability of mission success for S/C 1.

FOLDOUT FRAME 1

RE

TEST ITEM	1961 J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
1. Accelerometer, Flt. Control								○				⊗			
2. Switch, Inertia-Burnout Sensing								○							⊗
3. Accelerometer, Telemetry								○							⊗
4. Actuator, Roll Control									○				⊗		
5. Battery										○			⊗		
6. Control Electronics Set													○		
7. F/F and Gating Circuits												○			
8. Gas Jet System								○				⊗			
9. Gyro, Inertial										○		⊗			
10. Mechanism, Mirror Drive								○				⊗			
11. Mechanism, Ant./Solar Panel Positioner								○				⊗			
12. Power Control System "A"														○	
13. Electronic Power Switch													○		
14. Radar Altimeter & Doppler Vel. Sensor															
15. Radar Altitude Marker												○			
16. Receiver & Transponder													○		
17. Solar Panel (Partial)										○			⊗		
18. Sensor, Canopus													⊗		
19. TV Decoder & Processor															○
20. Transmitter and Diplexer													○		

○ Start Design & Fab. of Test Equipment, Fixtures, Jigs
⊗ Complete Reliability Assurance Test Specifications, Procedu

NAC Form 3110 (Rev. 6-55)

1-1

FIGURE 1

FOLDOUT FRAME 2

LIABILITY ASSURANCE TEST SCHEDULE

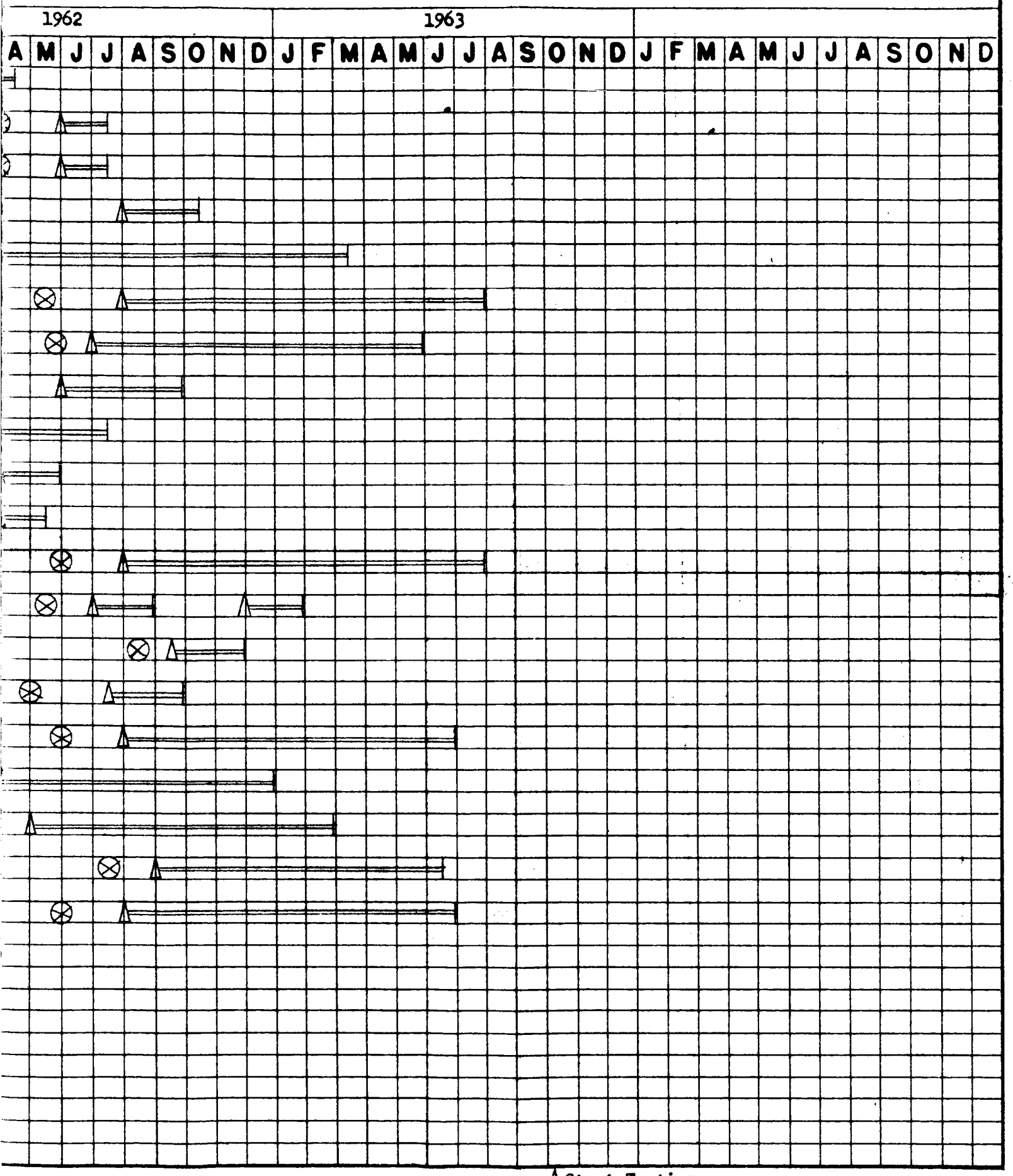
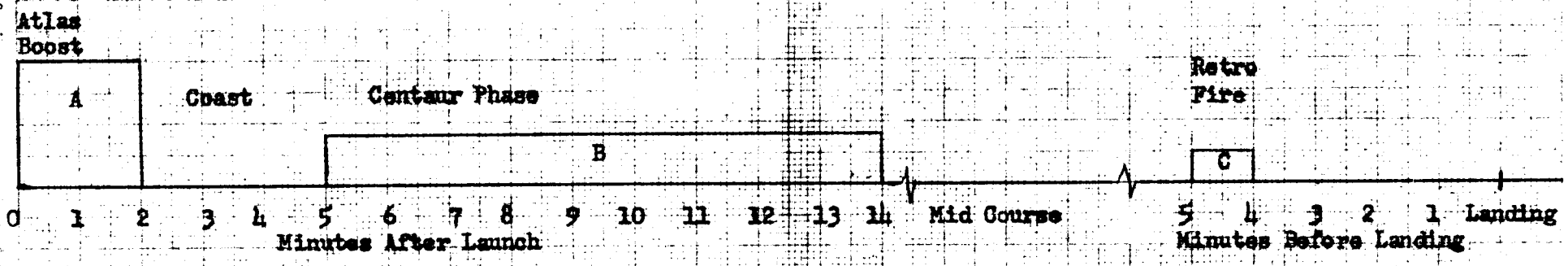


FIGURE 3

SURVEYOR VIBRATION & SHOCK ENVIRONMENT

TIME PROFILE

VIBRATION VS. TIME



SHOCK VS. TIME

A. 6 G 3σ RMS Noise 20 to 2000 cycles per second
1.3G Peak <50 CPS Sinesoidal Vibration
2 G Peak 50 to 400 CPS Sinesoidal Vibration
5 G Peak 400 to 2000 CPS Sinesoidal Vibration

B. 2.4 G 3σ RMS Noise 20 to 2000 CPS
Sinesoidal Vibration

C. Unknown at this time

D,E,F,G & H expected to be less than loads expected under vibration

J. 30 G 5 millisecond along thrust axis and 15 G 5 millisecond along transverse axes

FOLDOUT FRAME 1

EQUIPMENT INFORMATION						
Nomenclature	Part No.	No. to be tested	Mission Time or Cycles			Vil
			In Flight	Lunar		
				80 Hr.	1 Mo.	Phase
Accelerometer, F/C	236XXX	4	2 min	NA	NA	A,B
Switch, Inertial Burnout Sensing	236002	4	1 oper.	NA	NA	A,B,C_o
Accelerometer, Tele.	236001	2	66 hr.	NA	NA	A,B,C_o
Actuator, Roll Control	235000	3	6 Min.	NA	NA	A,B,C_o
Battery	237900	1 set,2 ea.	66 hr.	80 hr.	672 hr.	A_o,B_o,C_o
F/C Electronics	235800	2	66 hr.	NA	NA	A,B,C_o
F/F & Gating Circuits	----	2 groups 50 ea	66 hr	80 hr.	672 hr.	A_o,B_o,C_o
Gas Jet System	235600 235700	2	20 oper.	NA	NA	A,B
Gyro, Inertial	236XXX	2 sets,2 ea.	66 hr.	NA	NA	A_o,B_o,C_o
Mechanism, Mirror Drive	2362XX	8	NA	630 Cy.	Unk.	A,B,C
Positioner,Antenna/Solar Panel	2364XX	8	720 oper.	90 oper.	650 oper.	A,B,C
Power Control System "A"	233400	2	66 hr.	80 hr.	672 hr.	A_o,B_o,C_o
Power Switch	-----	2 groups 50 ea.	Unk.	Unk.	Unk.	A_o,B_o,C_o
Radar Altimeter & Doppler Velocity Sensor	232903 232904 232905 232906 232907	1	10 min.	NA	NA	A,B,C_o
Radar,Altitude Marking	232600	1	8 min.	NA	NA	A,B
Receiver & Transponder	231400	3	66 hr.	80 hr.	672 hr.	A_o,B_o,C_o
Solar Panel	237700	1	66 hr.	80 hr.	336 hr.	A,B,C
Sensor, Canopus	235300	2	66 hr.	NA	NA	A,B
T.V.,Decoder & Processer	233101 233000	1	18 min.	14 hr.	Unk.	A,B,C
Transmitter & Diplexer	231600 232500	2	14 hr.	80 hr.	672 hr.	A,B,C_o

*These figures indicate

FOLDOUT FRAME 2

TABLE 2

RELIABILITY ASSURANCE TEST PLAN

TEST ENVIRONMENT (See Fig. 3) Subscript "o" indicates equipment operating				Single test cycle		
ration Temp. Cycle °F	Shock	Hard Vacuum Time in Hrs.	Hard Vacuum Temp. Cycle °F	Time	Operations	Disore or Cor
0-50	D-F	75	0-50	2 min	—	C
0-50	D-F, G_o, H_o	198	0-50	--	1 pulse	D
0-50	D_o-J_o	198	0-50	--	5 oper.	D
0-25	D-F, G_o, H_o	198	0-25	--	9000 Oper	C
0-50	D_o-J_o	450	0-125	80 hr.	--	C
0-50	D-F, G_o, H_o	198	0-50	66 hr.	--	C
0-50	D_o-J_o	450	0-125	80 hr.	—	C
-10-(-50)	D-F	198	-100-(-50)	--	20 oper.	D
0-50	D_o-H_o	198	0-50	66 hr.	—	C
-50-0	D-J	450	-300-100	—	360 Cy	C
-50-0	D-J	450	-300-150	--	1440 oper.	D
0-50	D_o-J_o	450	0-125	80 hr.	--	C
0-50	D_o-J_o	450	0-125	--	1000 Cy.	D
0-50 -100-(-50)	D-F, G_o, H_o	198	0-50 -100-(50)	--	1 oper.	D
10-50	D-F	198	10-50	--	1 oper.	D
0-50	D_o-J_o	450	0-125	80 hr.	--	C
-200-160	D-J	450	-300-220	402 hr.	4*	C
0-50	D-F	198	0-50	66 hr.	--	C
-100-(-50)	D-J	450	-300-500	14 hr.	7*	C
0-50	D-F, G_o-J_o	450	0-125	80 hr.	*14 in flight cont. on moon	C

the number of on/off cycles during the indicated times.

TEST PLAN CRITERIA

ete nt.	Acceptance Criteria				Test Duration	
	Min. Acept. Rel.	Prob. of Acept.	Desired Rel.	Prob. of Accept.	Total Operating Hr. or Cycle	Expected length (mo.)
	.999	.10	.9999	.80	164 hr.	1
	.999	.20	.9999	.80	4130 Cy	1
	.999	.20	.9999	.80	20,650 Cy	1
	.999	.20	.9999	.80	36.9 MC	1
	.94	.10	.998	.90	7720 hr.	10½
	.98	.20	.998	.80	13,530 hr.	11
	.99944	.10	.99993	.80	690,000 hr.	10
	.999	.20	.9999	.80	82,600 Cy.	3
	.90	.20	.99	.80	2710 hr.	3
	.999	.20	.9999	.80	2.5 MC	2
	.999	.20	.9999	.80	5.9 MC	2
	.97	.20	.997	.80	10,950 hr.	9
	.9999	.10	.99999	.80	49 MC	1
	.993	.20	.9986	.80	548 Cy	1
	.999	.20	.9999	.80	4100 Cy	1½
	.97	.10	.999	.90	15440 hr.	9
	.95	.20	.995	.80	85,200 hr.	10
	.97	.20	.995	.80	8470 hr.	9
	.97	.10	.999	.90	2602 hr.	10
	.97	.20	.996	.80	10667 hr.	10

APPENDIX D

Components Parts Program - Surveyor

A major area of the reliability achievement effort on the Surveyor program is the following parts program. In order to achieve system reliability objectives, close attention must be directed toward the use of reliable components under closely surveillanced application limitations in order to achieve the respective potentials of the individual components. It must be clearly understood that in all cases where failure rates ascribed to piece parts have been developed, these failure rates are achievable only when adequate documentation for controlling purchased parts is established. The controls include qualification requirements, selected suppliers with known QC capabilities, well-defined lot acceptance criteria and the necessary quality control procedures associated with part usage in the Hughes or subcontractors manufacturing area. The following parts program will be implemented.

1. Preferred Parts List

A preliminary list of preferred parts has been established. Devices selected have been chosen on the basis of proven history in HAC systems. At the present, these devices have been listed as design guides for breadboard and experimental fabrication. In general, they are capable of meeting military environmental requirements and 125°C 48-hour sterilization requirements, and it is anticipated that they will meet Surveyor environmental and reliability requirements. It remains to validate certain environmental performance capabilities such as extreme low temperature and high vacuum conditions. To ensure reliability capabilities, adequate HAC procurement control documentation will be required. Parts application for lunar environment will be specified to assist in proper design. This will include stress derating factors for both mission phase and environment.

2. Specifications

Each component selected for use in the Surveyor spacecraft flight systems will be identified, purchased and controlled by detailed HAC procurement specifications which will completely define the component with appropriate quality control, reliability and packaging provisions. Parts used will conform to the qualification test requirements of the individual specifications. The component specifications will include environmental requirements imposed by mission objectives. Each lot supplied will require acceptance test data to be furnished with each lot. Pre-aging under load and at temperature will be accomplished by the supplier and only acceptable lots will be shipped to HAC. This will accomplish the necessary sterilization of the component interiors as well as accomplishing a part of the acceptance test routine. All specifications for parts

will include provisions for the prevention of impromptu and unauthorized changes in component design or manufacture.

3. Parts Handling

It has been established, on such programs as Minuteman, that the system and subsystem manufacturing areas can only degrade basic reliability of devices as received; they cannot improve reliability. Therefore, controls will be established for delivery of devices from suppliers and subsequent handling of devices upon receipt.

a. Packaging and Shipping

Packaging and shipping methods will be defined in each component specification in order to minimize the effects of adverse handling on the ultimate reliability of devices as received. These methods will include options dependent upon lot size.

b. Receiving Inspection

Parts as received will go through an Incoming Inspection procedure which will be detailed in each component specification. Small sample analyses may be appropriate for initial parameters.

c. Bonded Storage

Acceptable parts will be stored in special storage areas to be set up specifically for the purpose of controlling proper storage, lot identification, documentation and distribution of parts to the manufacturing area.

4. Quality Control

The QC organization will direct the Receiving Inspection activity and will actively monitor AQL levels of parts received. They will collect and review all acceptance test data received with each lot of material. The Components and Materials Department will receive regular status reports on acceptability of suppliers' products. With the concurrence of the Components and Materials Department, they will be empowered to reject materiel lots. QC will conduct an MRB, and jointly with manufacturing and Components Department, will accept or reject those lots requiring such review. The parts storage area will be set up and controlled by QC. Requirements for part storage will be established jointly by QC, manufacturing and Components Department.

5. Parts Application and Design Review

As a continuing aid to designers in their use and applications of components, the Components Department will actively participate in an advisory capacity in design reviews. In this manner, misapplication

of components will be minimized. Further, by consultation with component experts, designers will be enabled to optimize designs by proper selections, adequate derating and by making allowance for component parametric variation due to environment.

6. Engineering Evaluation and Reliability Studies

Special engineering evaluation and reliability studies will be conducted to aid designers in their choice and application of new parts which because of unique performance requirements become essential to mission objectives. Such parts approved for Surveyor usage will be defined by HAC specifications as previously described.

7. Failure Analysis

Component specialists will take an active part in analyzing component failures. Important in this effort is the identification of the component failure mode and the implementation of corrective action for recurrence prevention. The latter will be accomplished via the component specification requirements and changes thereto. In some cases, this may require the imposition of tighter or different process controls on the supplier.

APPENDIX E

HAC Preferred Parts and Materials Lists

In order to assist design personnel in the selection of materials suitable for the Surveyor environment, a Materials Manual is being prepared. The performance capabilities of various materials are being evaluated at extreme low temperatures and high vacuum conditions. From the tests conducted and information available the mechanical and electrical properties of these materials will be determined and the information disseminated.

In addition to the above, the Components and Materials Laboratory will recommend the conducting of specific tests to further prove or refute the validity of a material application. Only by use of exhaustive investigations and tests can there be assurance of the reliability to be achieved and of the mission to be accomplished. Several such studies underway are as follows.

Wire Evaluation

Because of the temperature extremes and high vacuum conditions encountered in a lunar mission, an electrical conductor evaluation is being carried out to determine the most desirable conductor and insulation system. Several conductors are being selected, both in size and type of material, and the current carrying capacitors are being established. Selection of an insulating material or materials will result from tests to determine which materials will not cause corona discharge due to chemical breakdown at the low pressures.

Dielectric Materials

Additional effort is being directed toward evaluation of dielectric materials for coaxial application. There is considerable latitude of movement for mechanical sampling equipment, solar panels, telescoping booms, etc., and hence, effort is being directed toward determination of the flexibility of coaxial, contour and other cable which may be used in the extreme temperature variations.

Additional current investigations are being made to determine (1) the most desirable solders to use where low pressure exists; (2) use of aluminum conductors in lieu of copper; and (3) use of shrinkable sleeving for soldered terminations.

HUGHES AIRCRAFT COMPANY

PREFERRED PARTS LIST

FOR SURVEYOR

COMPONENTS DEPARTMENT

COMPONENTS AND MATERIALS LABORATORY

Approved: C. G. Walance
C. G. Walance

Issue II

Date: 24 November 61

The Preferred Parts List for the Surveyor represents a preliminary tabulation of standard and preferred parts and suppliers, chosen on the basis of known quality and performance history. All the components listed are capable of withstanding exposure for 48 hours at 125° C, to effect internal sterilization of the device without degradation of applicable performance requirements.

The list is intended to provide design engineers with sufficient information to enable them to proceed with preliminary designs. In most instances, the basic physical and electrical characteristics have been entered, preliminary Hughes numbers have been assigned, and, where information is presently available, itemized part-number tables have been included.

It should be noted that the Hughes "X900000" number is a preliminary number only, which will become a formal 900000 number upon conclusion of the present test program in Components and Materials.

Prototype parts may be purchased by submitting a Components and Materials Engineering Request (CMER) to the Components Department.

This list constitutes the second issue. It will be periodically up-dated and will be supported by Hughes specifications controlling each part for which use is anticipated in the Surveyor. In those cases where specific requirements are not covered by the Preferred Parts List, users are requested to make their needs known to the Components Department.

CAPACITORS, FIXED

TYPE	CAPACITANCE RANGE	MAXIMUM WORKING VOLTAGE (DC)	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	REMARKS	HUGHES DOCUMENT NUMBER
CERAMIC DIELECTRIC	47-10,000pf	150	Vitramon Glenco	VK20, VK30 CK05, CK06	Types CK05 and CK06 per MIL-C-11015. Design tolerance of ±40% recommended.	X988504
CERAMIC DIELECTRIC -- FEEDTHRU	100-1,200pf	350	Maida	287	Stud-mounted type.	X988525
GLASS DIELECTRIC	1-1,200pf	300-500	Corning	CYFM	Axial lead style with positive temperature coefficient. (Similar to MIL-C-11272 types.)	X988503
PAPER-MYLAR DIELECTRIC -- METALLIZED	.01-12µf	200-600	Sprague	118P	Similar to paper types. For low-noise operation, limit operating voltage to 70% of rating or below. Virtually noiseless below 50% of rated voltage.	X988501
MICA DIELECTRIC -- DIPPED	5-5,100pf	300	El Menco	HR-SCIM & HRDM	Radial-lead type. Preferred to glass.	X988502
TANTALUM DIELECTRIC -- SOLID	.0047-330µf	6-50	Sprague Kemet	150D J	Polarized. Types CS12 and CS13, per MIL-C-26655	X988500

CAPACITOR, FIXED, GLASS (X988503)

CORNING CYFM

HUGHES NUMBER X988503-	CAPACITANCE C (μμf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE W	CASE SIZE L	CASE SIZE T
1 *	1.0	±.25	500	.204	.389	.110
2	2.2					
3	3.3					
4 *	4.7					
5	6.8	± 5				
6	8.2					
7 *	10.0					
8	12.0					
9	15.0					
10 *	22.0					
11	27.0					
12	33.0					
13	39.0					
14 *	47.0					
15	68.0					
16	82.0					
17 *	100.0					
18	150.0					
19 *	220.0		300			
20	300.0					
21	390.0		500	.298	.515	.156
22 *	470.0					
23	680.0		300			
24	820.0					

HUGHES NUMBER X988503-	CAPACITANCE C (μμf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE W	CASE SIZE L	CASE SIZE T
25 *	1000.0	± 5	300	.298	.515	.156
26	1200.0					
27	6.8	±.25	500	.204	.389	.110
28	8.2					
29	10.0					
30	12.0					
31	15.0					
32	22.0					
33	27.0	± 1				
34	33.0					
35	39.0					
36	47.0					
37	68.0					
38	82.0					
39	100.0					
40	150.0					
41	220.0		300			
42	300.0					
43	390.0		500	.298	.515	.156
44	470.0					
45	680.0					
46	820.0					
47	1000.0					
48	1200.0					

* Preferred values

CAPACITORS, FIXED, METALLIZED, PAPER-MYLAR (X988501)

SPRAGUE 118P

HUGHES NUMBER X988501-	CAPACITANCE C (μf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[1] 1 *	0.01	±10	200	.190	.780
2	0.015			.210	.780
3	0.022			.250	.780
4	0.033			.250	.780
5 *	0.047			.325	.905
6	0.068			.325	.905
7 *	0.1			.325	.905
8	0.15			.325	1.155
9 *	0.22			.415	.905
10	0.33			.415	1.155
11 *	0.47			.515	1.155
12	0.68			.515	1.155
13 *	1.0			.580	1.155
14	1.5			.580	1.655
15 *	2.0			.685	1.655
16	3.0			.685	1.905
17 *	4.0			.765	1.905
18	8.0			1.015	1.905
19	10.0			1.015	2.405
20 *	12.0			1.015	2.655
21 *	0.01		400	.325	.905
22	0.015			.325	.905
23	0.022			.325	.905
24	0.033			.325	1.155
25 *	0.047			.415	1.155
26	0.068			.415	1.155
27 *	0.1			.515	1.155
[1] 28	0.15			.515	1.155

HUGHES NUMBER X988501-	CAPACITANCE C (μf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[1] 29 *	0.22	±10	400	.580	1.405
30	0.33			.580	1.655
31 *	0.47			.685	1.655
32	0.68			.685	1.905
33 *	1.0			.765	1.905
34	1.5			1.015	1.905
35 *	2.0			1.015	1.905
36	3.0			1.015	2.655
37	0.001		600	.250	.780
38	0.0022			.250	.780
39	0.0047			.325	.905
40	0.0068			.325	.905
41 *	0.01			.325	.905
42	0.015			.325	.905
43 *	0.022			.325	1.155
44	0.033			.325	1.155
45 *	0.047			.415	1.155
46	0.068			.415	1.155
47 *	0.1			.515	1.155
48	0.15			.580	1.155
49 *	0.22			.580	1.405
50	0.33			.580	1.655
51 *	0.47			.685	1.655
52	0.68			.685	1.905
53 *	1.0			1.015	1.905
54	1.5			1.015	1.905
55 *	2.0			1.015	2.155
[1] 56	2.5			1.015	2.655

CAPACITORS, FIXED, METALLIZED, PAPER-MYLAR (X988501) -- Continued

HUGHES NUMBER X988501-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[1] 57 *	0.01	±10	200	.222	.842
58	0.015			.242	.842
59	0.022			.282	.842
60	0.033			.282	.842
61 *	0.047			.357	.967
62	0.068			.357	.967
63 *	0.1			.357	.967
64	0.15			.357	1.217
65 *	0.22			.447	.967
66	0.33			.447	1.217
67 *	0.47			.547	1.217
68	0.68			.547	1.217
69 *	1.0			.612	1.217
70	1.5			.612	1.717
71 *	2.0			.717	1.717
72	3.0			.717	1.967
73 *	4.0			.797	1.967
74	8.0			1.047	1.967
75	10.0			1.047	2.467
76 *	12.0			1.047	2.717
77 *	0.01		400	.357	.967
78	0.015			.357	.967
79	0.022			.357	.967
80	0.033			.357	1.217
81 *	0.047			.447	1.217
82	0.068			.447	1.217
83 *	0.1			.547	1.217
[1] 84	0.15			.547	1.217

HUGHES NUMBER X988501-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[2] 85 *	0.22	±10	400	.612	1.467
86	0.33			.612	1.717
87 *	0.47			.717	1.717
88	0.68			.717	1.967
89 *	1.0			.797	1.967
90	1.5			1.047	1.967
91 *	2.0			1.047	1.967
92	3.0			1.047	2.717
93	0.001		600	.282	.842
94	0.0022			.282	.842
95	0.0047			.357	.967
96	0.0068			.357	.967
97 *	0.01			.357	.967
98	0.015			.357	.967
99 *	0.022			.357	1.217
100	0.033			.357	1.217
101 *	0.047			.447	1.217
102	0.068			.447	1.217
103 *	0.1			.547	1.217
104	0.15			.612	1.217
105 *	0.22			.612	1.467
106	0.33			.612	1.717
107 *	0.47			.717	1.717
108	0.68			.717	1.967
109 *	1.0			1.047	1.967
110	1.5			1.047	1.967
111 *	2.0			1.047	2.217
[2] 112	2.5			1.047	2.717

[1] X988501-1 through -56, without insulating sleeve.

[2] X988501-57 through -112, with insulating sleeve.

* Preferred values.

CAPACITOR, MICA, DIPPED

HUGHES NUMBER X988502-	CAPACITANCE C (μμf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE W	CASE SIZE L	CASE SIZE T	ELMENCO TYPE NUMBER
1	5	± 5	300	.315	.210	.160	HR-SCDM-10
2 *	10						
3	15						
4 *	22						
5	27						
6	33						
7 *	47						
8	68						
9	82						
10 *	100						
11	150						
12 *	220						
13	270						
14	330			.437	.287	.170	HR-SCDM-15
15 *	470						
16	680						
17	820						
18 *	1000			.733	.375	.215	HRDM-16
19	1300						
20	1500			.750	.520	.250	HRDM-20
21 *	2200						
22	2700						
23	3300						
24	3900						
25 *	5100			.750	.520	.270	
26	68	± 1		.315	.210	.160	HR-SCDM-10
27	82						
28 *	100						
29	150						
30 *	220						

CAPACITOR, MICA, DIPPED -- Continued

HUGHES NUMBER X988502-	CAPACITANCE C (μμf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE W	CASE SIZE L	CASE SIZE T	ELMENCO TYPE NUMBER
31	270	±1	300	.315	.210	.160	HR-SCDM-10
32	330			.437	.287	.170	HR-SCDM-15
33 *	470						
34	680						
35	820						
36 *	1000			.733	.375	.215	HRDM-16
37	1300						
38	1500			.750	.520	.250	HRDM-20
39 *	2200						
40	2700						
41	3300						
42	3900						
43 *	5100			.750	.520	.270	HRDM-20

* Preferred values.

CAPACITOR, FIXED, SOLID ELECTROLYTE, TANTALUM

SPRAGUE 150 D; KEMET TYPE J

HUGHES NUMBER X988500-	CAPACITANCE C (μf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[1] 1	0.33	±20	50	.130	.410
2	0.47			.130	.410
3	0.68			.130	.410
4 *	1.0			.130	.410
5	1.5			.180	.600
6 *	2.2			.180	.600
7	3.3			.180	.600
8 *	4.7			.180	.600
9	6.8			.284	.810
10 *	10.0			.284	.810
11	15.0			.284	.810
12 *	22.0			.346	.920
13	0.0047		35	.130	.410
14	0.01			.130	.410
15	0.022			.130	.410
16	0.047			.130	.410
17	0.1			.130	.410
18	0.22			.130	.410
19	6.8			.180	.600
20 *	10.0			.284	.810
21	15.0			.284	.810
22 *	22.0			.284	.810
23	33.0			.346	.920
24 *	47.0		20	.346	.920
25	1.5			.130	.410
26 *	2.2			.130	.410
27 *	10.0			.180	.600
[1] 28	15.0			.180	.600

HUGHES NUMBER X988500-	CAPACITANCE C (μf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[1] 29	33.0	±20	20	.284	.810
30 *	47.0			.284	.810
31	68.0			.346	.920
32 *	100.0			.346	.920
33	3.3		15	.130	.410
34 *	22.0			.180	.600
35	68.0			.284	.810
36	150.0			.346	.920
37 *	4.7		10	.130	.410
38	33.0			.180	.600
39 *	100.0			.284	.810
40 *	220.0			.346	.920
41	6.8		6	.130	.410
42 *	47.0			.180	.600
43	150.0			.284	.810
44 *	330.0			.346	.920
45	0.33	±10	50	.130	.410
46	0.47			.130	.410
47	0.68			.130	.410
48	1.0			.130	.410
49	1.5			.180	.600
50	2.2			.180	.600
51	3.3			.180	.600
52	4.7			.180	.600
53	6.8			.284	.810
54	10.0			.284	.810
55	15.0			.284	.810
[1] 56	22.0			.346	.920

CAPACITOR, FIXED, SOLID ELECTROLYTE, TANTALUM -- Continued

HUGHES NUMBER X988500-	CAPACITANCE C (μf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[1] 57	0.0047	±10	35	.130	.410
58	0.01			.130	.410
59	0.022			.130	.410
60	0.047			.130	.410
61	0.1			.130	.410
62	0.22			.130	.410
63	6.8			.180	.600
64	10.0			.284	.810
65	15.0			.284	.810
66	22.0			.284	.810
67	33.0			.346	.920
68	47.0			.346	.920
69	1.5		20	.130	.410
70	2.2			.130	.410
71	10.0			.180	.600
72	15.0			.180	.600
73	33.0			.284	.810
74	47.0			.284	.810
75	68.0			.346	.920
76	100.0			.346	.920
77	3.3		15	.130	.410
78	22.0			.180	.600
79	68.0			.284	.810
80	150.0			.346	.920
81	4.7		10	.130	.410
82	33.0			.180	.600
83	100.0			.284	.810
84	220.0			.346	.920
85	6.8		6	.130	.410
[1] 86	47.0			.180	.600

HUGHES NUMBER X988500-	CAPACITANCE C (μf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[1] 87	150.0	±10	6	.284	.810
[1] 88	330.0			.346	.920
[2] 89	0.33	±20	50	.150	.440
90	0.47			.150	.440
91	0.68			.150	.440
92 *	1.0			.150	.440
93	1.5			.200	.630
94 *	2.2			.200	.630
95	3.3			.200	.630
96 *	4.7			.200	.630
97	6.8			.304	.840
98 *	10.0			.304	.840
99	15.0			.304	.840
100 *	22.0			.366	.950
101	0.0047		35	.150	.440
102	0.01			.150	.440
103	0.022			.150	.440
104	0.047			.150	.440
105	0.1			.150	.440
106	0.22			.150	.440
107	6.8			.200	.630
108 *	10.0			.304	.840
109	15.0			.304	.840
110 *	22.0			.304	.840
111	33.0			.366	.950
112 *	47.0			.366	.950
113	1.5		20	.150	.440
114 *	2.2			.150	.440
115 *	10.0			.200	.630
[2] 116	15.0			.200	.6[illegible]

CAPACITOR, FIXED, SOLID ELECTROLYTE, TANTALUM -- Continued

HUGHES NUMBER X988500-	CAPACITANCE C (uf)	CAPACITANCE TOLERANCE (%)	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[2] 117	33.0	±20	20	.304	.840
118 *	47.0			.304	.840
119	68.0			.366	.950
120 *	100.0			.366	.950
121	3.3		15	.150	.440
122 *	22.0			.200	.630
123	68.0			.304	.840
124	150.0			.366	.950
125 *	4.7		10	.150	.440
126	33.0			.200	.630
127 *	100.0			.304	.840
128 *	220.0			.366	.950
129	6.8		6	.150	.440
130 *	47.0			.200	.630
131	150.0			.304	.840
132	330.0			.366	.950
133	0.33	±10	50	.150	.440
134	0.47			.150	.440
135	0.68			.150	.440
136	1.0			.150	.440
137	1.5			.200	.630
138	2.2			.200	.630
139	3.3			.200	.630
140	4.7			.200	.630
141	6.8			.304	.840
142	10.0			.304	.840
143	15.0			.304	.840
144	22.0			.366	.950
145	0.0047		35	.150	.440
[2] 146	0.01			.150	.440

HUGHES NUMBER X988500-	CAPACITANCE C (uf)	CAPACITANCE TOLERANCE	D-C WORKING VOLTAGE (VOLTS)	CASE SIZE D	CASE SIZE L
[2] 147	0.022		35	.150	.440
148	0.047			.150	.440
149	0.1			.150	.440
150	0.22			.150	.440
151	6.8			.200	.630
152	10.0			.304	.840
153	15.0			.304	.840
154	22.0			.304	.840
155	33.0			.366	.950
156	47.0			.366	.950
157	1.5		20	.150	.440
158	2.2			.150	.440
159	10.0			.200	.630
160	15.0			.200	.630
161	33.0			.304	.840
162	47.0			.304	.840
163	68.0			.366	.950
164	100.0			.366	.950
165	3.3		15	.150	.440
166	22.0			.200	.630
167	68.0			.304	.840
168	150.0			.366	.950
169	4.7			.150	.440
170	33.0			.200	.630
171	100.0			.304	.840
172	220.0			.366	.950
173	6.8			.150	.440
174	47.0			.200	.630
175	150.0			.304	.840
[2] 176	330.0			.366	.950

[1] X988500-1 through -88, without insulating sleeve.

[2] X988500-89 through -176 with insulating sleeve.

* Preferred values.

CAPACITORS, VARIABLE

TYPE	CAPACITANCE RANGE	MAXIMUM WORKING VOLTAGE (DC)	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	REMARKS	HUGHES DOCUMENT NUMBER
CERAMIC DIELECTRIC	1.5 to 7 pf - 7 to 45 pf	500	Erie	TS	Type CV11, per MIL-C-81.	X988520
GLASS DIELECTRIC	1 to 14 pf - 1 to 90 pf	500	JFD	MC	Piston type.	X988521

CONNECTORS

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	REMARKS	HUGHES NUMBER
PLUG, ELECTRICAL -- MINIATURE POWER	Deutsch	DS	Round, quick-disconnect, removable crimp contacts, environmentally sealed.	X988203
PLUG, ELECTRICAL -- MINIATURE POWER	Microdot	43	Round quick-disconnect, high contact density, environmentally sealed	X988205
PLUG, ELECTRICAL -- MINIATURE POWER	Bendix Cannon	PTS PTS	Straight, round quick-disconnect, environmentally sealed.	X988207
RECEPTACLE, ELECTRICAL -- MINIATURE POWER	Deutsch	DS	Round quick-disconnect, removable crimp contacts, environmentally sealed.	X988204
RECEPTACLE, ELECTRICAL -- MINIATURE POWER	Microdot	43	Round quick-disconnect, high contac density, environmentally sealed.	X988206
RECEPTACLE, ELECTRICAL -- MINIATURE POWER	Bendix Cannon	PTS PTS	Single-hole mounting, round quick-disconnect, environmentally sealed.	X988208
RECEPTACLE, ELECTRICAL -- MINIATURE POWER	Bendix Cannon	PTS PTS	Hermetically sealed, round quick-disconnect, environmentally sealed.	X988209
RECEPTACLE, ELECTRICAL -- MINIATURE POWER	Bendix Cannon	PTS PTS	Flange mounting, square, quick-disconnect, environmentally sealed	X988210
PLUG OR RECEPTACLE, ELECTRICAL -- MINIATURE POWER	Continental	SM	Rectangular screw locking, not environmentally sealed. Use only for internal connections	X988202
PLUG OR RECEPTACLE, ELECTRICAL -- PRINTED CIRCUIT	Cannon	DPZ	Not environmentally sealed. Use only for internal connections.	X988200
PLUG OR RECEPTACLE, ELECTRICAL -- RACK AND PANEL	Cannon	DSM	Removable crimp contacts, not environmentally sealed. Use only for internal connections.	X988201

HARDWARE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	MATERIAL	FINISH	HUGHES NUMBER
INSERT, SCREW THREAD -- SELF-LOCKING	Newton Insert	NAS 1395	CRES A286	Molybdenum disulfide	X988000
INSERT, SCREW THREAD -- NON-LOCKING	Newton Insert	NAS 1395	CRES A286	Passivated	X988001
NUT, PLAIN, HEXAGON	Brilos Mfg.	NAS 671	CRES 18-8	Passivated	X988010
NUT, PRESS	Rosan Inc.	FPN	CRES A286	Molybdenum disulfide	X988011
NUT, SELF-LOCKING, HEXAGON	Kaynar Mfg. Elastic Stop Nut	NAS 1291	CRES A286	Molybdenum disulfide	X988012
NUT, SELF-LOCKING, PLATE -- FLOATING ANCHOR	Kaynar Mfg. Elastic Stop Nut	NAS 1068	CRES A286	Molybdenum disulfide	X988013
NUT, SELF-LOCKING, PLATE -- NON-FLOATING ANCHOR	Kaynar Mfg. Elastic Stop Nut	NAS 697	CRES A286	Molybdenum disulfide	X988014
PIN, COTTER	Corland	MS 24665	CRES 18-8	Passivated	X988055
PIN, LOCK	Standard Pressed Steel	MS 9105	CRES 18-8	Passivated	X988056
PIN, SPRING	CEM	Type HDP	CRES 18-8	Passivated	X988057
RIVET, BLIND -- PROTRUDING HEAD	Olympic Screw & Rivet	RV-840	CRES A286		X988069
RIVET, BLIND -- COUNTERSUNK HEAD	Olympic Screw & Rivet	RV-841	CRES A286		X988070
RIVET, SOLID -- COUNTERSUNK HEAD	Pastushin Industries	NAS 1199	CRES A286		X988071

HARDWARE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	MATERIAL	FINISH	HUGHES NUMBER
RIVET, SOLID -- UNIVERSAL HEAD	Pastushin Industries	NAS 1198	CRES A286		X988072
SCREW, MACHINE -- FLAT HEAD	Air Industries	NAS 1620 NAS 1628	CRES A286	Passivated	X988025
SCREW, MACHINE -- PAN HEAD	Air Industries	NAS 1630 NAS 1634	CRES A286	Passivated	X988026
SCREW, MACHINE -- FLAT HEAD	Air Industries	NAS 1102	CRES A286	Passivated	X988027
SCREW, MACHINE -- FLAT FILLISTER HEAD	Air Industries	NAS 1101	CRES A286	Passivated	X988028
SETSCREW	Standard Pressed Steel	MS 51021	CRES 18-8	Passivated	X988029
WASHER, FLAT	Seastrom Mfg.	AN 960	CRES 18-8	Passivated	X988040
WASHER, LOCK -- SPLIT	Seastrom Mfg.	MS 35337	CRES 18-8	Passivated	X988041

RESISTORS, FIXED

TYPE	RESISTANCE RANGE	POWER RATING (WATTS)	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	REMARKS	HUGHES DOCUMENT NUMBER
COMPOSITION	47 ohms - 10 megohms	1/10	Allen-Bradley	TR	Type "CB" preferred for values over 1.0 megohm.	X988600
COMPOSITION	10 ohms - 22 megohms	1/4	Allen-Bradley	CB	Preferred for general usage. Type RC07, per MIL-R-11.	X988601
COMPOSITION	10 ohms - 22 megohms	1/2	Allen-Bradley	EB	Type RC20, per MIL-R-11	X988602
COMPOSITION	2.7 ohms - 22 megohms	1	Allen-Bradley	GB	Type RC32, per MIL-R-11	X988603
COMPOSITION	10 ohms - 22 megohms	2	Allen-Bradley	HB	Type RC42, per MIL-R-11	X988604
FILM -- DEPOSITED CARBON	25 ohms - 50 kilohms	1/8	Texas Instruments	CO 1/8	Sealed glass type; temperature coefficient is approximately 300 ppm/° C.	X988610
FILM -- DEPOSITED CARBON	50 kilohms - 500 kilohms	1/8	Mepco	R-85	Hermetically sealed high-reliability ceramic type; temperature coefficient is approximately 300 ppm/° C.	X988612
FILM -- DEPOSITED CARBON	25 ohms - 100 kilohms	1/4	Texas Instruments	CG 1/4	Sealed glass type; temperature coefficient is approximately 300 ppm/° C.	X988611
FILM -- DEPOSITED CARBON	100 kilohms - 1 megohm	1/4	Mepco	R-170N	Hermetically sealed high-reliability ceramic type; temperature coefficient is approximately 300 ppm/° C.	X988613
FILM -- DEPOSITED CARBON	10 ohms - 2 megohms	1/2	Mepco	R-173 AN	Hermetically sealed high-reliability ceramic type; temperature coefficient is approximately 300 ppm/° C.	X988614

RESISTORS, FIXED

TYPE	RESISTANCE RANGE	POWER RATING (WATTS)	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	REMARKS	HUGHES DOCUMENT NUMBER
FILM -- METAL	10 ohms - 100 kilohms	1/8	IRC	XLT-A	Sealed glass type. ±1.0% tolerance. Temperature coefficient is approximately ±50 ppm/° C.	X988623
FILM -- METAL	4 kilohms - 1 megohm	1/4	Allen-Bradley	CAH	±0.1% tolerance and temperature coefficient of ±25 ppm/° C available.	X988620
FILM -- METAL	2 kilohms - 1 megohm	1/2	Allen-Bradley	EAH	±0.1% tolerance and temperature coefficient of ±25 ppm/° C available.	X988621
FILM -- METAL	1 kilohm - 2 megohms	1	Allen-Bradley	GAH	±0.1% tolerance and temperature coefficient of ±25 ppm/° C available.	X988622
WIREWOUND -- POWER	0.1 ohm- 1.6 kilohms	2	Dale	ARS-2	1% tolerance. Larger power rating and case sizes preferred for higher values of resistance.	X988630
	0.1 ohm - 4 kilohms		Sage	SB2W		
WIREWOUND -- POWER	0.1 ohm - 5 kilohms	5	Dale	ARS-5	1% tolerance.	X988631
	0.1 ohm - 12 kilohms		Sage	SS5W		
WIREWOUND -- POWER	1 ohm - 14 kilohms	10	Dale	ARS-10	1% tolerance.	X988632
	0.1 ohm - 51 kilohms		Sage	SS10W		
WIREWOUND (ACCURATE)	50 ohms - 100 kilohms	1/8	Daven	R9900	Approximate size is 1/4-in. diameter by 11/32-in. long.	X988640

RESISTORS, FIXED, COMPOSITION
ALLEN-BRADLEY, MIL-R-11 TYPE

RESISTANCE (OHMS ±5%)	TYPE TR HUGHES NUMBER X988600-	TYPE CB HUGHES NUMBER X988601-	TYPE EB HUGHES NUMBER X988602-	TYPE GB HUGHES NUMBER X988603-	TYPE HB HUGHES NUMBER X988604-
2.7	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	1	NOT AVAILABLE
3.0				2	
3.3				3	
3.6				4	
3.9				5	
4.3				6	
4.7				7	
5.1				8	
5.6				9	
6.2				10	
6.8				11	
7.5				12	
8.2				13	
9.1				14	
10*	1	1	1	15	1
11	2	2	2	16	2
12	3	3	3	17	3
13	4	4	4	18	4
15*	5	5	5	19	5
16	6	6	6	20	6
18	7	7	7	21	7
20	8	8	8	22	8
22*	9	9	9	23	9
24	10	10	10	24	10
27	11	11	11	25	11
30	12	12	12	26	12
33*	13	13	13	27	13
36	14	14	14	28	14
39	15	15	15	29	15
43	16	16	16	30	16
47*	17	17	17	31	17
51	18	18	18	32	18
56	19	19	19	33	19
62	20	20	20	34	20
68*	21	21	21	35	21
75	22	22	22	36	22
82	23	23	23	37	23
91	24	24	24	38	24

RESISTANCE (OHMS ±5%)	TYPE TR HUGHES NUMBER X988600-	TYPE CB HUGHES NUMBER X988601-	TYPE EB HUGHES NUMBER X988602-	TYPE GB HUGHES NUMBER X988603-	TYPE HB HUGHES NUMBER X988604-
100*	25	25	25	39	25
110	26	26	26	40	26
120	27	27	27	41	27
130	28	28	28	42	28
150*	29	29	29	43	29
160	30	30	30	44	30
180	31	31	31	45	31
200	32	32	32	46	32
220*	33	33	33	47	33
240	34	34	34	48	34
270	35	35	35	49	35
300	36	36	36	50	36
330*	37	37	37	51	37
360	38	38	38	52	38
390	39	39	39	53	39
430	40	40	40	54	40
470*	41	41	41	55	41
510	42	42	42	56	42
560	43	43	43	57	43
620	44	44	44	58	44
680*	45	45	45	59	45
750	46	46	46	60	46
820	47	47	47	61	47
910	48	48	48	62	48
1000*	49	49	49	63	49
1100	50	50	50	64	50
1200	51	51	51	65	51
1300	52	52	52	66	52
1500*	53	53	53	67	53
1600	54	54	54	68	54
1800	55	55	55	69	55
2000	56	56	56	70	56
2200*	57	57	57	71	57
2400	58	58	58	72	58
2700	59	59	59	73	59
3000	60	60	60	74	60
3300*	61	61	61	75	61
3600	62	62	62	76	62

*PREFERRED VALUES FOR STANDARDIZATION PURPOSES

RESISTORS, FIXED, COMPOSITION
ALLEN-BRADLEY, MIL R-11 TYPE

RESISTANCE (OHMS ±5%)	TYPE TR HUGHES NUMBER X988600-	TYPE CB HUGHES NUMBER X988601-	TYPE EB HUGHES NUMBER X988602-	TYPE GB HUGHES NUMBER X988603-	TYPE HB HUGHES NUMBER X988604-
3900	63	63	63	77	63
4300	64	64	64	78	64
4700*	65	65	65	79	65
5100	66	66	66	80	66
5600	67	67	67	81	67
6200	68	68	68	82	68
6800*	69	69	69	83	69
7500	70	70	70	84	70
8200	71	71	71	85	71
9100	72	72	72	86	72
10K	73	73	73	87	73
11K	74	74	74	88	74
12K	75	75	75	89	75
13K	76	76	76	90	76
15K*	77	77	77	91	77
16K	78	78	78	92	78
18K	79	79	79	93	79
20K	80	80	80	94	80
22K*	81	81	81	95	81
24K	82	82	82	96	82
27K	83	83	83	97	83
30K	84	84	84	98	84
33K*	85	85	85	99	85
36K	86	86	86	100	86
39K	87	87	87	101	87
43K	88	88	88	102	88
47K*	89	89	89	103	89
51K	90	90	90	104	90
56K	91	91	91	105	91
62K	92	92	92	106	92
68K*	93	93	93	107	93
75K	94	94	94	108	94
82K	95	95	95	109	95
91K	96	96	96	110	96
100K*	97	97	97	111	97
110K	98	98	98	112	98
120K	99	99	99	113	99
130K	100	100	100	114	100

RESISTANCE (OHMS ±5%)	TYPE TR HUGHES NUMBER X988600-	TYPE CB HUGHES NUMBER X988601-	TYPE EB HUGHES NUMBER X988602-	TYPE GB HUGHES NUMBER X988603-	TYPE HB HUGHES NUMBER X988604-
150K*	101	101	101	115	101
160K	102	102	102	116	102
180K	103	103	103	117	103
200K	104	104	104	118	104
220K*	105	105	105	119	105
240K	106	106	106	120	106
270K	107	107	107	121	107
300K	108	108	108	122	108
330K*	109	109	109	123	109
360K	110	110	110	124	110
390K	111	111	111	125	111
430K	112	112	112	126	112
470K*	113	113	113	127	113
510K	114	114	114	128	114
560K	115	115	115	129	115
620K	116	116	116	130	116
680K*	117	117	117	131	117
750K	118	118	118	132	118
820K	119	119	119	133	119
910K	120	120	120	134	120
1.0M*	121	121	121	135	121
1.1M	122	122	122	136	122
1.2M	123	123	123	137	123
1.3M	124	124	124	138	124
1.5M*	125	125	125	139	125
1.6M	126	126	126	140	126
1.8M	127	127	127	141	127
2.0M	128	128	128	142	128
2.2M*	129	129	129	143	129
2.4M	130	130	130	144	130
2.7M	131	131	131	145	131
3.0M	132	132	132	146	132
3.3M*	133	133	133	147	133
3.6M	134	134	134	148	134
3.9M	135	135	135	149	135
4.3M	136	136	136	150	136
4.7M*	137	137	137	151	137
5.1M	138	138	138	152	138

*PREFERRED VALUES FOR STANDARDIZATION PURPOSES

RESISTORS, FIXED, COMPOSITION
ALLEN-BRADLEY, MIL-R-11 TYPE

RESISTANCE (OHMS ±5%)	TYPE TR HUGHES NUMBER X988600-	TYPE CB HUGHES NUMBER X988601-	TYPE EB HUGHES NUMBER X988602-	TYPE GB HUGHES NUMBER X988603-	TYPE HB HUGHES NUMBER X988604-
5.6M	139	139	139	153	139
6.2M	140	140	140	154	140
6.8M*	141	141	141	155	141
7.5M	142	142	142	156	142
8.2M	143	143	143	157	143
9.1M	144	144	144	158	144
10M*	145	145	145	159	145
11M	146	146	146	160	146
12M	147	147	147	161	147
13M	148	148	148	162	148
15M*	149	149	149	163	149
16M	150	150	150	164	150
18M	151	151	151	165	151
20M	152	152	152	166	152
22M*	153	153	153	167	153

*PREFERRED VALUES FOR STANDARDIZATION PURPOSES

CASE SIZES (MAX DIMENSIONS)

TYPE	DIA	LENGTH
TR	.075	.160
CB	.098	.265
EB	.148	.406
GB	.233	.593
HB	.320	.719

RESISTORS, FIXED, COMPOSITION
ALLEN-BRADLEY, MIL-R-11 TYPE

RESISTANCE (OHMS ±5%)	TYPE TR HUGHES NUMBER X988600-	TYPE CB HUGHES NUMBER X988601-	TYPE EB HUGHES NUMBER X988602-	TYPE GB HUGHES NUMBER X988603-	TYPE HB HUGHES NUMBER X988604-
5.6M	139	139	139	153	139
6.2M	140	140	140	154	140
6.8M*	141	141	141	155	141
7.5M	142	142	142	156	142
8.2M	143	143	143	157	143
9.1M	144	144	144	158	144
10M*	145	145	145	159	145
11M	146	146	146	160	146
12M	147	147	147	161	147
13M	148	148	148	162	148
15M*	149	149	149	163	149
16M	150	150	150	164	150
18M	151	151	151	165	151
20M	152	152	152	166	152
22M*	153	153	153	167	153

*PREFERRED VALUES FOR STANDARDIZATION PURPOSES

CASE SIZES (MAX DIMENSIONS)

TYPE	DIA	LENGTH
TR	.075	.160
CB	.098	.265
EB	.148	.406
GB	.233	.593
HB	.320	.719

RESISTOR, FIXED, FILM (DEPOSITED-CARBON TYPE)

RESISTANCE (OHMS ±1%)	TEXAS INSTRUMENTS CG-1/8 HUGHES NUMBER X988610-	TEXAS INSTRUMENTS CG-1/4 HUGHES NUMBER X988611-	MEPCO R-85 HUGHES NUMBER X988612-	MEPCO R-170N HUGHES NUMBER X988613-	MEPCO R-173AN HUGHES NUMBER X988614-
10.0	1	1	1	1	1
11.0	2	2	2	2	2
12.4	3	3	3	3	3
13.7	4	4	4	4	4
15.0	5	5	5	5	5
16.5	6	6	6	6	6
18.2	7	7	7	7	7
20.0	8	8	8	8	8
22.1	9	9	9	9	9
24.3	10	10	10	10	10
26.7	11	11	11	11	11
29.4	12	12	12	12	12
32.4	13	13	13	13	13
35.7	14	14	14	14	14
39.2	15	15	15	15	15
43.2	16	16	16	16	16
47.5	17	17	17	17	17
52.3	18	18	18	18	18
57.6	19	19	19	19	19
63.4	20	20	20	20	20
69.8	21	21	21	21	21
76.8	22	22	22	22	22
84.5	23	23	23	23	23
93.1	24	24	24	24	24
100	25	25	25	25	25
110	26	26	26	26	26
124	27	27	27	27	27
137	28	28	28	28	28
150	29	29	29	29	29
165	30	30	30	30	30
182	31	31	31	31	31
200	32	32	32	32	32
221	33	33	33	33	33
243	34	34	34	34	34
267	35	35	35	35	35
294	36	36	36	36	36
324	37	37	37	37	37
357	38	38	38	38	38
392	39	39	39	39	39

RESISTANCE (OHMS ±1%)	TEXAS INSTRUMENTS CG-1/8 HUGHES NUMBER X988610-	TEXAS INSTRUMENTS CG-1/4 HUGHES NUMBER X988611-	MEPCO R-85 HUGHES NUMBER X988612-	MEPCO R-170N HUGHES NUMBER X988613-	MEPCO R-173AN HUGHES NUMBER X988614-
432	40	40	40	40	40
475	41	41	41	41	41
523	42	42	42	42	42
576	43	43	43	43	43
634	44	44	44	44	44
698	45	45	45	45	45
768	46	46	46	46	46
845	47	47	47	47	47
931	48	48	48	48	48
1000	49	49	49	49	49
1100	50	50	50	50	50
1240	51	51	51	51	51
1370	52	52	52	52	52
1500	53	53	53	53	53
1600	54	54	54	54	54
1820	55	55	55	55	55
2000	56	56	56	56	56
2210	57	57	57	57	57
2430	58	58	58	58	58
2670	59	59	59	59	59
2940	60	60	60	60	60
3240	61	61	61	61	61
3570	62	62	62	62	62
3920	63	63	63	63	63
4320	64	64	64	64	64
4750	65	65	65	65	65
5230	66	66	66	66	66
5760	67	67	67	67	67
6340	68	68	68	68	68
6980	69	69	69	69	69
7680	70	70	70	70	70
8450	71	71	71	71	71
9310	72	72	72	72	72
10.0K	73	73	73	73	73
11.0K	74	74	74	74	74
12.4K	75	75	75	75	75
13.7K	76	76	76	76	76
15.0K	77	77	77	77	77
16.5K	78	78	78	78	78

RESISTOR, FIXED, FILM (DEPOSITED-CARBON TYPE)

RESISTANCE (OHMS ±1%)	TEXAS INSTRUMENTS CG-1/8 HUGHES NUMBER X988610-	TEXAS INSTRUMENTS CG-1/4 HUGHES NUMBER X988611-	MEPCO R-85 HUGHES NUMBER X988612-	MEPCO R-170N HUGHES NUMBER X988613-	MEPCO R-173AN HUGHES NUMBER X988614-
18.2K	79	79	79	79	79
20.0K	80	80	80	80	80
22.1K	81	81	81	81	81
24.3K	82	82	82	82	82
26.7K	83	83	83	83	83
29.4K	84	84	84	84	84
32.4K	85	85	85	85	85
35.7K	86	86	86	86	86
39.2K	87	87	87	87	87
43.2K	88	88	88	88	88
47.5K	89	89	89	89	89
52.3K	90	90	90	90	90
57.6K	91	91	91	91	91
63.4K	92	92	92	92	92
69.8K	93	93	93	93	93
76.8K	94	94	94	94	94
84.5K	95	95	95	95	95
93.1K	96	96	96	96	96
100K	97	97	97	97	97
110K	98	98	98	98	98
124K	99	99	99	99	99
137K	100	100	100	100	100
150K	101	101	101	101	101
165K	102	102	102	102	102
182K	103	103	103	103	103

RESISTANCE (OHMS ±1%)	TEXAS INSTRUMENTS CG-1/8 HUGHES NUMBER X988610-	TEXAS INSTRUMENTS CG-1/4 HUGHES NUMBER X988611-	MEPCO R-85 HUGHES NUMBER X988612-	MEPCO R-170N HUGHES NUMBER X988613-	MEPCO R-173AN HUGHES NUMBER X988614-
200K	104	104	104	104	104
221K	105	105	105	105	105
243K	106	106	106	106	106
267K	107	107	107	107	107
294K	108	108	108	108	108
324K	109	109	109	109	109
357K	110	110	110	110	110
392K	111	111	111	111	111
432K	112	112	112	112	112
475K	113	113	113	113	113
523K	114		114		114
576K	115		115		115
634K	116		116		116
698K	117		117		117
768K					118
845K					119
931K					120
1.00M					121
1.10M					
1.24M					
1.37M					
1.50M					
1.65M					
1.82M					
2.00M					

RESISTANCE RANGES AND NOMINAL CASE DIMENSIONS

MANUFACTURER	TYPE	RANGE (OHMS)	DIMENSIONS L	DIMENSIONS D	WATTS
TEXAS INSTRUMENTS	CG-1/8	24.9 to 50K	.240	.125	1/8
TEXAS INSTRUMENTS	CG-1/4	24.9 to 100K	.360	.140	1/4
MEPCO	R-85	10 to 500K	.281	.156	1/8
MEPCO	R-170N	10 to 1 Meg	.434	.155	1/4
MEPCO	R-173AN	10 to 2 Meg	.640	.244	1/2

RESISTORS, FIXED, FILM (PRECISION)
ALLEN BRADLEY

RESISTANCE (OHMS ±1%)	TYPE CAH[1] HUGHES NUMBER X988620--	TYPE EAH[2] HUGHES NUMBER X988621-	TYPE GAH[3] HUGHES NUMBER X988622-
1000	NOT AVAILABLE	NOT AVAILABLE	1
1100			2
1210			3
1330			4
1460			5
1610			6
1780			7
2000		1	8
2210		2	9
2430		3	10
2670		4	11
2910		5	12
3210		6	13
3570		7	14
3920		8	15
4320	1	9	16
4750	2	10	17
5230	3	11	18
5760	4	12	19
6340	5	13	20
6980	6	14	21
7680	7	15	22
8450	8	16	23
9310	9	17	24
10.0K	10	18	25
11.0K	11	19	26
12.4K	12	20	27
13.7K	13	21	28
15.0K	14	22	29
16.5K	15	23	30
18.2K	16	24	31
20.0K	17	25	32
22.1K	18	26	33
24.3K	19	27	34
26.7K	20	28	35
29.4K	21	29	36
32.4K	22	30	37
35.7K	23	31	38

RESISTANCE (OHMS ±1%)	TYPE CAH[1] HUGHES NUMBER X988620-	TYPE EAH[2] HUGHES NUMBER X988621-	TYPE GAH[3] HUGHES NUMBER X988622-
39.2K	24	32	39
43.2K	25	33	40
47.5K	26	34	41
52.3K	27	35	42
57.6K	28	36	43
63.4K	29	37	44
69.8K	30	38	45
76.8K	31	39	46
84.5K	32	40	47
93.1K	33	41	48
100K	34	42	49
110K	35	43	50
124K	36	44	51
137K	37	45	52
150K	38	46	53
165K	39	47	54
182K	40	48	55
200K	41	49	56
221K	42	50	57
243K	43	51	58
267K	44	52	59
294K	45	53	60
324K	46	54	61
357K	47	55	62
392K	48	56	63
432K	49	57	64
475K	50	58	65
523K	51	59	66
576K	52	60	67
634K	53	61	68
698K	54	62	69
768K	55	63	70
845K	56	64	71
931K	57	65	72
1.00M	58	66	73
1.10M			74
1.24M			75
1.37M			76

RESISTORS, FIXED, FILM (PRECISION)
ALLEN BRADLEY

RESISTANCE (OHMS ±1%)			TYPE GAH (3) HUGHES NUMBER X988622-
1.50M			77
1.65M			78
1.82M			79
2.00M			80

CASE DIMENSIONS, WATTAGE RATINGS, AND TEMPERATURE COEFFICIENTS

TYPE	CASE SIZE L	CASE SIZE D	POWER RATING (WATTS) AT 100° C	TEMPERATURE COEFFICIENT (PPM/° C)
(1) CAH	.560	.033	0.25	±25
(2) EAH	.830	.033	0.50	±25
(3) GAH	.975	.033	1.00	±25

RESISTORS, FIXED, FILM (PRECISION)

RESISTANCE (OHMS ±1%)	HUGHES NUMBER X988623-
10.0	1
11.0	2
12.4	3
13.7	4
15.0	5
16.5	6
18.2	7
20.0	8
22.1	9
24.3	10
26.7	11
29.4	12
32.4	13
35.7	14
39.2	15
43.2	16
47.5	17
52.3	18
57.6	19
63.4	20
69.8	21
76.8	22
84.5	23
93.1	24
100	25
110	26
124	27
137	28
150	29
165	30
182	31
200	32
221	33
243	34

RESISTANCE (OHMS ±1%)	HUGHES NUMBER X988623-
267	35
294	36
324	37
357	38
392	39
432	40
475	41
523	42
576	43
634	44
698	45
768	46
845	47
931	48
1000	49
1100	50
1240	51
1370	52
1500	53
1650	54
1820	55
2000	56
2210	57
2430	58
2670	59
2940	60
3240	61
3570	62
3920	63
4320	64
4750	65
5230	66
5760	67
6340	68

RESISTANCE (OHMS ±1%)	HUGHES NUMBER X988623-
6980	69
7680	70
8450	71
9310	72
10.0K	73
11.0K	74
12.4K	75
13.7K	76
15.0K	77
16.5K	78
18.2K	79
20.0K	80
22.1K	81
24.3K	82
26.7K	83
29.4K	84
32.4K	85
35.7K	86
39.2K	87
43.2K	88
47.5K	89
52.3K	90
57.6K	91
63.4K	92
69.8K	93
76.8K	94
84.5K	95
93.1K	96
100K	97

IRC TYPE XLT-A 1/8 W AT 125° C
L = .281, DIA = .155
TEMPERATURE COEFFICIENT ±25 PPM

RESISTORS, FIXED, WIREWOUND (POWER TYPE)

RESISTANCE (OHMS ±1%)	HUGHES NUMBER X988630--	DALE TYPE ARS-2	SAGE TYPE SB2W	HUGHES NUMBER X988631-	DALE TYPE ARS-5	SAGE TYPE SS5W	HUGHES NUMBER X988632-	DALE TYPE ARS-10	SAGE TYPE SS10W
0.10*	1	1	2	1	3	4	1		6
0.11	2			2			2		
0.12*	3			3			3		
0.13	4			4			4		
0.15*	5			5			5		
0.16	6			6			6		
0.18*	7			7			7		
0.20	8			8			8		
0.22*	9			9			9		
0.24	10			10			10		
0.27*	11			11			11		
0.30	12			11			11		
0.33*	13			13			13		
0.36	14			14			14		
0.39*	15			15			15		
0.43	16			16			16		
0.47*	17			17			17		
0.51	18			18			18		
0.56*	19			19			19		
0.62	20			20			20		
0.68*	21			21			21		
0.75	22			22			22		
0.82*	23			23			23		
0.91	24			24			24		
1.0*	25			25			25	5	
1.1	26			26			26		
1.2*	27			27			27		
1.3	28			28			28		
1.5*	29			29			29		
1.6	30			30			30		
1.8*	31			31			31		
2.0	32			32			32		
2.2*	33			33			33		
2.4	34			34			34		
2.7*	35			35			35		
3.0	36			36			36		
3.3*	37			37			37		
3.6	38			38			38		
3.9*	39			39			39		
4.3	40	1	2	40	3	4	40	5	6

RESISTORS, FIXED, WIREWOUND (POWER TYPE)

RESISTANCE (OHMS ±1%)	HUGHES NUMBER X988630-	DALE TYPE ARS-2	SAGE TYPE SB2W	HUGHES NUMBER X988631-	DALE TYPE ARS-5	SAGE TYPE SS5W	HUGHES NUMBER X988632-	DALE TYPE ARS-10	SAGE TYPE SS10W
4.7*	41	1	2	41	3	4	41	5	6
5.1	42	↑	↑	42	↑	↑	42	↑	↑
5.6*	43			43			43		
6.2	44			44			44		
6.8*	45			45			45		
7.5	46			46			46		
8.2*	47			47			47		
9.1	48			48			48		
10*	49			49			49		
11	50			50			50		
12*	51			51			51		
13	52			52			52		
15*	53			53			53		
16	54			54			54		
18*	55			55			55		
20	56			56			56		
22*	57			57			57		
24	58			58			58		
27*	59			59			59		
30	60			60			60		
33*	61			61			61		
36	62			62			62		
39*	63			63			63		
43	64			64			64		
47*	65			65			65		
51	66			66			66		
56*	67			67			67		
62	68			68			68		
68*	69			69			69		
75	70			70			70		
82*	71			71			71		
91	72			72			72		
100*	73			73			73		
110	74			74			74		
120*	75			75			75		
130	76			76			76		
150*	77			77			77		
160	78			78			78		
180*	79			79			79		
200	80	1	2	80	3	4	80	5	6

RESISTORS, FIXED, WIREWOUND (POWER TYPE)

RESISTANCE (OHMS ±1%)	HUGHES NUMBER X988630-	DALE TYPE ARS-2	SAGE TYPE SB2W	HUGHES NUMBER X988631-	DALE TYPE ARS-5	SAGE TYPE SS5W	HUGHES NUMBER X988632-	DALE TYPE ARS-10	SAGE TYPE SS10W
220*	81	1	2	81	3	4	81	5	6
240	82			82			82		
270*	83			83			83		
300	84			84			84		
330*	85			85			85		
360	86			86			86		
390*	87			87			87		
430	88			88			88		
470*	89			89			89		
510	90			90			90		
560*	91			91			91		
620	92			92			92		
680*	93			93			93		
750	94			94			94		
820*	95			95			95		
910	96			96			96		
1.0K*	97			97			97		
1.1K	98			98			98		
1.2K*	99			99			99		
1.3K	100			100			100		
1.5K*	101			101			101		
1.6K	102	1		102			102		
1.8K*	103			103			103		
2.0K	104			104			104		
2.2K*	105			105			105		
2.4K	106			106			106		
2.7K*	107			107			107		
3.0K	108			108			108		
3.3K*	109			109			109		
3.6K	110			110			110		
3.9K*	111		2	111			111		
4.3K				112			112		
4.7K*				113	3		113		
5.1K				114			114		
5.6K*				115			115		
6.2K				116			116		
6.8K*				117			117		
7.5K				118			118		
8.2K*				119			119		
9.1K				120		4	120	5	6

RESISTORS, FIXED, WIREWOUND (POWER TYPE)

RESISTANCE (OHMS ±1%)	HUGHES NUMBER X988630-	DALE TYPE ARS-2	SAGE TYPE SB2W	HUGHES NUMBER X988631-	DALE TYPE ARS-5	SAGE TYPE SS5W	HUGHES NUMBER X988632-	DALE TYPE ARS-10	SAGE TYPE SS10W
10K*				121		4	121	5	6
11K				122			122		
12K*				123			123		
13K							124	5	
15K*							125		
16K							126		
18K*							127		
20K							128		
22K*							129		
24K							130		
27K*							131		
30K							132		
33K*							133		
36K							134		
39K*							135		
43K							136		
47K*							137		
51K							138		6

RESISTANCE RANGES, CASE DIMENSIONS, AND POWER RATINGS

MANUFACTURER'S TYPE	RESISTANCE RANGE (OHMS)	POWER RATING (WATTS)	CASE DIMENSIONS L (±.062)	CASE DIMENSIONS D (±.031)
1 Dale ARS-2	0.1 to 1.6K	2	.812	.188
2 Sage SB2W	0.1 to 4K	2	.812	.188
3 Dale ARS-5	0.1 to 5K	5	.906	.312
4 Sage SS5W	0.1 to 12K	5	.875	.312
5 Dale ARS-10	1.0 to 14 K	10	1.812	.375
6 Sage SS10W	0.1 to 51K	10	1.812	.375

SEMICONDUCTOR DEVICES, DIODE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	WIV WORKING INVERSE VOLTAGE (Vdc)	I_O AVERAGE RECTIFIED CURRENT (mAdc)	I_F FORWARD CURRENT (mAdc)	t_{rr} REVERSE RECOVERY TIME (SEC $\times 10^{-9}$)	REMARKS	HUGHES NUMBER
GENERAL-PURPOSE RECTIFIER	Rheom		70	200	100	--	Selected 1N483B	X988700-1
GENERAL-PURPOSE RECTIFIER	Rheom		180	200	100	--	Selected 1N485B	X988700-2
GENERAL-PURPOSE RECTIFIER	Rheom		225	200	100	--	Selected 1N486B	X988700-3
GENERAL-PURPOSE RECTIFIER	Pacific Semi-conductor		225	400	400	--	Selected 1N645	X988701-1
GENERAL-PURPOSE RECTIFIER	Pacific Semi-conductor		400	400	400	--	Selected 1N647	X988701-2
GENERAL-PURPOSE RECTIFIER	Pacific Semi-conductor		600	400	400	--	Selected 1N649	X988701-3
SWITCHING DIODE	Fairchild		50	75	10	4	Selected 1N3064	X988702-1
SWITCHING DIODE	Fairchild		175	100	100	50	Selected 1N3070	X988703-1

SEMICONDUCTOR DEVICES, DIODE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	V_Z AT I_Z		TEMPERATURE COEFFICIENT	REMARKS	HUGHES NUMBER
			V_Z (Vdc ±5%)	I_Z (mAdc)			
ZENER DIODE	Hoffman Pacific Semi-conductor		2.6	5	--		X988704-1
ZENER DIODE	Hoffman Pacific Semi-conductor		3.3	5	--		X988704-2
ZENER DIODE	Hoffman Pacific Semi-conductor		.6	5	--		X988704-3
ZENER DIODE	Hoffman Pacific Semi-conductor		.9	5	--		X98870 4
ZENER DIODE	Hoffman Pacific Semi-conductor		4.3	5	--		X988704-5
ZENER DIODE	Hoffman Pacific Semi-conductor		4.7	5	--		X988704-6
ZENER DIODE	Hoffman Pacific Semi-conductor		5.1	5	--		X988704-7
ZENER DIODE	Hoffman Pacific Semi-conductor		5.6	5	--		X988704-8
ZENER DIODE	Hoffman Pacific Semi-conductor		6.2	5	--		X988704-9
ZENER DIODE	Hoffman Pacific Semi-conductor		6.8	5	--		X988704-10

SEMICONDUCTOR DEVICES, DIODE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	V_Z AT I_Z		TEMPERATURE COEFFICIENT	REMARKS	HUGHES NUMBER
			V_Z (Vdc ±5%)	I_Z (mAdc)			
ZENER DIODE	Hoffman Pacific Semi-conductor		7.5	5	—		X988704-11
ZENER DIODE	Hoffman Pacific Semi-conductor		8.2	5	—		X988704-12
ZENER DIODE	Hoffman Pacific Semi-conductor		9.1	5	—		X988704-13
ZENER DIODE	Hoffman Pacific Semi-conductor		10.0	5	—		X988704-14
ZENER DIODE	Hoffman Pacific Semi-conductor		11.0	5	—		X988704-15
ZENER DIODE	Hoffman Pacific Semi-conductor		12.0	5	—		X988704-16
ZENER DIODE	Hoffman Pacific Semi-conductor		13.0	5	—		X988704-17
ZENER DIODE	Hoffman Pacific Semi-conductor		15.0	5	—		X988704-18
ZENER DIODE	Hoffman Pacific Semi-conductor		16.0	5	—		X988704-19
ZENER DIODE	Hoffman Pacific Semi-conductor		18.0	5	—		X988704-20

SEMICONDUCTOR . S, DIODE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	VZ AT		TEMPERATURE COEFFICIENT	REMARKS	HUGHES NUMBER
			VZ (Vdc ±5%)	Z (dc)			
ZENER DIODE	Hoffman Pacific Semi-conductor		20.0	5	--		X988704-21
ZENER DIODE	Hoffman Pacific Semi-conductor		22.0	5	--		X988704-22
ZENER DIODE	Hoffman Pacific Semi-conductor		24.0	5	--		X988704-23

SEMICONDUCTOR DEVICES, DIODE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	V_Z AT I_Z		TEMPERATURE COEFFICIENT (%/° C)	REMARKS	HUGHES NUMBER
			V_Z (Vdc ±5%)	I_Z (mAdc)			
ZENER DIODE	Pacific Semi-conductor		8.25	0.2	--		X988705-1
ZENER DIODE	Pacific Semi-conductor		10.50	0.2	--		X988705-2
ZENER DIODE	Pacific Semi-conductor		12.75	0.2	--		X988705-3
ZENER DIODE	Pacific Semi-conductor		15.75	0.2	--		X988705-4
ZENER DIODE	Pacific Semi-conductor		19.00	0.2	--		X988705-5
ZENER DIODE	Pacific Semi-conductor		23.50	0.2	--		X988705-6
ZENER DIODE	Pacific Semi-conductor		28.50	0.2	--		X988705-7
ZENER DIODE	Motorola		6.2	7.5	.01		X988706-1
ZENER DIODE	Motorola		6.2	7.5	.005		X988706-2
ZENER DIODE	Motorola		6.2	7.5	.001		X988706-3
ZENER DIODE	Motorola		8.4	10	.01		X988707-1
ZENER DIODE	Motorola		8.4	10	.005		X988707-2
ZENER DIODE	Motorola		8.4	10	.001		X988707-3
ZENER DIODE	Motorola		9.0	7.5	.01		X988708-1
ZENER DIODE	Motorola		9.0	7.5	.001		X988708-2
ZENER DIODE	Motorola		11.7	7.5	.01		X988709-1

SEMICONDUCTOR DEVICES, DIODE

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	V_Z AT I_Z		TEMPERATURE COEFFICIENT (%/° C)	REMARKS	HUGHES NUMBER
			V_Z (Vdc ±5%)	I_Z (mAdc)			
ZENER DIODE	Motorola		11.7	7.5	.005		X988709-2
ZENER DIODE	Motorola		11.7	7.5	.001		X988709-3

SEMICONDUCTOR DEVICES -- SILICON CONTROLLED RECTIFIER

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	V_{BO} AT I_O [1] MINIMUM FORWARD BREAKOVER VOLTAGE AT SPECIFIED OUTPUT CURRENT		I_G PEAK GATE CURRENT (Adc)	REMARKS	HUGHES NUMBER X988900-
			V_{BO} (Vdc)	I_O (Adc)			
SILICON CONTROLLED RECTIFIER	General Electric		25	1	0.1	Similar to C5U	1
SILICON CONTROLLED RECTIFIER	General Electric		50	1	0.1	Similar to C5F	2
SILICON CONTROLLED RECTIFIER	General Electric		100	1	0.1	Similar to C5A	3
SILICON CONTROLLED RECTIFIER	General Electric		150	1	0.1	Similar to C5G	4
SILICON CONTROLLED RECTIFIER	General Electric		200	1	0.1	Similar to C5B	5
SILICON CONTROLLED RECTIFIER	General Electric		250	1	0.1	Similar to C5H	6
SILICON CONTROLLED RECTIFIER	General Electric		300	1	0.1	Similar to C5C	7
SILICON CONTROLLED RECTIFIER	General Electric		400	1	0.1	Similar to C5D	8

[1] WITH 1000 OHMS OR LESS CONNECTED FROM GATE TO CATHODE.

TRANSFORMERS

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER			REMARKS	HUGHES NUMBER X988400-
	Hughes Aircraft	872722			Similar to UTC DO-T36	1
	Hughes Aircraft	872723			Similar to UTC DO-T41	2

TRANSISTORS, SILICON

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	BV_{CBO} COLLECTOR-TO-BASE BREAKDOWN VOLTAGE (Vdc)	h_{FE} AT I_C STATIC CURRENT GAIN AT SPECIFIED COLLECTOR CURRENT (h_{FE})	I_C (mAdc)	f_T GAIN-BANDWIDTH PRODUCT (MC, MIN)	REMARKS	HUGHES NUMBER
NPN -- GENERAL PURPOSE	Fairchild		75	40-120 20 min	150 0.1	60	Selected 2N718A (2N1613 in TO-18 case)	X988800-1
PNP -- GENERAL PURPOSE	Fairchild		-50	30-90 25 min	-150 -50	60	Selected 2N722 (2N1132 in TO-18 case)	X988801-1
NPN -- GENERAL PURPOSE	Fairchild		100	100 min 75 min 35 min	150 10 0.1		Selected 2N871 (TO-18 case)	X988802-1
NPN -- GENERAL PURPOSE	Fairchild		75	100 min	150		Selected 2N956 (2N1711 in TO-18 case) $V_{CE(sat)}$ = 1.5Vdc max at I_C = 150 µAdc NF = 8 db max at V_{CE} = Vdc and I_C = 300 µAdc	X988803-1
NPN -- SWITCHING	Fairchild		40	30-120	10		Selected 2N708 Switching time: t_{on} = 40 sec x 10^{-9} max t_{off} = 70 sec x 10^{-9} max	X988804-1
PNP -- SWITCHING	Fairchild		-25	20 min	-10	100	Selected 2N869	X988805-1

TRANSISTORS, SILICON

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	BVCBO COLLECTOR-TO-BASE BREAKDOWN VOLTAGE (Vdc)	h_{FE} AT I_C STATIC CURRENT GAIN AT SPECIFIED COLLECTOR CURRENT		f_T GAIN-BANDWIDTH PRODUCT (MC, MIN)	REMARKS	HUGHES NUMBER
				(h_{FE})	I_C (mAdc)			
NPN -- SWITCHING (LOW SATURATION)	Motorola		40	20-40	10	350	Selected 2N834 $V_{CE(sat)}$=0.25Vdc max at I_C = 10 mAdc and I_B = 1 mAdc	X988806-1
PNP -- SWITCHING (LOW SATURATION)	Philco		-40	25-100	5	6	Selected 2N859 $V_{CE(sat)}$=-0.15Vdc max at I_C = -5 mAdc and I_B = -0.5 mAdc	X988807-1

TRANSISTORS, SILICON

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	BV_{CBO} COLLECTOR-TO-BASE BREAKDOWN VOLTAGE (Vdc)	h_{FE} AT I_C STATIC CURRENT GAIN AT SPECIFIED COLLECTOR CURRENT		f_T GAIN-BANDWIDTH PRODUCT (MC, MHz)	REMARKS	HUGHES NUMBER
				(h_{FE})	I_C (mAdc)			
NPN -- LOW NOISE	Texas Instruments		45	40-120 60 min	0.01 0.5		Selected 2N929 h_F = 4 db max at I_C = 10 uAdc and V_{CE} = 5 Vdc	X988803-1
PNP -- LOW LEVEL CHOPPER	National Semiconductor		-50				Selected 2N2004 Offset voltage: -1.00 mVdc at I_B = -200 µAdc -1.25 mVdc at I_B = -500 µAdc V_{EC}(sat) = -3 V max at I_E = -25 µAdc and I_B = -300 µAdc	X988809-1
DIFFERENTIAL AMPLIFIER (2-TRANSISTOR)	Fairchild		100	35 min (1) 25 min (1)	1.0 0.1		Selected 2N2060 h_{FE1}/h_{FE2} = 0.9 min at I_C = 0.1 mAdc and V_{CE} = 10 Vdc $\Delta(V_{BE1} - V_{BE2})$ = 10 µVdc/°C max	X988810-1
NPN -- HIGH FREQUENCY	Fairchild		30	20-50	3.0		Selected 2N917 (TO-5 case) V_{CE}(sat) = 0.5 Vdc at I_C = 3 mAdc and I_B = 0.15 mAdc P_{out} = 17 mW min at 500 mc C_{ob} = 3 p[illegible] max at V_{CB} = 50 [illegible]	X988811-1

(1) FOR EACH SIDE

TRANSISTORS, SILICON

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	BV_{CBO} COLLECTOR-TO-BASE BREAKDOWN VOLTAGE (Vdc)	h_{FE} AT I_C STATIC CURRENT GAIN AT SPECIFIED COLLECTOR CURRENT		f_T GAIN-BANDWIDTH PRODUCT (MC, MIN)	REMARKS	HUGHES NUMBER
				(h_{FE})	I_C (mAdc)			
NPN -- HIGH FREQUENCY	RCA						Selected TA2084 (TO-5 case) P_{out} = 3 W min at 200 mc C_{ob} = 15 pf max at V_{CB} = 50 Vdc	X988812-1
NPN -- HIGH FREQUENCY	Pacific Semi-conductor		75	7.5-75	350	210	Selected 2N1709 (TO-18 case) P_{out} = 4 W min at 70 mc C_{ob} = 40 pf max at V_{CB} = 28 Vdc	X988813-1
NPN -- POWER AMPLIFIER	Fairchild			40-120	500		Selected TA6200 (TO-5 case) $V_{CE(sat)}$ = 1.3 Vdc max at I_C = 1 Adc P_T = 2 W max at T_C = 100° C	X988814-1
NPN -- POWER AMPLIFIER	Texas Instruments			20-60	200		Selected 2N1720 (TO-5 case, with integral heat sink) $V_{CE(sat)}$ = 2.0 Vdc max at I_C = 200 mAdc P_T = 10 W max at T_C = 100° C	X988815-1
NPN -- POWER AMPLIFIER	Texas Instruments			20-90	2 Adc		Selected 2N1724 (7/16-in. hex stud case) $V_{CE(sat)}$ = 1.0 Vdc max at I_C = 2.0 Adc P_T = 50 W max at T_C = 100° C	X988816-1

TRANSISTORS, SILICON

TYPE	MANUFACTURER	MANUFACTURER'S TYPE OR PART NUMBER	BV_{CBO} COLLECTOR-TO-BASE BREAKDOWN VOLTAGE (Vdc)	h_{FE} AT I_C STATIC CURRENT GAIN AT SPECIFIED COLLECTOR CURRENT		f_T GAIN-BANDWIDTH PRODUCT (MC, MIN)	REMARKS	HUGHES NUMBER
				(h_{FE})	I_C (mAdc)			
NPN -- POWER AMPLIFIER	Transitron			30-90	500		Selected 2N1650 (7/16-in. hex stud case) P_T = 20 W max at T_C = 100° C	X988817-1