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RELIABILITY EVALUATION TEST PLANNING STUDY FOR BGM-34C REMOTELY--ETC(U)

SEP 77 R R BROOKS, K J BRAMAN, D M KELLY F33657-77-D-0029

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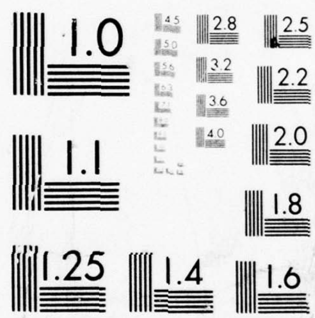

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RELIABILITY EVALUATION TEST PLANNING STUDY FOR BGM-34C REMOTELY PILOTED VEHICLE

September 1977

Prepared for

AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
Wright-Patterson Air Force Base, Ohio

Under Contract F33657-77-D-0029-0006

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Results are presented of a study performed by ARINC Research Corporation for the Aeronautical Systems Division to provide the criteria from which the Government can plan for the most effective approach to a reliability test program for the BGM-34C remotely piloted vehicle. Three levels of test scope are defined for Government consideration.

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1
INTRODUCTION

This report presents the results of a study conducted by ARINC Research Corporation under Contract F33657-77-D-0029-0006 with the Aeronautical Systems Division, Air Force Systems Command (ASD/AFSC). Objective of the study was to provide criteria for the development of reliability evaluation test plans for the BGM-34C remotely piloted vehicle (RPV). Three test-scope levels were to be identified to provide the Government with benefit-versus-resource options in developing the most effective reliability test planning approach.

The BGM-34C RPV consists of a mix of Government inventory (existing and modified) and newly developed items. Thus far in the BGM-34C development, sufficient data do not exist for an adequate system-reliability assessment. Plans for such an assessment are being made by ASD, to be accomplished under the vehicle's production contract. ARINC Research was contracted to develop the framework within which test plans can be developed to yield an adequate data base for reliability assessment, problem identification, and assignment of priorities to the allocation of corrective action resources.

Section 2 of this report describes the technical approach to the study. Section 3 discusses the analytical techniques and rationale for selection of candidate test articles. Section 4 addresses test environments and test equipment; Section 5, test ground rules; and Section 6, the optional reliability test programs, including a recommended approach. Support and reference data appear in the appendixes, as identified in the text.

2
TECHNICAL APPROACH

The overall technical approach to this study was to define the test articles, environments, and ground rules at each of three levels of reliability assessment of the BGM-34C remotely piloted vehicle. The following paragraphs describe the tasks conducted by ARINC Research in developing the test planning criteria.

2.1 DEFINE TEST ARTICLES

The initial task in the study was to identify those units warranting reliability evaluation on the basis of complexity, mission criticality, and confidence in available data. Pertinent data sources were the BGM-34C system specification; reliability and maintainability allocation, assessment, and analysis reports on the BGM-34C [4,5,6*]; and flight-test printouts from the Systems Effectiveness Data System (SEDS). The tradeoff between testing all selected units simultaneously as an integrated whole, versus testing smaller groups or individual items, was to be considered; and the best approach recommended, together with the underlying rationale.

2.2 DEFINE TEST ENVIRONMENT

A combination and/or sequence of test environments reflecting the range of operational usage of the BGM-34C was to be selected on the basis of a study of operational flight profiles, anticipated preflight and maintenance environments, the system specification, and available flight test data. The test environments were to be documented, together with 1) any unusual requirements and 2) recommended test equipment for simulating the environments.

2.3 DEVELOP TEST GROUND RULES

Test ground rules were developed by:

a. Reviewing the operation and/or duty cycling of the selected test articles

b. Establishing criteria for assessing reliability on the basis of test results

c. Establishing definitions for relevant and nonrelevant failures, and requirements for evaluation and implementation of corrective actions

d. Outlining the method of accrual of test time, to account for interrupts due to failures and resulting corrective actions.

*Superscripts denote reference documents, Appendix C.

2.4 DEFINE TEST PROGRAM SCOPE LEVELS

Three possible levels of testing were to be defined to provide the Government with test options based on stated resources and directed toward reducing both Government and contractor production risks. Test articles, environments, and ground rules were to be identified for each of three test levels:

a. Unconstrained Program – No limitations on test time, types of test chamber, or items tested.

b. Intermediate Program – Less than 2,000 hours of test calendar time (16,000 total test hours) utilizing eight MIL-STD-781B chambers (4' x 4' x 4'), of which one chamber will have random vibration capability.

c. Minimum Program – Less than 2,000 hours of test calendar time (8,000 total test hours) utilizing four MIL-STD-781B chambers (4' x 4' x 4'), of which one chamber will have random vibration capability.

3
TEST ARTICLE IDENTIFICATION

3.1 SELECTION CRITERIA

To achieve maximum benefits from the BGM-34C reliability test program, it is necessary to identify those articles for which reliability assessment would yield the most useful results. A hierarchy of selection criteria for identification of articles to be tested was developed, based on either operational characteristics or data availability. These criteria were formulated into a decision diagram (see Figure 3-1) and used to screen each BGM-34C line replaceable unit (LRU), as listed in Appendix A. As an input to this study, the Government directed that the following articles be excluded from consideration in the test-selection analysis:

a. Mid-Air Recovery System (MARS) equipment

b. Ground launch equipment, except the ground launch interface control unit (GLICU)

c. Strike and reconnaissance mission equipment

d. EW transmitters.

LRUs excluded by the above guidelines are identified in Appendix B.

The overriding consideration in the test-article selection process was the availability of data. Since the BGM-34C comprises a mix of old, modified, and newly developed items, a large number of its LRUs have sufficient operational data available for a reliability assessment. TRA report 14711-4[8] provided the necessary information for establishing whether each BGM-34C LRU has been used on previous RPV systems.

For LRUs that have been in Government inventory for less than 2 years, available data were assumed to be insufficient to permit reliability assessment. These LRUs were further screened to identify the ones for which reliability evaluations would be desirable. The selection criteria were premised on failure modes and effects analyses previously conducted by Teledyne Ryan and Lear-Siegler[4,5,6]. The selected LRUs were then identified as to their operational criticality, in the following categories (ranked according to severity):

a. <u>Class I — Personnel Safety Critical.</u> LRU failure could result in loss of life.

b. <u>Class II — Recovery Critical.</u> LRU failure could result in loss of the RPV.

c. <u>Class III — Mission Critical.</u> LRU failure could result in launch or flight abort.

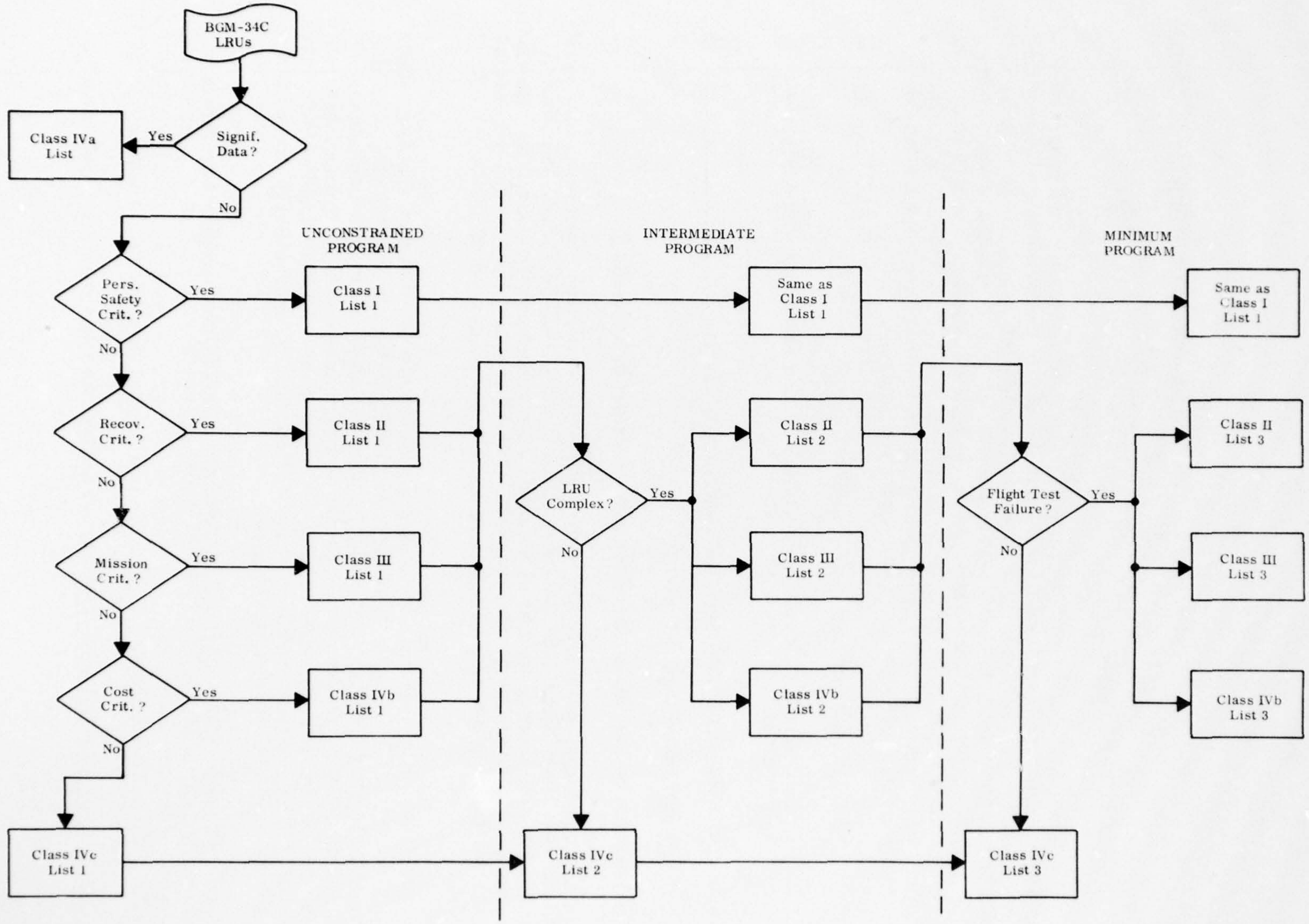


Figure 3-1. Test Article Selection Process

d. Class IVb - Cost Critical. LRU has high failure rate and/or high maintenance costs, and experience data are insufficient for evaluating operational availability.

e. Class IVc - Non-Critical. LRU has insufficient experience data to permit reliability assessment, but failure could result only in degradation of non-critical system-performance parameters. Therefore, reliability predictions for these LRUs may be used until field experience data become available.

f. Class IVa - LRU experience data are sufficient for performing an operational reliability assessment without further testing; or LRU is excluded by ASD-provided selection guidelines.

For purposes of test-article selection, an LRU was listed only in the most severe applicable category.

3.2 PROGRAM TEST ARTICLES

Based on the above criteria, test articles for the Unconstrained, Intermediate, and Minimum test programs were selected as discussed below.

3.2.1 Unconstrained Program Test Articles

Test articles recommended for the Unconstrained Program constitute the "List 1" LRUs of Table 3-1. The following paragraphs provide the rationale for the selection of LRUs where not obvious.

The List 1, Personnel Safety Critical (Class I) LRUs include the servo actuators and the module that supplies power to the rudder and aileron actuators. These LRUs were classified Personnel Safety Critical during air launch due to potential hardover output from the actuator, which could cause the RPV to become uncontrollable and possibly collide with the launch aircraft.

In the Recovery Critical (Class II) area, the fuel system valves failing in an open mode would cause the main tank to continue to vent above 25,000 feet, and this loss of tank pressure could cause engine flameout above 38,000 feet when the fuel level is less than 8 inches above the boost pump. The same problem will result from failure of the right/left fuel pod transfer relay of the pod control unit (with pods off or empty). This relay completes the power circuits to the fuel system pressure/vent valves. Failures occurring in the remaining LRUs of Class II will diminish control of the RPV to the point of probable loss of the vehicle.

For Mission Critical (Class III) LRUs, except for the two fuel valves, failure will cause either 1) an automatic abort or 2) a manual return to the recovery area due to severe degradation of the functions detected by telemetry. Failure of the pilot float-operated valve and fuel-level control valve in the closed position during prelaunch will prevent the RPV main fuel tank from being replenished, resulting in a short mission.

All LRUs in the Cost Critical (Class IVb) list have high maintenance and/or failure rates, together with insufficient experience history from which to make an evaluation.

TABLE 3-1. SELECTED TEST ARTICLES

Scope of Test Program 1	2	3	Personnel Safety Critical (Class I)	Recovery Critical (Class II)	Mission Critical (Class III)	Cost Critical (Class IVb)
UNCONSTRAINED ↓	INTERMEDIATE ↓	MINIMUM	Aileron servo actuator Elevator servo actuator Rudder servo actuator Power module, ±12 Vdc	Ground launch interface control Flight control computer Interface control unit AHR displacement gyro	Digital processor unit	Doppler velocity sensor Loran Recovery control unit MCGS transponder
				Pod control unit AHR electronic control amplifier Throttle servo actuator Main power control box	Normal accelerometer Lateral accelerometer Throttle position transducer	
				Pressure/vacuum relief valve Manual drain valve, vent system Main tank fuel vent valve RH & LH fuel pod quick disconnect Voltage regulator Inverter, 750 VA Air data subsystem	Pilot float operated valve Fuel level control SO valve Relay assembly - ac power control Generator ECM control box Transmitter cooling valves Limiter assembly "E" high & low control box	Chaff pod selector box Umbilical distribution box

3.2.2 Intermediate Program Test Articles

For the Intermediate Program (List 2, Table 3-1), LRUs classified as Personnel Safety Critical remain the same as for the Unconstrained Program. Other test articles for the Intermediate Program are those selected from the Unconstrained Program on the basis of technological complexity of operation or design at the circuit/component level. The primary driver used after considering vintage of the equipment was state-of-the-art technology. In general, the Intermediate Program list contains LRUs designed with a large complement of microcircuitry or other unique and current design features. In addition, LRUs were selected that contain a large mix of parts of of varying quality.

Articles in Classes II, III and IVb were selected according to the above screening criteria. Exceptions were the gyro, accelerometers, and transducer, which were chosen because they represent an electromechanical design technology that is unique although not new.

3.2.3 Minimum Program Test Articles

Test articles for the Minimum Program (List 3, Table 3-1) are those selected from the Intermediate Program list on the basis of System Effectiveness Data System (SEDS) data on preflight and flight test data.[10] While SEDS failure data are generally based on a small number of operational hours, it can be reasoned that recurring failures of listed LRUs can be expected to continue until corrective measures are taken. The inclusion of these items in the test program will allow corrective action resources to be allocated in a manner responsive to greatest expected system-reliability benefits.

Personnel Safety Critical items for the Minimum Program are the same as those of the Unconstrained Program due to the critical nature of operational failures.

For the Minimum Program, Recovery Critical (Class II) items deleted from the Intermediate Program list include the pod control unit, main power control box, AHR electronic control amplifier, and throttle servo. These LRUs have not exhibited significant problems during flight testing. However the GLICU, for which no failures have been reported, remains on the list because it is expected to have a high failure rate and since limited ground-launch data exist for the BGM-34C.

To date, the DPU has experienced more failures than any other LRU in the BGM-34C vehicle, and therefore remains on the Minimum Program list. All other Mission Critical (Class II) items of the Intermediate Program have experienced few or no failures, and therefore were not selected for the Minimum Program.

All Cost Critical LRUs on the Intermediate Program list have failed often enough to warrant additional evaluation; therefore, this list remains the same for the Minimum Program.

3.2.4 Non-Selected LRUs

Excluded from all three test options are LRUs that have significant operational history, and thus do not need further evaluations (Class IVa); and those screened by the three programs per the criteria discussed in Sections 3.2.1 through 3.2.3 (Class IVc, Lists 1-3). These lists appear in Appendix B.

3.3 TEST PHILOSOPHY

Ideally, conditions of BGM-34C reliability evaluation testing should approach those under which the equipment will be operated. However, consideration must be given to the tradeoffs among selected test articles, test equipment, test space requirements, interface compatibility, and level of operating performance. The decision can then be made whether to conduct the testing at the system, integrated subsystem, or individual LRU level, as discussed in the following paragraphs.

3.3.1 System Reliability Evaluation Approach

A total system evaluation approach test would involve the use of a complete BGM-34C vehicle; an environmental chamber (combined or individual environments) large enough to accept all selected LRUs of the vehicle; and the system test console (STC). This approach has the following advantages and disadvantages.

Advantages

- Provides each equipment with the inputs and output loads most representative of actual operation.

- Provides actual interface marriages (cables, connectors, etc.) to verify interface compatibility and freedom from undesirable interactions under dynamic conditions.

- Permits monitoring parameters at an acceptable level of performance for system functions essential for each phase of the operational mission profile.

Disadvantages

- Environmental simulation chambers large enough to accommodate the total BGM-34C vehicle are not readily available.

- The STC, due to its large size, requires a correspondingly large test setup space.

- The STC instrumentation cables are too numerous to be accommodated by access openings in standard environmental chambers.

3.3.2 Integrated Subsystem Evaluation Approach

The integrated subsystem approach involves testing at the "segment" level (avionic, navigation/guidance, propulsion, etc.) defined in Appendix A; use of an environmental test chamber (combined or individual environments); and use of portions of the STC with its existing software or subsystem-level test monitoring equipment, such as the direct control panel.

Advantages

- Provides each equipment with inputs and output loads representative of actual operation.

– Provides interface marriages (cables, connectors, etc.) of some selected subsystems to verify interface compatibility and freedom from undesirable interactions under dynamic conditions.

– Permits the monitoring of parameters at acceptable levels of performance for selected subsystem functions essential for specific phases of the operational mission profile.

– Provides the capability for combining environmental tests for simultaneous application.

– Provides for test monitoring with either STC, subsystem testers, or individual LRU testers.

Disadvantages

– All interfaces are not checked for undesirable interactions.

– Some percentage of subsystem inputs are simulated, and accuracy of simulation is an unknown factor.

– Assessment of the total mission profile is extremely difficult.

3.3.3 LRU Evaluation Approach

The LRU evaluation approach involves testing of individual LRUs in environmental chambers (combined environments) with individual LRU test equipment.

Advantages

– Permits evaluation of a greater portion of system circuits/components than system or integrated subsystem level testing.

– Provides for identification of LRU-level stability and degradation of performance.

– Test equipment is readily available.

– Combined environmental testing can be easily accomplished.

Disadvantages

– The simulation of operational inputs is more complex, and therefore these inputs are potentially less accurate.

– Interfaces and interactions among LRUs cannot be evaluated for compatibility or their effects on the system.

– Operational mission profile performance is difficult or impossible to assess.

– Installation problems are difficult to assess.

4
TEST ENVIRONMENT

This section discusses environmental considerations associated with BGM-34C reliability testing. Section 4.1 presents an evaluation of the system operating environment; Section 4.2 describes how the environment can be simulated for three test-scope levels (Unconstrained, Intermediate, and Minimum); Section 4.3 addresses specific types of equipment needed to simulate the environment for the three levels of testing; and Section 4.4 identifies test performance monitoring equipment.

4.1 OPERATIONAL ENVIRONMENT EVALUATION

Field environmental data derived from actual measurements, analyses, and experience as published in technical reports (see references, Appendix C) were reviewed to determine the environment to which the LRUs are exposed during operation. Table 4-1 summarizes the findings.

From a study performed by Grumman Aerospace Corporation,[13] an analysis of field failure data related to environmentally induced failures for various types of jet aircraft, the distribution of failures was found to be as follows:

Environmental Factor	Percentage of Failures Attributed to Factor
Temperature	40
Vibration	27
Moisture	19
Sand and dust	6
Salt	4
Altitude	2
Shock	2

As can be seen, approximately 85% of all environmentally-induced field failures of the subject electronic equipment are attributable to temperature, vibration, and moisture. Therefore the BGM-34C environmental test plans will be limited to those three factors.

The approach to developing a laboratory program simulating the temperature, moisture, and vibration environments expected in the field utilizes RPV mission experience as its basis. Although RPVs with different mission goals have slightly different profiles, certain generalizations of profile can be made. Every RPV experiences the following sequence of events during a nominal mission:

a. Ground operation

b. Launch and altitude attainment

TABLE 4-1. ENVIRONMENTAL STRESSES

Environment	Stress Level		Exposure Duration	Rate of Change
Temperature				
Low (forward)	40° F to 10° F		1 hr	0.6° F/min
Low (aft)	80° F to 75° F		1 hr	0.1° F/min
High (both)	70° F to 115° F		1 hr	1.0° F/min
Vibration				
	(Fwd Comp)	(Aft Comp)		
Random				
10-100 Hz	0.01 g^2/Hz	0.01 g^2/Hz	25 min (max PSD) and 35 min (75% max PSD)	±6 db/octave
100-500 Hz	0.007 g^2/Hz	0.40 g^2 Hz		
500-2,000 Hz	0.005 g^2/Hz	0.68 g^2/Hz		
Sinusoidal	0.1" DA, 10-20 Hz; 2.2g peak accel., 20-2,000 Hz		1 hr	1.22 octaves/min
Humidity	(One Cycle)			
	95% relative humidity		9 hr	1.0° F/min
	85% relative humidity		3 hr	1.0° F/min
	(each at 73° to 115° F)			

c. Mission objective

d. Recovery

e. Ground storage (non-operation).

Utilizing this general sequence and separating the environments of concern into their constituent parts, definitions of the environmental stress levels and durations were generated. For purposes of gathering as much data as possible applicable to flight operations, the ground-operation and storage-time segments of the simulated mission profile will be greatly reduced from the observed field durations.

The operational environment will now be discussed in terms of temperature (Section 4.1.1), vibration (Section 4.1.2), and humidity (Section 4.1.3).

4.1.1 Thermal Levels

A review of field environmental data for minimum temperature levels indicated a wide variation of minimum temperatures in various compartments of RPVs. However a distinct band was noted in the vicinity of +10° F at sea level. This minimum temperature represents a worst-case steady-state condition that will be simulated for LRUs installed in the BGM-34C nose compartment. The minimum temperature for equipment-compartment LRUs is about +75° F (see Figure 4-1).

Figure 4-2 depicts a typical worst-case, high-temperature operational profile. Since the end temperature maximums for both the nose and equipment compartment of a jet-powered RPV are approximately 115° F (ref. 9), this single worst-case high temperature will be used for testing purposes.

The above low- and high-temperature test requirements disregard ground operating and storage temperature extremes. Since the objective of this testing is to determine the operational suitability of the articles, and since previous production, reliability, and quality acceptance tests have demonstrated the effects of these temperature extremes, only operational temperatures will be considered.

4.1.2 Vibrational Levels

The vibrational forces imposed on an equipment may be random, sinusoidal, or a combination of the two. The Grumman[13] and Air Force Flight Dynamics Laboratory[9] reports agree that major sources of vibration in jet-powered air vehicles produce displacements of a random nature, and MIL-STD-810C[12] requires a random vibration test for equipment installed in external stores carried on airplanes. Therefore a random-vibration environment is recommended for the BGM-34C reliability test program. However, if facility limitations preclude random vibration testing, the sinusoidal vibration test of Table 4-1 could be conducted; but for assessment purposes the two may not be combined since they are different environments.

The operational vibration environments for articles installed in the nose, engine, and equipment compartments (Figures 4-3, 4-4, and 4-5, respectively) were chosen for the BGM-34C reliability test program since 1) all selected LRUs are located in those three compartments, as opposed to stores and other external locations; and 2) these areas represent the conditions of highest vibrational level, representative frequency, and duration of application expected to be associated with BGM-34C operation.

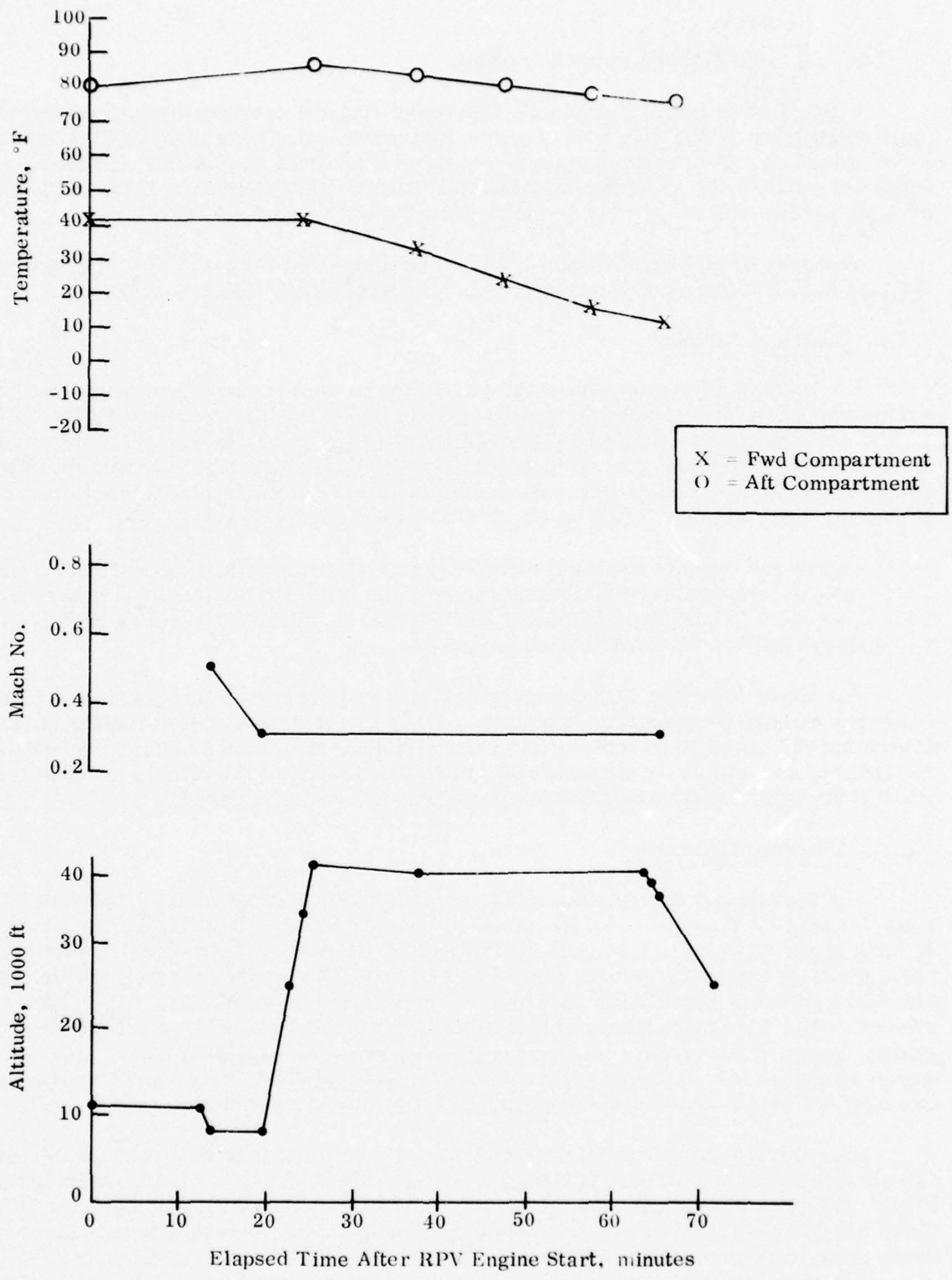


Figure 4-1. Typical High-Altitude Temperature Profile

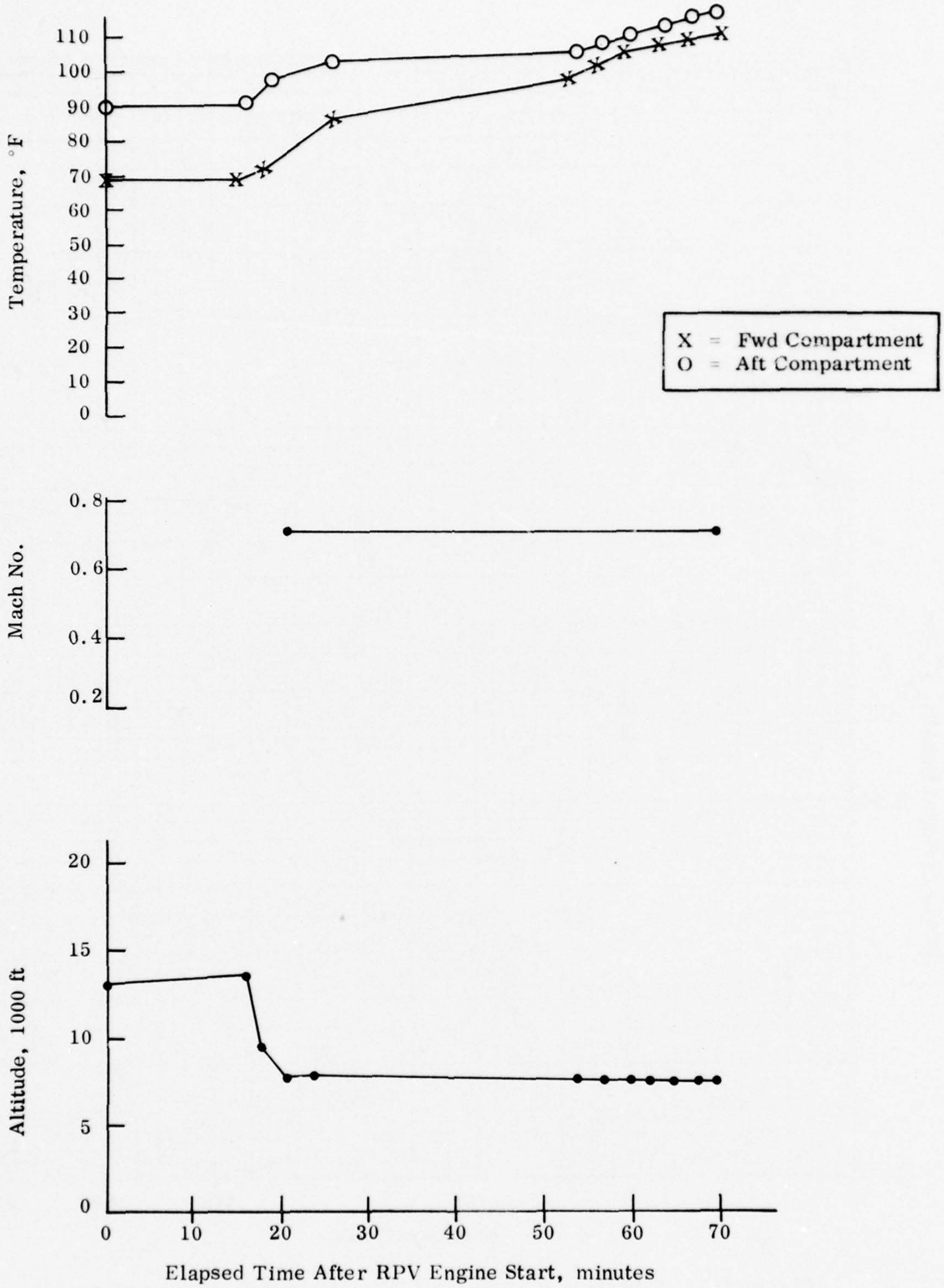


Figure 4-2. Typical Low-Altitude Temperature Profile

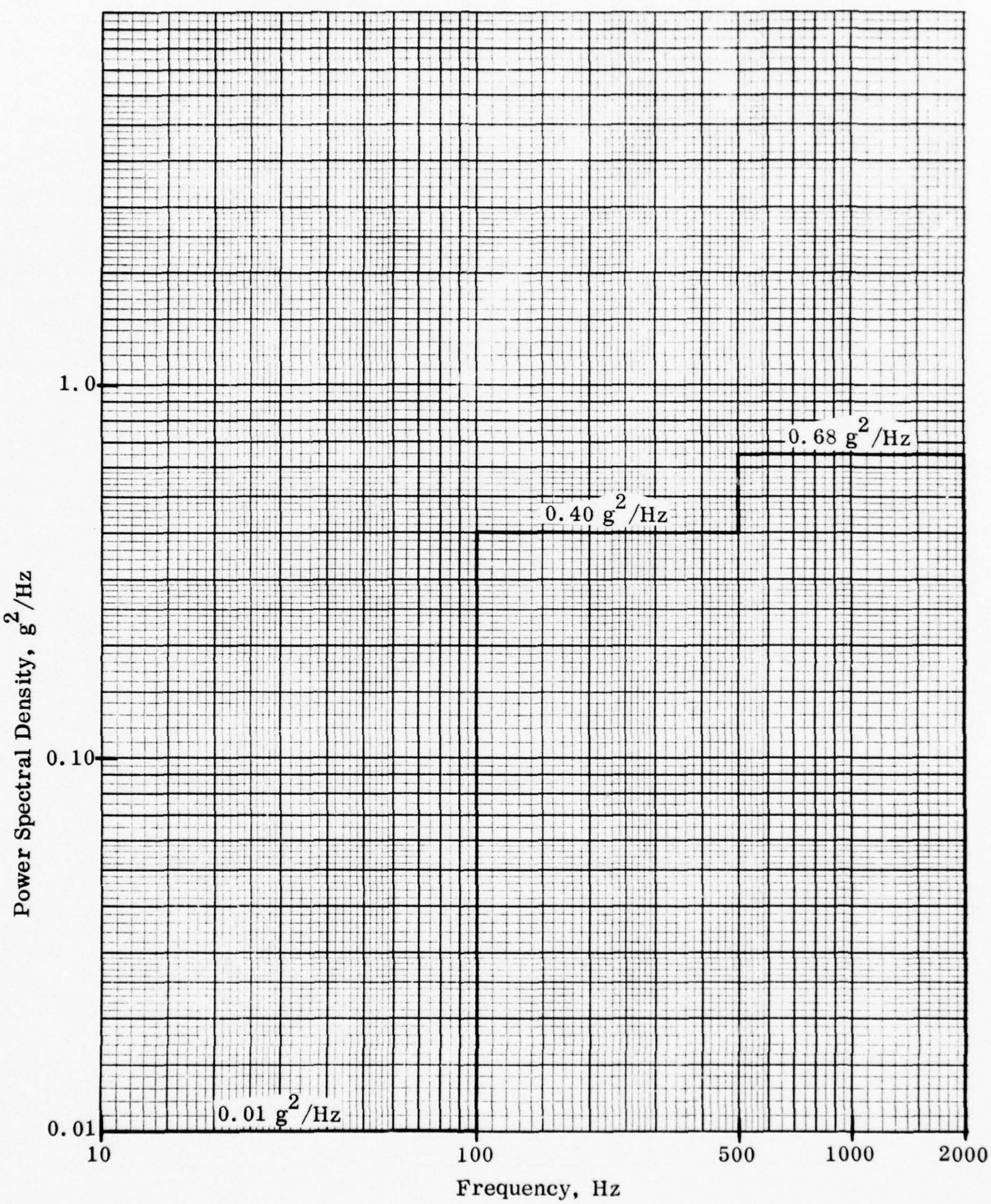


Figure 4-3. Vibration Profile for LRUs Located in Aft Compartment

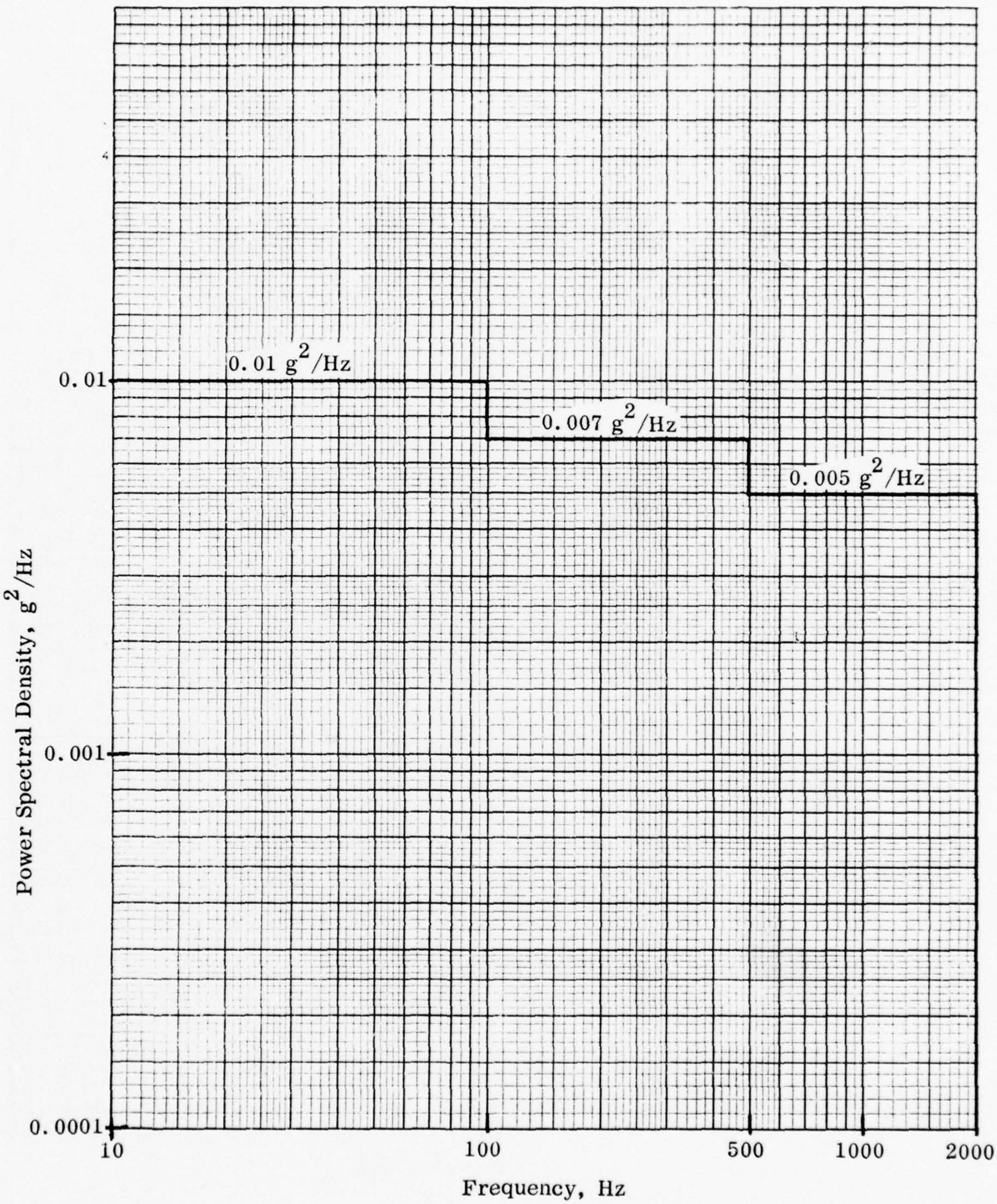


Figure 4-4. Vibration Profile for LRUs Located in Forward Compartment

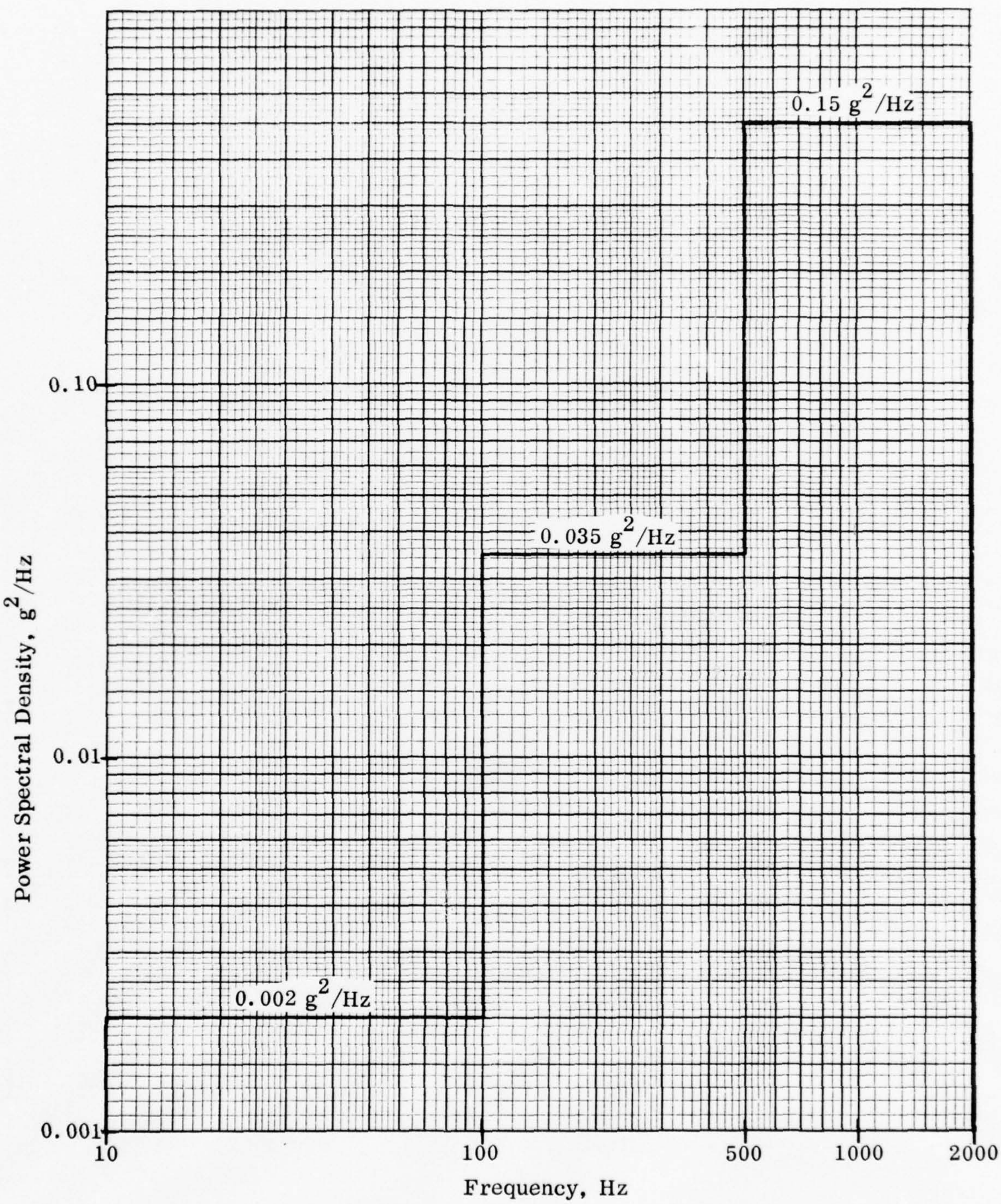


Figure 4-5. Vibration Profile for LRUs Located in Engine Compartment

The duration of vibration exposure is based on a typical BGM-34C EW mission, during which vibrational conditions are severe for approximately 25 minutes and at a more benign level during the cruise and loiter phases. As indicated by Figure 4-6, a reduction of 25% of the maximum power spectral density (PSD) levels for random vibration is recommended during the less severe portion of the mission.

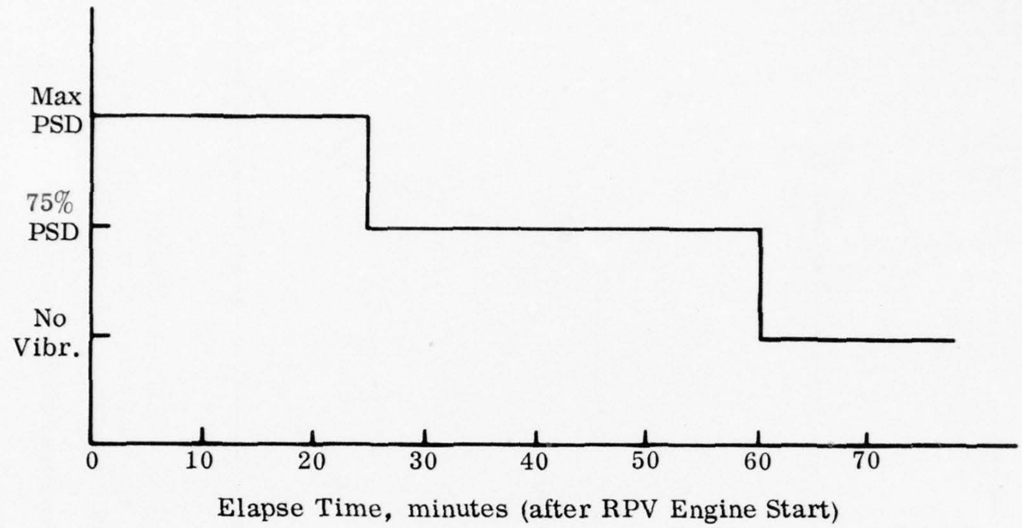


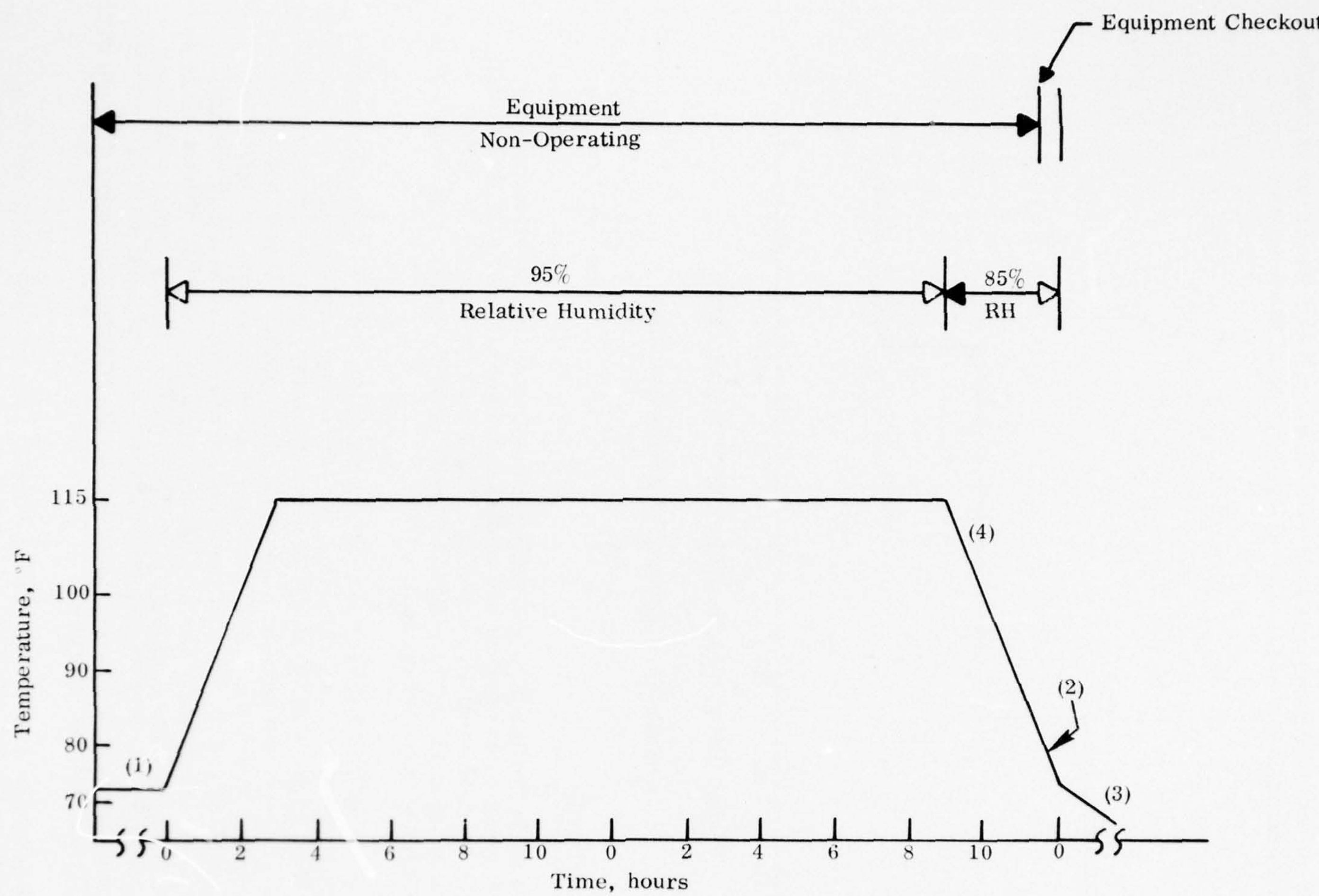
Figure 4-6. Typical Vibration Duration

4.1.3 Humidity Level

As was noted in Section 4.1, a significant number of field avionic failures attributable to environmental causes are moisture-related (19 percent of the total). Since there are a limited amount of applicable flight data from which to relate humidity-exposure duration and levels to a mission profile, engineering judgment is needed to approximate this environment.

Ideally, any proposed humidity test should simulate the full range of moisture environments expected during service life. The full range encompasses all conditions between 1) hot-day, high-relative-humidity ground storage, and 2) high-speed climb/dive through varying thermal/pressure layers of atmosphere. This range cannot be practically duplicated in a laboratory. Recognizing this limitation, standard test methods, i.e., MIL-STD-810, involve manipulating certain of the environment's driver and driven constituents to produce the desired long-term life effects. The same approach has been utilized to develop a cycle for the BGM-34C program. Because standard humidity tests are of a nonoperating nature, and the purpose of this test program is to accumulate operating time, the total cyclic exposure has been reduced and dispersed throughout the test interval.

For purposes of BGM-34C reliability testing, the standard test cycle of MIL-STD-810 has been modified as shown in Figure 4-7. The "rise-to-temperature" period has been extended to 3 hours to assure realization of 95% relative humidity at 115°F. This extension, coupled with an 18-hour soak, will afford the greatest



(1) Basic cycle - Set chamber at 73° F and permit adequate soak time to stabilize.
(2) Operational checkout (short duration, GO/NO-GO only) – Equipment off at end of checkout.
(3) Reduce chamber temperature to next-cycle starting temperature and then soak for 1/2 hour with equipment non-operating.
(4) Drying cycle – Actual duration controlled by 85% relative humidity requirement.

Figure 4-7. Humidity Profile

opportunity for moisture migration. The drying period, represented by the reduction in temperature to 73°F, has been shortened to 3 hours. The recognized risk associated with reducing the drying time (free moisture precipitant within the chamber) is minimized by imposing the 85% relative humidity requirement, which will in actuality govern the duration of this period. Thus the actual drying time may exceed 3 hours, depending upon the capability of the test equipment to reduce the absolute water content.

To assure obtaining the full effect of each humidity exposure while distributing the total exposure throughout the entire test period, each exposure will consist of two modified cycles, back-to-back. This arrangement affords two opportunities for the driver constituent (temperature) to have its full effect.

Constructing the humidity exposure and positioning it between basic cycles, as previously outlined, requires that sufficient time be allocated before and after the humidity cycle to allow the test article to stabilize at the desired initial temperature. Further, operational checkout of the test article is considered mandatory at the completion of each humidity exposure. Upon completion of the basic thermal/vibration cycle, the chamber temperature is set at 73° F with the equipment nonoperating. After allowing sufficient time for the LRU to stabilize at 73° F, humidity exposure will begin. At the conclusion of humidity exposure, an abbreviated operational checkout of the test article is performed when the chamber temperature reaches 73° F. Following this checkout, the chamber temperature is adjusted to the next thermal/vibration cycle.

4.2 ENVIRONMENTAL STRESS OPTIONS

The following variations of environmental stress are provided to offer the Government a range of choices for simulation of the environments encountered by selected LRUs of the BGM-34C during field operation. Also included are requirements for unusual environmental-simulation equipments.

4.2.1 Unconstrained Program Environments

The selected LRUs will be subjected to all environmental stresses defined in Table 4-1. The temperature and vibration stresses will be applied simultaneously, and humidity individually. Figure 4-8 shows the environmental profile.

4.2.2 Intermediate Program Environments

The selected LRUs will be subjected to the temperature and vibration stresses listed in Table 4-1, applied simultaneously. Figure 4-9 shows the environmental profile.

4.2.3 Minimum Program Environments

The selected LRUs will be subjected to the temperature and vibration stresses listed in Table 4-1, applied simultaneously. Figure 4-9 shows the environmental profile.

4.3 ENVIRONMENTAL TEST EQUIPMENT

Environmental test equipment required for simulating the stresses defined above is identified in the following paragraphs.

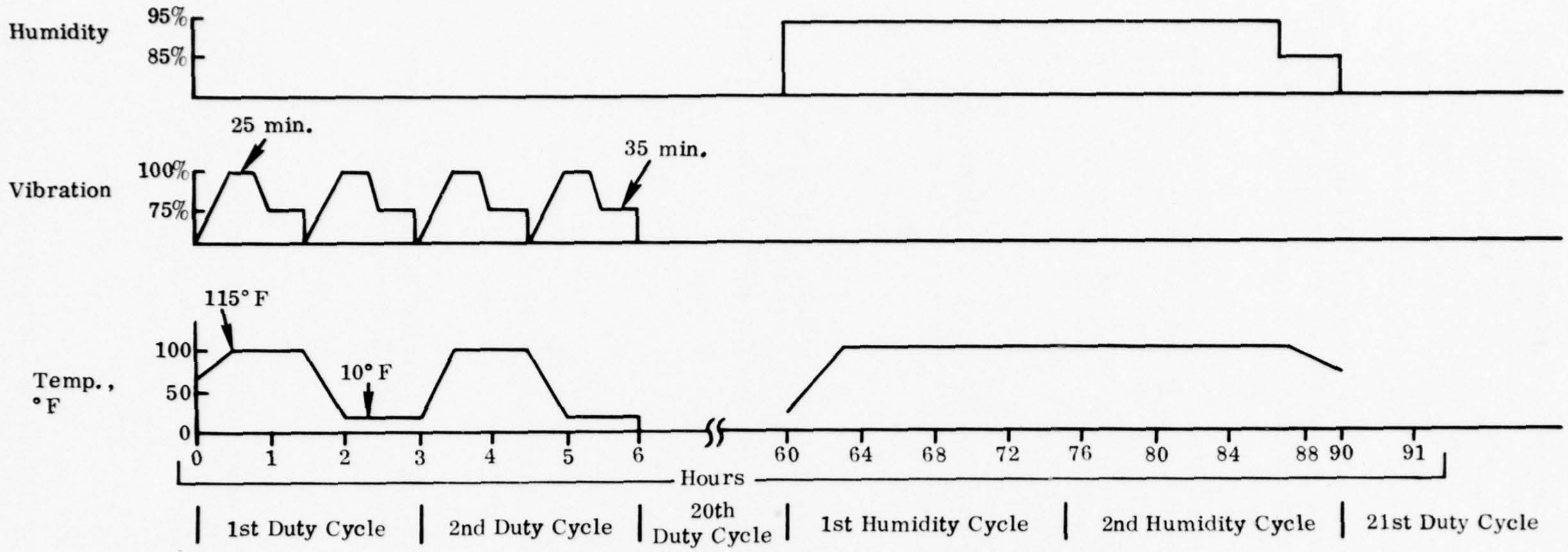


Figure 4-8. Unconstrained Program Environmental Profile

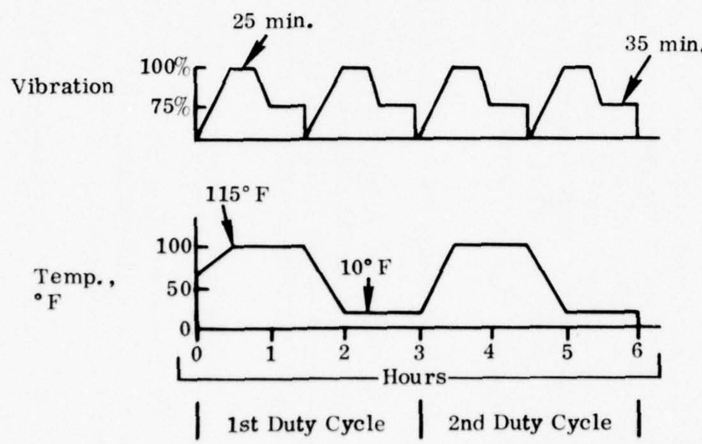


Figure 4-9. Intermediate and Minimum Program Environmental Profile

4.3.1 Unconstrained Program Environmental Equipment

The test facility or chamber will be large enough to accommodate the assembled test articles of Table 3-1. The chamber shall be capable of providing temperature and random vibration stresses simultaneously, and humidity individually.

4.3.2 Intermediate Program Environmental Equipment

Environmental test chambers with inside dimension measuring 4' x 4' x 4' will be used to apply temperature and vibration stresses simultaneously to the test articles. Test chambers needed are:

a. One AGREE Test Chamber 27CF10-10 or equivalent, with random vibration capability

b. Seven AGREE Test Chambers 27CF10-10 or equivalent, with sinusoidal vibration capability; or seven separate sinusoidal vibration exciters.

4.3.3 Minimum Program Environmental Equipment

Environmental test chambers (4' x 4' x 4') required to satisfy Minimum Program stresses are:

a. One AGREE Test Chamber 27CF10-10 or equivalent, with random vibration capability

b. Three AGREE Test Chambers 27CF10-10 or equivalent, with sinusoidal vibration capability; or three separate sinusoidal vibration tables.

4.4 TEST MONITORING EQUIPMENT

Based on the foregoing analyses, the following test monitoring equipment is needed.

4.4.1 Unconstrained Program Monitoring Equipment

For the Unconstrained Program, the selected LRUs of Table 3-1 will be configured as completely functional subsystems and then assembled to operate per the BGM-34C system requirements. The system test console (STC) will be used to test and monitor the articles during operational testing. LRUs not selected for testing, but required to support the integrated system test concept, may be used as required.

4.4.2 Intermediate Program Monitoring Equipment

Selected test articles listed in Table 3-2 for the Intermediate Program will be assembled into operational subsystem configurations (see Section 6). Where possible, actual system interfaces (cables, connectors, etc.) will be utilized. This is the same testing configuration used for DC-130 upload and preflight tests. About 95% of the selected LRUs are checked by this test.

The LRUs assembled into subsystems will be tested and monitored, with support test equipment consisting of the following:

a. Direct Control Panel of Launch Control Console

b. Umbilical Distribution Box

c. Special Test Adapter

4.4.3 Minimum Program Monitoring Equipment

Testing a sample of four of each LRU listed in Table 3-1, individually or as a group, requires the following operational support test sets:

a. Loran Test Set 458050
b. MCG Test Set AN/APM 37 MOD
c. Doppler Radar Velocity Sensor Test Set 1001Z0001-G1
d. Gyro Test Set LT5601-01-01
e. Interface Control Unit Test Set 458700
f. Universal Avionic Component Tester (UACT) 457400
g. Adapter, UACT 458610 (for flight computer)
h. Adapter, UACT 458400 (for recovery control unit)
i. Extended Purpose Adapter, UACT 458650 (for RCU)
j. Digital Processor Test Set 458100
k. Servo Actuator Test Set 458400
l. Ground Launcher Console 259G030-1

5
TEST GROUND RULES

This section describes the ground rules, guidelines, procedures, reports, and statistical assessment methods required for the effective conduct of a reliability test program. The definitions and methods are consistent with those called out in MIL-STD-781[11] and other test specifications and standards.

5.1 GENERAL GUIDELINES

The contractor will prepare a detailed reliability test plan having the purposes of:

a. Providing the necessary coordination between the procuring activity and the contractor to ensure mutual agreement on the test approach

b. Precluding post-test disputes over the validity of test results

c. Minimizing changes and arbitrary on-the-spot decisions during the conduct of the test, which could invalidate the test results

d. Assuring that all necessary test support is planned, scheduled, and made available in a manner that will preclude costly delays in test initiation or invalidation of test results.

5.1.1 Detailed Reliability Test Procedures

The contractor will prepare detailed test procedures and obtain approval of the procedures from the procuring activity. The test procedures should include the following details:

a. Test purpose, concepts, and general description

b. A listing and brief description of all units that will be tested

c. Test equipment to be used

d. How the test equipment will be monitored

e. Operational and environmental conditions under which testing is to be conducted

f. Preventive maintenance measures to be performed

g. Performance parameters to be measured

h. Performance limits beyond which a failure is deemed to have occurred

i. Step-by-step test procedures

j. Samples of report and log forms

k. Test-data assessment techniques

l. Test team organization and responsibilities

m. Failure analysis and corrective action procedures.

5.1.2 Design and Performance Testing

Design, performance, environmental, preproduction, individual, or other required tests will be completed prior to reliability testing, unless otherwise specified by the procuring activity.

5.1.3 Test Preparations

The contractor will conduct an environmental equipment evaluation, utilizing the articles to be tested, to assure that proper environmental stress conditions are obtainable for testing.

5.1.4 Inspection

Procuring activity personnel will visit the test facility or perform other inspections as necessary to assure compliance with reliability test and evaluation requirements. The contractor will provide the necessary administrative support to the inspection personnel.

5.2 BASIC TEST PROCEDURE

The procedure for reliability assessment involves the following basic steps:

a. Select samples of the LRUs to be tested. All LRUs so selected will have passed the individual tests described in the acceptance test portion of the equipment specification.

b. Install the LRUs in the test facility, together with the instrumentation needed for testing and to provide for the safety of equipment, test facility, and test personnel.

c. Conduct the testing under procuring activity surveillance and in accordance with approved test conditions and procedures.

d. Record the test elapsed-time and time-to-failure data.

e. Diagnose, analyze, categorize, and classify each failure.

f. Assess the equipment reliability from accrued time and failure records.

g. Summarize all test results in a final reliability evaluation test report.

5.3 TEST TIME ACCRUAL

Throughout the test period, time (for purposes of assessment) is accrued on the test articles only when they are in their operating mode. The operational duty cycle is intended to be representative of BGM-34C field operations.

5.4 INCIDENT OCCURRENCE

In the event of an incident that requires test shutdown, complete log and data records will be maintained.

If corrective maintenance actions are required, the contractor will be responsible for implementing them. Following correction, a test for verification of correction effectiveness will be witnessed and approved by the procuring activity, after which the system will be returned to the reliability test configuration and test sequence existing prior to the incident.

Incident identification reports will be prepared for each incident. In the event that parts or subassemblies of failed LRUs are removed and replaced, a Spare Parts Use Log entry will be completed along with a failure analysis report. Suggested formats for these reports are presented in Section 5.7.

5.4.1 Failure Definition

For purposes of the subject testing, "failure" is defined as any performance deviation of a test article beyond acceptable limits, for which a level of performance has been established. Examples of failure include, but are not limited to:

a. Deviation of monitored functional parameters beyond established limits

b. Catastrophic or structural failure

c. Mechanical binding or loose parts, including screws, clamps, bolts, and nuts, that clearly result in article failure

d. Degradation of system performance below established limits

e. Deterioration, corrosion, or change in tolerance limits of any internal or external parts, which in any manner prevents the article from meeting operational requirements.

5.4.2 Failure Relevancy

All failures will be considered relevant for purposes of article reliability assessment, unless as otherwise directed by the procuring activity or as judged nonrelevant under the following guidelines:

a. External Causes — Failures determined to have been caused by a condition external to the article under test (e.g., caused by a malfunction of the test equipment or of any interconnecting test cables).

b. Human Error — Failures resulting from operation of the article in excess of specified limits; or occurring during fault isolation, adjustment, repair, or diagnostics that are not part of reliability testing.

c. Unverified Failures — A nonrecurring phantom indication on test monitoring equipment, which cannot be subsequently verified.

d. Secondary Failures — The failure of an article due to failure of another article.

5.4.3 Analysis of Failures

The cause of each test article or part failure, including government furnished equipment (GFE) or parts to be included in or as part of the test group, will be determined by investigative methods and analysis. No substitution for an equipment item being tested may be made during reliability testing unless the LRU can be unmistakably demonstrated by the repair activity to be outside of specification tolerances, and that its repair will delay the test program excessively.

All failures observed during reliability testing will be confirmed. Lack of failure confirmation should be cause for close review of the test methods and facility.

5.4.4 Verification of Repair

Following repair/corrective action and prior to the resumption of testing, it will be permissible to operate articles in the test facility. Test procedures will specify, for all LRUs under test, the period of operation or number of cycles needed to verify the effectiveness of the repair. Failures and elapsed time during this period will be recorded and reported. While these data will not be used in the MTBF determination, they will be subject to analysis.

5.5 CORRECTIVE ACTION PLAN

The contractor will promptly develop and propose a plan for correction of all relevant failures occurring during reliability testing that were determined by analysis to be manufacturer design and/or workmanship. The plan will be submitted to the procuring activity for review and approval.

At the conclusion of the reliability test program, all proposed corrective actions not incorporated during testing, and any recommendations for possible future improvements of the reliability of the articles, will be prioritized for an incorporation decision based on criteria established by the procuring activity.

5.6 PREVENTIVE MAINTENANCE

Preventive maintenance procedures specified for the test articles during normal operation will be applied during the reliability tests. No additional preventive maintenance will be allowed during testing or actual repair. Preventive maintenance or calibrations may be performed on test equipment as necessary.

5.7 DATA COLLECTION AND REPORTING

Data collecting and reporting at the reliability test site will include the following activities:

a. Developing and implementing a method for collecting performance test data. The associated procedures will be prescribed in the test plan.

b. Maintaining (i.e., recording all necessary entries in) the Test Log and Data Record. This function includes all event observations and notification of incidents.

c. Initiation of failure reports.

d. Maintaining the Spare Parts Use Log.

5.7.1 Records

The primary purpose of test records is to document all events and activities having direct or indirect impact on the reliability test decision process. Only one complete "official" set of records will be maintained during the actual test. The on-duty test team members will both initial and date all records. Full signatures will be shown where conclusions are reached and recorded.

5.7.2 Test Log and Data Record

The Test Log and Data Record is used for recording operating and down time, and to describe progress, problems, solutions, and other information necessary to document the progress of testing. All incidents will be recorded and certified in this log, whether internal or external to the system configuration. Entries will be made at the time the incidents occur. Following are examples of the types of events that will be recorded:

a. Facility interruptions

b. Data errors

c. Equipment errors

d. Unauthorized activity, either on the equipment or in the area facility

e. Any activity that was planned and scheduled but did not occur

f. Certification and results of all scheduled activities

g. Unplanned activities such as downtime (any device), facility or equipment rearrangement, acts of God, waiting time as a result of critical parts, or people shortages

h. Disagreements between authorized test personnel in the resolution or actuality of specific incidents

i. Results of failure analysis, as the information becomes available.

5.7.3 Failure Report

A failure report (see example form, Figure 5-1) will be prepared each time an incident arises as identified in the Test Log and Data Record. Generation of this form will be the vehicle by which fault investigation and analysis, if required, are initiated. For each part or subassembly removed from equipment during testing, and which is known or suspected to be defective, a failure report will be generated immediately at the test site.

FAILURE REPORT

1. Report No.	2. Program		
3. Item in Test — Name	4. Part No.	5. Serial No.	6. Failure Date
7. Major Assembly/LRU	8. Part No.	9. Mfr.	10. Serial No.
11. Subassembly — Name	12. Part No.	13. Vendor	14. Serial No./Ref. Desig.
15. Component/Part — Name	16. Part No.	17. Vendor	18. Ref. Desig./IPB

19. Failure Detected During

20. Test Documentation

OP ________ Table ________ Step ________

OP ________ Table ________ Step ________

Other ________________________________

21. Cumulative Operating Time

________ Hours ________ Minutes ________ Cycles

22. Failure Description

23. Reported by

24. Cause of Failure

25. Reported by

26. Repair/Corrective Action

29. Approved by

27. Repaired by

28. Date Repaired

30. Comments/Approval

31. Comments/Approved by

Figure 5-1. Failure Report Form

5.7.4 Equipment Failure Record

An equipment failure record (see example form, Figure 5-2) will be maintained for each equipment, representing a summation of failures attributed to that equipment. Both relevant and nonrelevant failures will be recorded. Columns for cumulative relevant failures and usage time are provided. This record will be continuously maintained and updated immediately after each determination of failure and its cause. Cross-reference to the associated failure report will be included.

5.7.5 Sparing and Spare Parts Use Log

Based on the expected MTBF of the LRUs to be tested, one set of spare parts/subassemblies (board level) for selected LRUs should be made available for removal and repair actions. Replacement of LRUs may be accomplished only as directed by the procuring activity. Therefore, LRU sparing is not considered necessary.

A spare parts use log (see example, Figure 5-3) will be kept and retained at the test site. All activities associated with the flow of spare parts at the test site will be recorded in this log, particularly the identification of parts removed from or added to stock.

5.7.6 Final Report

The contractor will prepare and submit a final report within 30 days after completion of the reliability testing. This report will summarize all test results obtained during the contract.

5.8 TEST ASSESSMENT

The purpose of the BGM-34C reliability test program is to establish MTBF indices for critical subsystems/components and identify candidates for a Reliability Improvement Program (RIP). The failure analysis and corrective action requirements previously discussed in this section described the methods necessary for identifying RIP candidates. The following three statistical techniques describe methods to be used in establishing achieved MTBF and confidence in the results. It must be noted that the reliability test itself does not determine the true/actual MTBF of the article under test. However, the techniques used will give a realistic reliability estimate if a reasonable number of failures is observed.

5.8.1 Unconstrained Program Assessment

For the Unconstrained Program, the test time is unlimited. For test assessment purposes, the failure-truncated test method will yield valid MTBF evaluation results more efficiently than a time-truncation test if the observed MTBF is small. Assumptions and equations supporting this conclusion, together with sample calculations, appear in Appendix D.

5.8.2 Intermediate Test Level Assessment

The total test time for the Intermediate Program is 16,000 hours (see Section 2.4). Based on a time-truncated test of 16,000 equipment operating hours, MTBFs can be generated corresponding to one-sided confidence limits for various numbers of failures occurring during testing. If it is found that failures are distributed exponentially as a function of time, the mathematical framework and tables usable for the calculations appear in references 14 and 15, respectively (see Appendix D for sample table). Similarly, tables for failure distributions other than exponential may be generated.

5.8.3 Minimum Test Level Assessment

The total test time for the Minimum Program is 8,000 hours (see Section 2.4). Based on a time-truncated test of 8,000 equipment operating hours, a table of MTBF values corresponding to one-sided confidence limits for various numbers of failures similar to those described in Section 5.8.2 can be generated.

EQUIPMENT FAILURE RECORD

Equipment Name	P/N ______	S/N ______	Page __ of __

Item No.	Date	Accum. Usage Time	Accum. Non-Usage Time	Time Meter	Description of Failure	Relevant Yes/No

Verification	Contractor______________ Customer ____________

Figure 5-2. Equipment Failure Record Form

SPARE PARTS USE LOG

Item	Date	From Spares		To Replace		Next Assembly		Ref. FAR	Approval
		Part No.	Serial No.	Part No.	Serial No.	Part No.	Serial No.		

Figure 5-3. Spare Parts Use Log Form

6
TESTING PROGRAMS

This section defines three levels of reliability testing for Government planning considerations. These levels, which have been identified in this report as Unconstrained, Intermediate, and Minimum, are defined in terms of the following elements:

a. Test article selection
b. Test philosophy
c. Test environments
d. Test equipment
e. Test assessment
f. Test ground rules
g. Test profile.

Table 6-1 is a matrix summarizing the scope of each element for each level of testing.

The elements of the various test levels have been defined in a manner that makes each element independent (to the extent possible) of the others; thus, the elements of the three test levels can be combined into composite test approaches combining the best features of each test level. The test program that will be recommended in this report (see Section 6.4) will comprise essentially those elements indicated by shading in Table 6-1. The three levels described represent three of several approaches which could be considered. Table 6-1 shows the test planning criteria used to develop the three programs.

6.1 UNCONSTRAINED PROGRAM

In the Unconstrained Program, one set of test articles configured as shown in Figure 6-1 will be tested in accordance with the test profile depicted in Figure 6-2. Only one set of test articles is recommended because of the limited availability of STC and random vibration equipment. If additional test capabilities are available, it may be more economical to test additional articles simultaneously. As shown in Figure 6-2, test system performance characteristics of test articles will be checked only during times when the article is operating in its prescribed manner and environment for the BGM-34C system. Testing will be conducted per the ground rules presented in Sections 5.1 through 5.7. Test termination and assessment criteria will be as presented in Section 5.8.1. MTBFs for the system, and its subsystems and LRUs, can be determined from this test program.

TABLE 6-1. BGM-34C RELIABILITY TEST PLANNING MATRIX

Program Scope	Test Articles	Test Philosophy	Test Environments	Test Equipment	Test Assessment	Test Ground Rules
Unconstrained	Table 3-1, List 1	Integrated system	Combined Temp. Vibr. (all random) Individual Hum. (Sect. 4.2.1)	System test console (Sect. 4.4.1)	Failure-truncated (Sect. 5.8.1)	Section 5.1 - 5.7
Intermediate	Table 3-1, List 2	Integrated subsystem (Sect. 3.3.2)	Combined Temp. Vibr. (1 random, 7 sine) (Sect. 4.2.2)	Direct control panel test setup (Sect. 4.4.2)	Time-truncated, 16,000-hour MTBF test (Sect. 5.8.2)	
Minimum	Table 3-1, List 3	Individual LRU (Sect. 3.3.3)	Combined Temp. Vibr. (1 random, 3 sine) (Sect. 4.2.3)	Individual LRU field test sets (Sect. 4.4.3)	Time-truncated, 8,000-hour MTBF test (Sect. 5.8.3)	

NOTE: Shading denotes elements of recommended composite program; see Section 6.4.

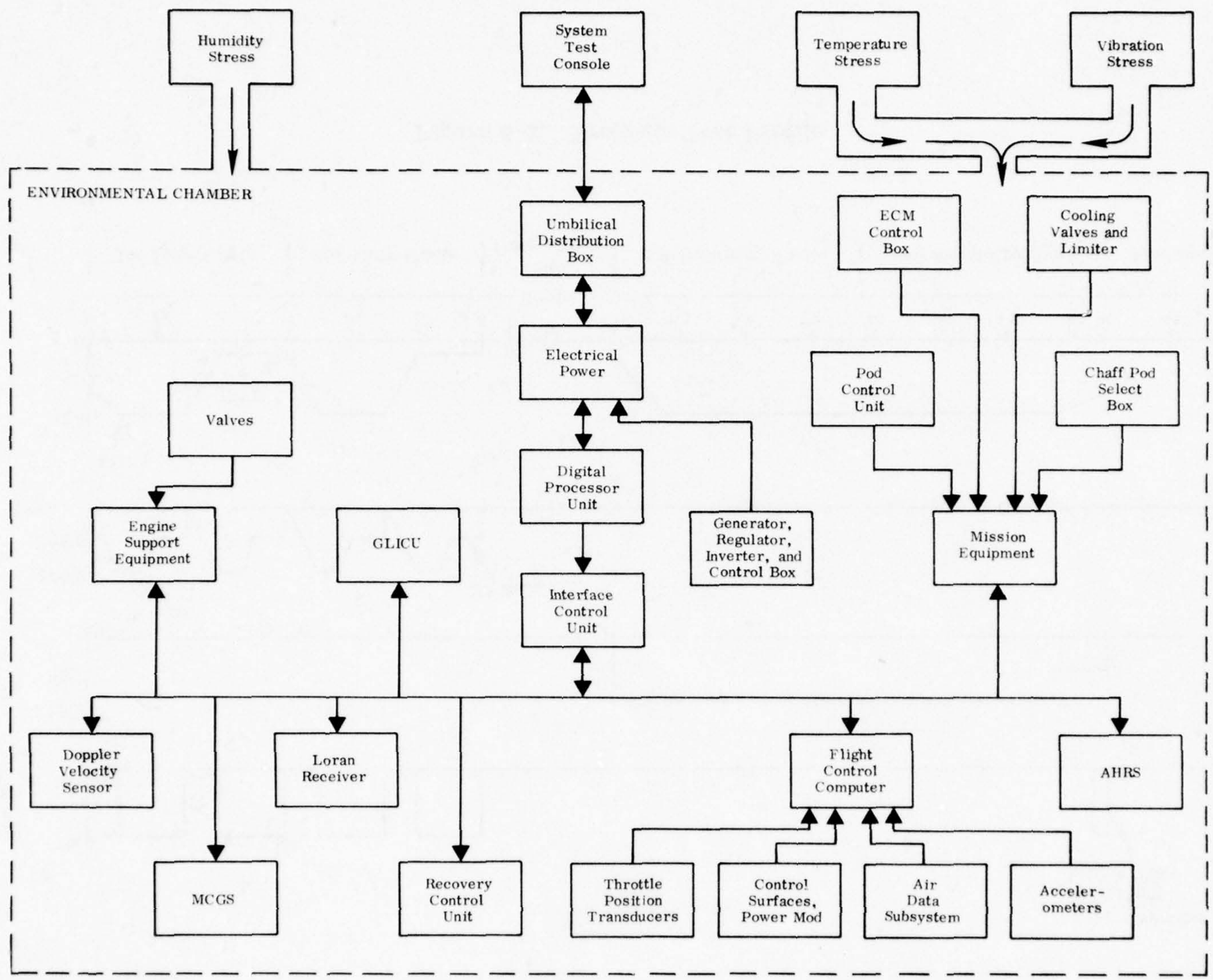


Figure 6-1. Unconstrained Program Test Configuration

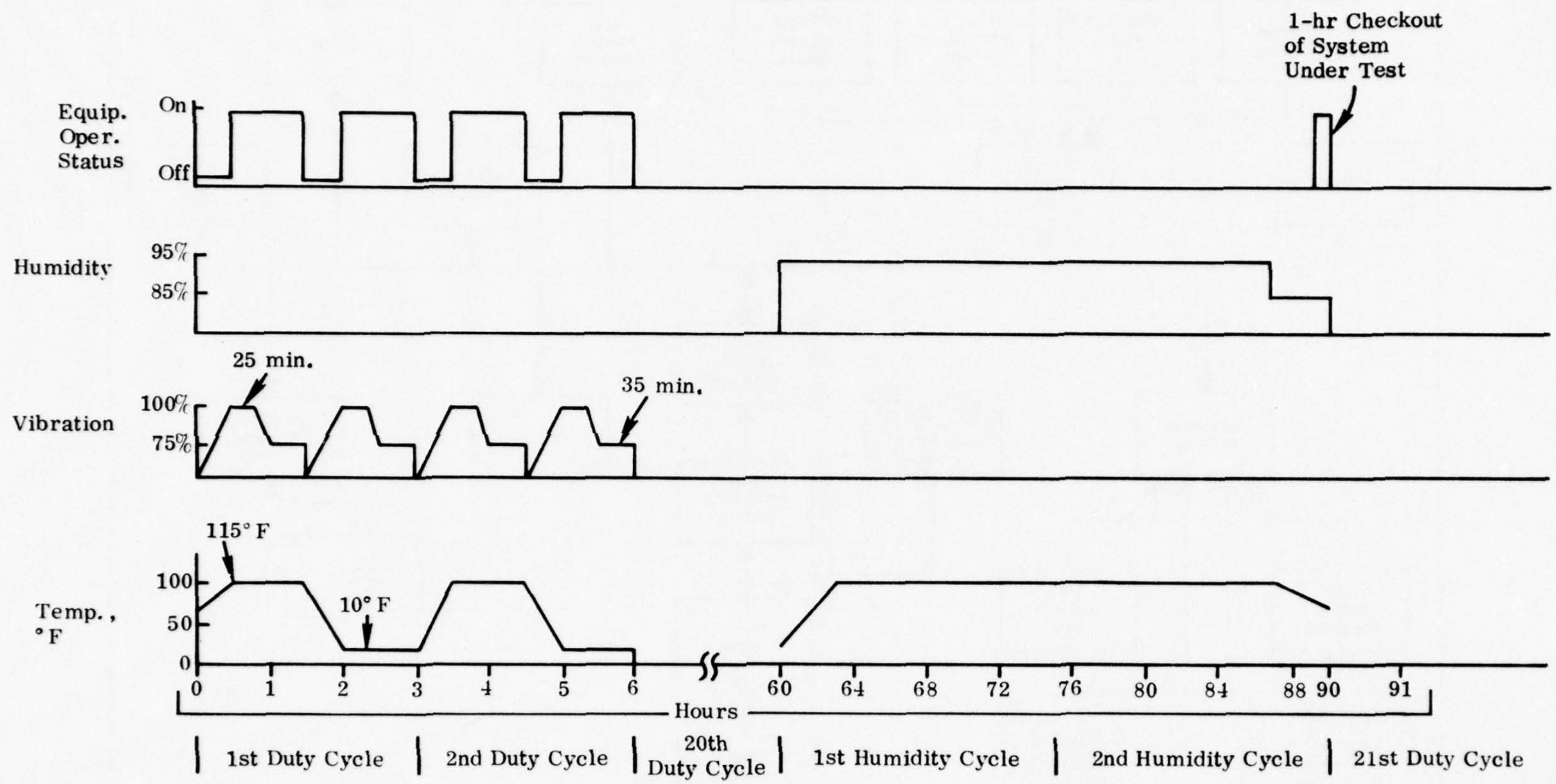


Figure 6-2. Program Test Profile

6.2 INTERMEDIATE PROGRAM

In the Intermediate Program, eight sets of test articles configured as shown in Figure 6-3 will be tested in accordance with the test profile of Figure 6-2, except that the humidity cycle will be omitted and vibration may be performed with one random and seven sinusoidal exciters if a total random capability does not exist. The test ground rules of Sections 5.1 through 5.7 will be applied. This testing program will be truncated after 16,000 hours of testing (2,000 hours per configuration), and the observed MTBF for the subsystems and LRUs will be determined by the methods described in Section 5.8.2.

6.3 MINIMUM PROGRAM

In the Minimum Program, four sets of test articles configured as shown in Figure 6-4 will be tested in accordance with the test profile of Figure 6-2, except that the humidity cycles will be omitted and vibration may be performed with one random and three sinusoidal exciters if a total random capability does not exist. However, the test profile will be modified to permit performance checking of only one or two LRUs per duty cycle. This modification is necessary due to the length of time required for an individual LRU test. The detailed test procedures generated in accordance with Section 5 will delineate the LRU test order and the required abbreviation of test monitoring steps necessary for a 2-hour (one duty cycle) LRU checkout limitation. The Figure 6-4 configuration is one of several possible test arrangements for the Minimum Program. For example, it may be found advantageous to place four loran receivers, four recovery control units, and four flight control computers in one chamber for testing, and different groups of LRUs in the other three chambers. These configurations will permit better test-performance monitoring.

With each of the four sets of LRUs tested for a period of 2,000 hours, the overall test will be completed after 8,000 hours and the observed MTBF for each LRU will be determined by the method described in Section 5.8.2.

6.4 RECOMMENDED PROGRAM

A composite reliability test program shown by the shaded boxes of Figure 6-1 is the recommended approach for BGM-34C test planning. It is believed that this approach incorporates the most desirable features of the three program plans from a standpoint of economy of resources and adequacy of evaluation.

Figures 6-5 and 6-6 show the recommended test program configuration and test profile, respectively.

The rationale for selection of each program element is as follows:

a. Test Articles – The Minimum Program test article list includes all new or modified LRUs (except the umbilical distribution box, which is not considered complex or a high-failure item), and other LRUs that are system critical and/or exhibit high failure rates on the basis of limited test experiences. One set of articles is recommended because of the anticipated availability of only one random vibration exciter. If more than one exciter is available or more than one set of articles can be placed in one chamber, multiple-set testing is recommended.

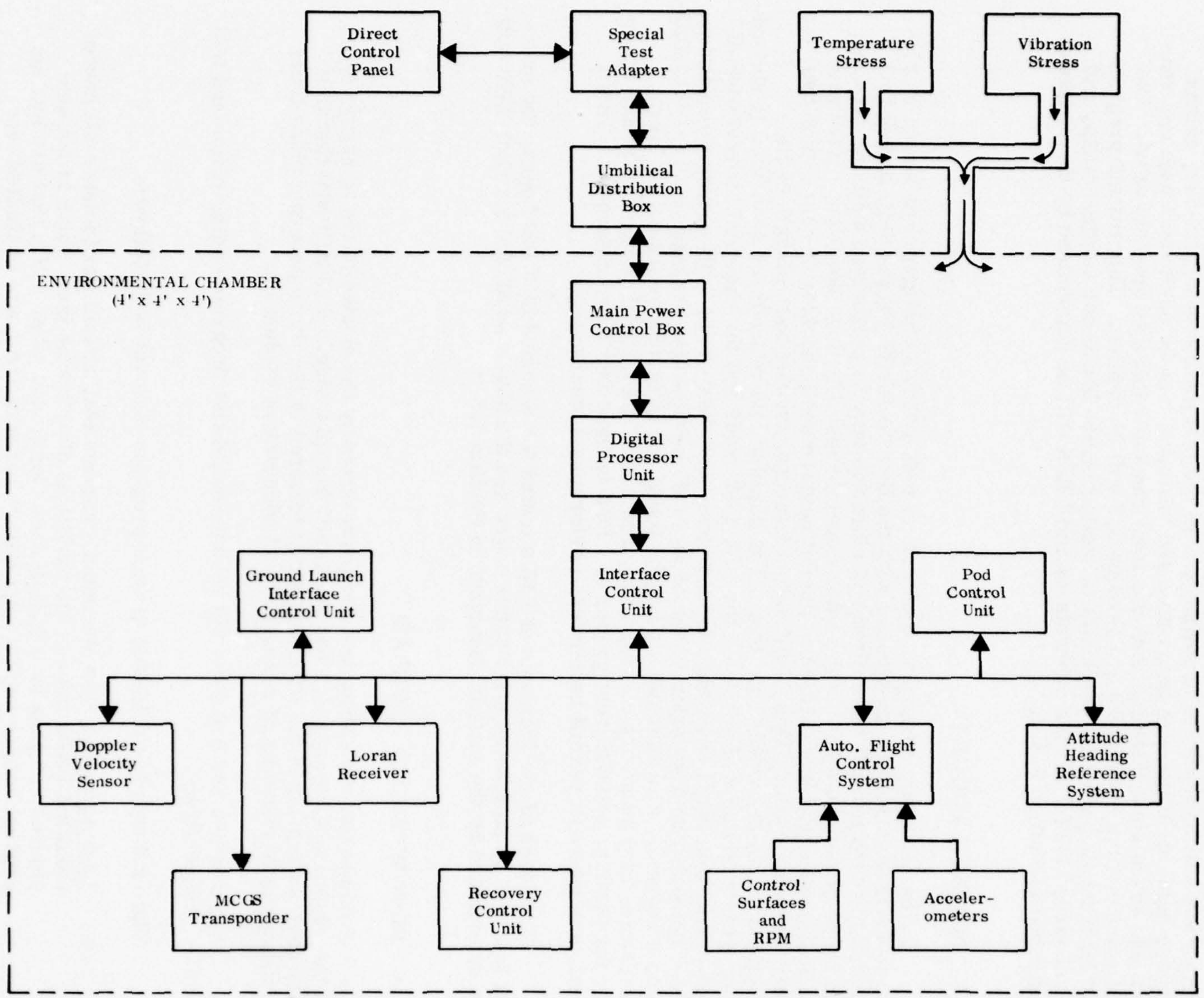


Figure 6-3. Intermediate Program Test Configuration

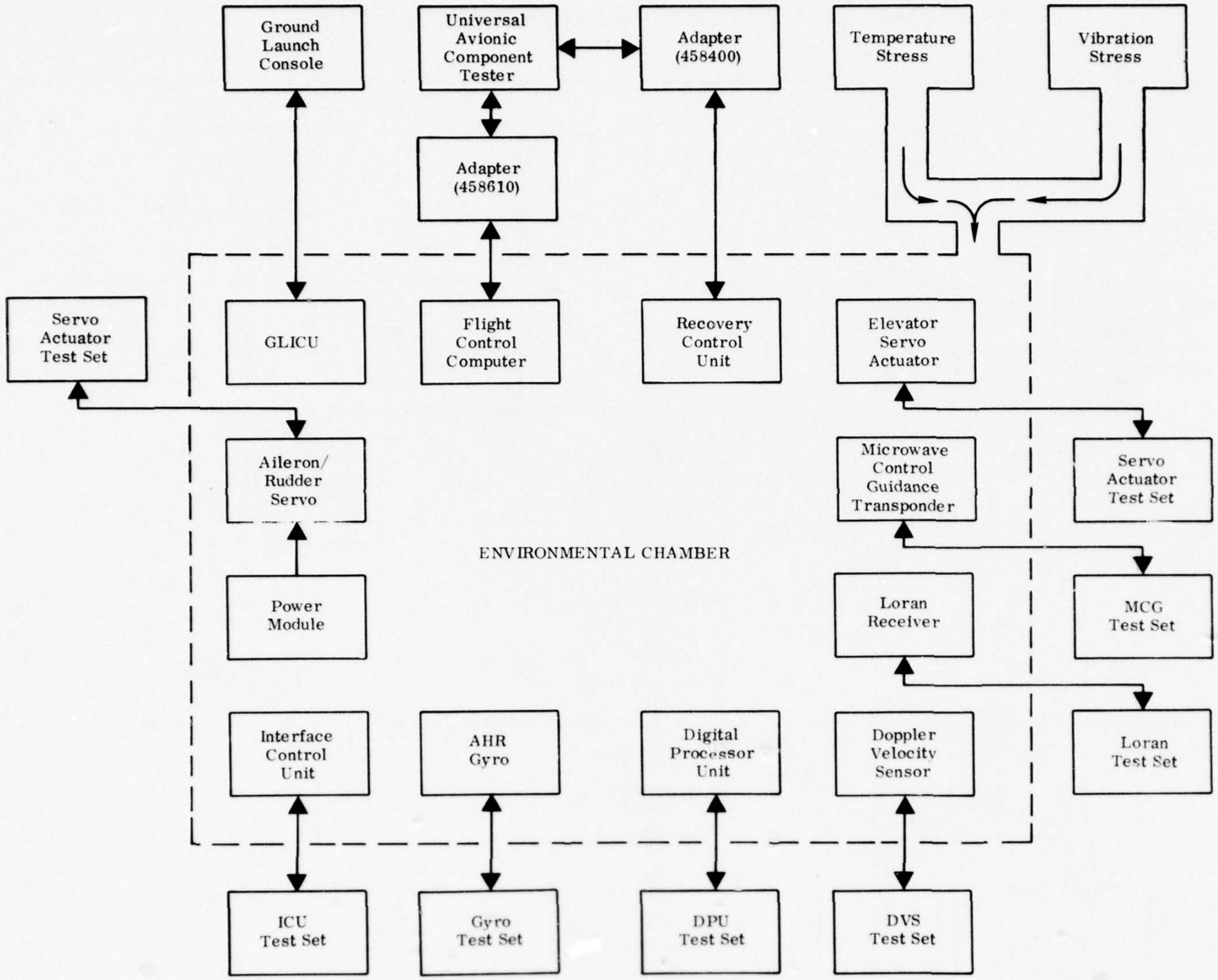


Figure 6-4. Minimum Program Test Configuration

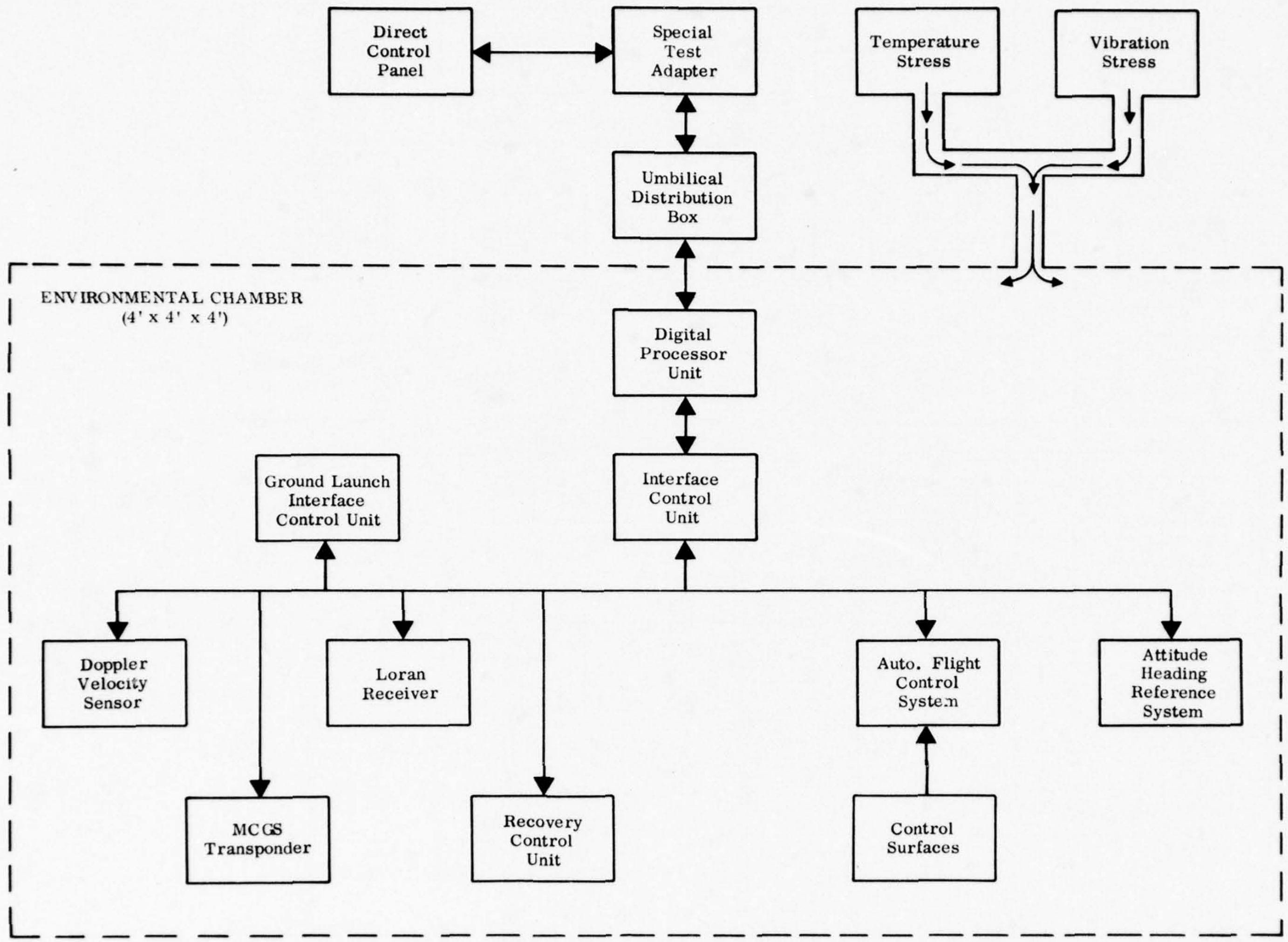


Figure 6-5. Recommended Program Test Configuration

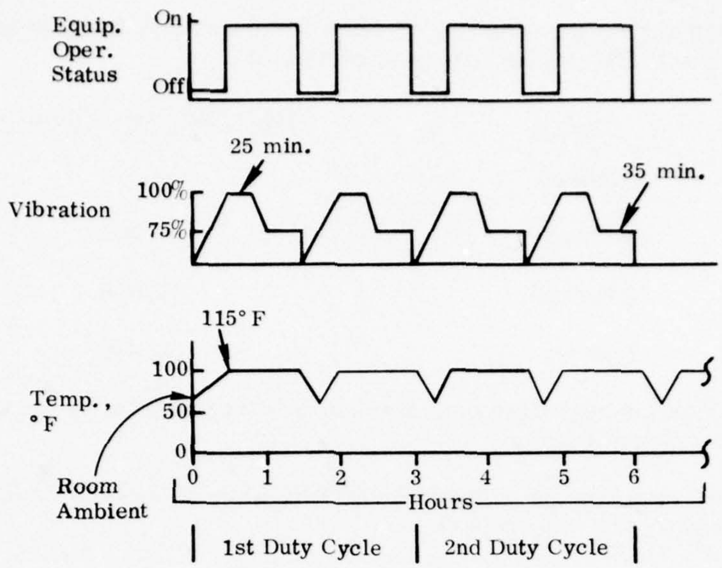


Figure 6-6. Recommended Program Test Profile

b. Test Philosophy – The integrated subsystem testing approach is recommended because it offers more valid inputs to total system evaluation than the individual LRU test approach, and permits better evaluation of individual LRUs than the integrated system approach.

c. Test Environments – Combined temperature and random vibration environments are recommended, with the following modifications. The low temperature requirement of 10°F will be eliminated because this temperature is considered benign to electronic items. Sinusoidal vibration is omitted because analysis of similar RPV equipment shows only random vibrational experience.

d. Test Equipment – A direct control panel for subsystem performance monitoring is recommended. The number and types of LRUs selected make it uneconomical to use a system test console due to its large cost; and use of individual LRU test sets is excessively time-consuming for operational checkout.

e. Test Assessment – The failure-truncated MTBF test is selected because the present BGM-34C flight test data show a high incident of failure for the LRUs recommended for testing. Statistically valid observed MTBFs with determined confidence intervals will be derived from a 41-failure termination test. If the flight-test failure data are indicative of typical LRU test failure rates, then the test time estimated for 41 failures of LRUs having various MTBF levels are as shown below:

MTBF	Expected Test Time, hr
Highest	10,250
Median	6,355
Average	5,300
Lowest	2,270

A maximum test time of 5,500 hours is recommended for estimating maximum testing length.

f. Test Ground Rules – Test ground rules are as described in Sections 5.1 through 5.7 of this report.

g. Test Profile – The test profile of Figure 6-2 is modified to delete the humidity and low temperature cycles. Thus the temperature will be cycled only between room ambient and 115°F for each duty cycle.

The test program described above would provide not only the statistical data base by which subsystems and LRUs could be assessed, but also for detailed and precise problem-identification and corrective-measures assessments.

APPENDIX A

LISTING OF BGM-34C LINE REPLACEABLE UNITS

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Airframe	Wing	1	Wing Assembly	259W105-1
		2	Wing Tips, LH, RH	259W102-1, -2
		2	Aileron Assembly	259S101-1
		2	Pylon Assembly, LH, RH	259W150-1, -2
	Empennage			
		1	Vertical Stablizer	259T103-1
		1	Horizontal Stabilizer	147T942-9
		1	Rudder Assembly	259S102-1
		2	Elevator Assembly	147S214-1
	Fuselage			
		1	Nose Module	255N101-1
		1	Nacelle	255N100-5
		1	Fairing	255F111-3
		1	Main Chute Container	259L100-1
		1	Drag Chute Container	147L6000-1
Propulsion	Engine	1	Engine	J69-T-41A TCAE712540
		1	Fuel Control	Chandler Evans MC-16-87900-E1
		1	Throttle Actuator	Globe 67A246B
		1	Prestart Fuel Valve	CAE 303612
		1	Throttle Servo	451070-01-01
	Fuel	1	Motorized Fuel Expulsion Valve	SCDP0008-1 Gen Con AV 1631637
		1	Fuel Shut Off Solenoid Valve	SCDP0006-3 Valvor-V-14500-109
		2	RH & LH Fuel Pod Quick Disconnect	259P221-1
		1	Fuel Sump Drain Valve	MS29530-8
		1	Filter, Engine Bleed Air	Circle Seal 422XT-6TT

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Propulsion (continued)	Fuel (continued)	2	Pilot Float Operated Valve	259P204-1
		1	Check Valve, Engine Bleed Air	Allen Aircraft 6C240-3
		1	Fuel Boost Pump	61P238-1
		1	Pressure/Vacuum Relief Valve	259P301-1 Sterer
		1	Air Pressure Regulator	SCDRA0011-1 Altair
		1	Refueling Pressure Regulator	259P206-1
		1	2 Position 3 way Solenoid Valve	SCDVA002-1 Sterer
		2	Fuel Pod Solenoid Valve LH & RH	259P237-1
		1	Hi Pressure Fuel Adapter	MS24484-2
		1	Pressure Check Quick Disconnect	AVHN6-6-56
		2	Fuel Level Control S. O. Valve	259P203-1
		1	Manual Drain Valve, Vent System	MS29530-8
		2	Pilot Float Operated Valve	255P302-1
		1	Pressure/Vacuum Relief Valve (Fuel Vent)	259P301-1
		1	Pressure/Vacuum Relief Valve	147P4629-1
		1	Main Tank Fuel Vent Valve	SCDP0007-1
		1	25K Fuel Vent Baro	Gorn GBC-300-6
		1	Engine Bleed Air Valve	Valcor V-4700-12
		1	Engine Anti Bleed Valve	Valcor V-4700-12
		1	Fuel Vent System Tank	255P308-1

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Propulsion (continued)	Fuel (continued)	1	Pressure/Vacuum Relief Valve Pneumatic	259301-1
	Oil			
		1	Oil Tank Vent Shutoff Valve	Valcor V-14500-52
		1	Pressure/Vacuum Relief Valve	Clary 97870-2
		1	Oil Filter	Part of Engine
		1	Oil Tank Drain	Auto Valve 750B-2S
	Exhaust			
		1	Tailpipe Assembly	147P103-41
		1	Shroud, Upper Forward	124P314-179
		1	Shroud, Upper Aft	147P199-25
		1	Shroud, Lower	147P199-27
		1	Clamp, V-Band	Marman 53413-2118SH
		1	Tailpipe V-Band Clamp	Marman MVT67086R1350M
		1	Termocouples & Harness	706314
		2	LH & RH Rule Pods	Sargent-Fletcher 15-67-48081-2
		2	LH & RH Fuel Pod Low Level Switches	Sargent-Fletcher 15-67-20489
		4	LH & RH Pod Drain Valves (2 ea)	Sargent-Fletcher 50163
Electrical	Common Electric			
		1	Main Power Control Box	259E250-1
		1	Special Devices Box	LSI 456030-01
		1	Umbilical Dist. Box	LSI 454980-01
		1	Recovery Control Unit	LSI 454300-01
		1	Fuel Expulsion Control Box	147E318-3

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Electrical (continued)	Common Electric (continued)	2	Main Initiator LH No. 1 and No. 2	147L1501-1
		1	Barometric Switch Assembly	455310-01-01
		4	Resistor Cans	147E136-1
		2	Main Initiator Center No. 1 & No. 2	147L150-1
		2	Main Initiator RH No. 1 & No. 2	147L1501-1
		2	Drag Initiator LH No. 1 & No. 2	147L1501-1
		2	Drag Initiator RH No. 1 & No. 2	147L1501-1
		1	Battery Back-up	147E381-1
		1	Battery-Main	147E2156-1 Yardney 203065
		1	Voltage Regulator	MS18071-2
		1	Relay Assembly - AC Power Control	259E554-1
		1	Door Interlock Switch	12459-112-1
		1	Chaff Pod Selector Box	259E550-1
		1	Pod Control Unit	259E750-1
	Mars Electrical			
		1	Stab Chute Switch	Grayhill 39-101
		1	Cable Cutter	Holex R9312-1
	Surface Retrieval Electrical			
		1	Riser Release Explosive Bolt	166L020-1
		1	"G" Switch 5K Baro	LSI 453393-01
		1	"G" Switch No. 1	154L0191-1
		1	"G" Switch No. 2	154L0191-1

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Electrical (continued)	Electrical Power			
		1	Generator	147E2152-3 14759-360
		1	Inverter 750VA, 30	MS17406-3
Avionics	Navigation/ Guidance			
		1	Doppler Velocity Sensor (DVS)	TRESS 1001A0001-G1
		1	Radar Altimeter	AN/APM-194
		2	Antenna, Radar Altimeter, LH & RH	LSI 454804-01-01
		1	Loran Receiver	LSI 4546301-01-01
		1	Loran Coupler	LSI 454660-01
		1	Loran Antenna	147R6007-3
		1	Bulk Storage Unit	LSI 454850-01-01
		1	"D" Band Beacon	Vega 316L
		1	"D" Band Antenna	124R407-1
		1	"G" Band Beacon	SST-171C
		1	"G" Band Antenna	147R1064
	Automatic Flight Control			
		1	Flight Control Computer	LSI 4511800-01-01
		1	Pitot-Static Tub	SCDT0001-3
		1	Total Air Temp Probe	LSI 455004-01
		1	AHR Electronic Control Amplifier	LSI 454904-01-01
		1	AHR Displacement Gyro	LSI 454903-01-01
		1	Compass Transmitter	259E657-1

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Avionics (continued)	Automatic Flight Control (cont)	1	Normal Accelerometer	LSI 429916-01-01
		1	Lateral Accelerometer	LSI 429916-01-01
		1	Throttle Position Transducer	LSI 451400-01-01
		2	Aileron Servo Actuator	2590002-1
		1	Elevator Servo Actuator	LSI 428895-02-01
		1	Rudder Servo Actuator	2590002-1
		1	Power Module ±12 VDC	SCDP0008-1
		1	Interface Control Unit	LSI 453800-01-01
		1	Digital Processor	LSI 454500-01
		1	DPU/BSU Power Control Relay	LSI 453424-01
Remote Control Guidance	MCGS			
		1	MCGS Transponder	AN/APW-26
		1	MCGS Antenna	Sperry 2589170
		1	MCGS Waveguide Filter	259E570-1
		1	MCGS Waveguide	259K056-1
		1	MCGS Waveguide	259K056-3
			Telemetry	
		1	Tachometer	GEU-7/A
		1	Fuel Sensor	Edcliff 118301-7
		1	AC/DC Frequency Convertor	Foxboro FR 320-101
		1	Aft Equipment Compartment Vent Valve	259K017-3
		1	Environmental Control Relay	MS24140-D1
		1	Pressure Vacuum Relief Valve	147P4612-1 Sterer 47600

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
	Environmental Control System			
		1	Environmental Control Module	259P101-7, -9, -13
		1	Refrigerant Storage Bottle	259P101-15
		2	Quick Disconnect	Seaton Wilson ZN-1452-4-M4D
		1	Temperature Gage	TBD
		1	Pressure Gage	TBD
		1	45K Pressure Baro Switch	Gorn GBC-300-48
		1	Door Interlock Switch	12459-112-1
		1	Quick Disconnect	Seaton Wilson ZN-1452-4-M4D
		1	Blower Assembly	Woodstock 026942
		1	"A" Transmitter Cooling Valve	255P115-1
		2	"C" Transmitter Cooling Valve	255P115-1
		2	"E" High, Low Transmitter Cooling Valve	255P115-3
Payload	Strike			
		1	Television Camera	Fairchild MX-8035/AXQ-2
		1	Power Supply Synchronizer	Fairchild PP-6012/AXQ-2
		1	TV Camera Tilt Actuator	SCDAA0001-1
		1	Static Invertor 750VA, 30	MS17406-3
		1	Store Interface Unit	259E1150-1
		1	Launcher Electronic Unit	Hughes 3102368
		1	Exciter, TWTA	Univac 2278758

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Payload (continued)	Strike (continued)	1	Antenna Controller	Univac 2279064-00
		1	Waveguide Adaptor	MS22641/19-01
		1	Waveguide Isolator	Univac 2279067
		1	Waveguide Filter	259E570-3
		1	Waveguide, Flex	FG090ACCA08
		1	Antenna and Drive Unit, 2 Axis	Univac 2279065-00
		2	Launcher Rail Assembly LH & RH	Hughes D3088665-1-1
		2	Maverick Store, RH & LH	AGM-65A
		1	ECM Control Box	255E1000-1
		1	Limiter Assembly	255E1050-1
		2	"E" High, Low Control Box	Melpar R458983-1
		1	"A" Transmitter	Melpar R539444
	EW			
		2	"C" Transmitter	Melpar R539426-1
		1	"E" High Transmitter	Melpar R539427-2
		1	"E" Low Transmitter	Melpar R539427-3
		1	"A" Antenna	255R550-1
		1	C_1 and C_2 Antenna	255R551-1
		1	"E" High Antenna	255R552-3
		1	"E" Low Antenna	255R552-1
		2	Chaff Pod RH & LH	AN/ALE-2 or AN/ALE-38
	RECCE			
		1	Static Inverter 1KVA,10	MS17406-1
		1	Camera Set With Data Annotation	Fairchild K120A

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Recovery	Pilot Chute			
		1	Pilot Chute	Pioneer 2.1413GR-1
		1	Bridle	Pioneer 13.627GR-2
		1	Lanyard Tie Break	Pioneer 9.192GR-1
		1	Break Tape	
	Drag Chute			
		1	Drag Chute	Pioneer 19.1889GR8
		1	Deployment Bag	Pioneer 13.2156GR-1
		2	Reefing Cutter	Pioneer 15.143
	Main Chute			
		1	Main Chute	Pioneer 19.1887GR16D
		1	Deployment Bag	Pioneer 13.2276GR-1
		2	Reefing Cutter	Tech Ord 211520
		1	Release Mechanism	147L1065-5
		1	Riser	147Q011-53
	Engagement Chute			
		1	Engagement Chute Canopy	Pioneer 1.3366GR-5
		1	Load Line	Pioneer 3.7466GR-1
		2	Reefing Cutter	Tech Ord 211622
		2	Apex Tie Cutter	Tech Ord 212219
		1	Apex Break Cord	

BGM-34C LRU LISTING

SEGMENT	ELEMENT	LRU		
		NO.	NOMENCLATURE	PART NUMBER
Ground Launch Propulsion	Rocket Motor			
		1	Rocket Motor	Thiokol TU793/01
		1	Forward Support Assembly	259M021-1
		1	Aft Support Assembly	259M022-1
		1	Ground Launch Interface Control Element	259E950-1
		1	Rocket Motor Igniter Element	Thiokol 7U46649-01
		1	Thrust Vestor Control Element	Thiokol TU-795L415476

APPENDIX B

SELECTED TEST ARTICLES

B.1 UNCONSTRAINED PROGRAM LRUs (LIST 1)

B.1.1 Personnel Safety Critical LRUs (Class I)

Failure of any LRU on this list would constitute a personnel safety threat; available experience data are insufficient to permit evaluation of their operational reliability.

Aileron servo actuator

Elevator servo actuator

Rudder servo actuator

Power module, ±12 Vdc

B.1.2 Recovery Critical LRUs (Class II)

Failure of any LRU on this list could prevent recovery of the RPV; available experience data are insufficient to permit evaluation of LRU operational reliability.

Pressure/vacuum relief valve

Manual drain valve, vent system

Main tank fuel vent valve

Main power control box

RH & LH fuel pod quick disconnect

Ground launch interface control unit

Pod control unit

Voltage regulator

Inverter, 750 VA

Flight control computer

Interface control unit

Air data subsystem (pitot-static and total air temperature)

AHR electronic control amplifier

AHR displacement gyro

Throttle servo actuator

B.1.3 Mission Critical LRUs (Class III)

Failure of any LRU on this list could prevent mission completion; experience data are insufficient to permit evaluation of their operational reliability.

Pilot float operated valve

Fuel level control S.O. valve

Relay assembly, AC power control

Generator

ECM control box

Transmitter cooling valve (A, C, and E)

Limiter assembly

High and low control box (E)

Normal accelerometer

Lateral accelerometer

Throttle position transducer

Digital processor unit

B.1.4 Cost Critical LRUs (Class IVb)

LRUs on this list have high predicted failure rates and/or high maintenance costs; available experience data are insufficient to permit evaluation of their operational impact on the system.

Umbilical distribution box

Chaff pod selector box

Doppler velocity sensor

Loran

Recovery control unit

MCGS transponder

B.1.5 Non-Critical, No Test LRUs (Class IVc)

LRUs on this list are new or modified items that are not safety, recovery, mission, or cost critical (regardless of experience data availability). Reliability predictions for these LRUs may be used until experience data become available for assessment.

Battery, main

Battery, back-up

Radar altimeter

Telemetry

Tachometer

Fuel sensor

AC/DC frequency converter

Aft equipment comp. vent valve

B.2 INTERMEDIATE PROGRAM LRUs (LIST 2)

B.2.1 Personnel Safety Critical LRUs (Class I)

Failure of any LRU on this list would constitute a personnel safety threat; available experience data are insufficient to permit evaluation of their operational reliability.

Aileron servo actuator

Elevator servo actuator

Rudder servo actuator

Power module, ±12 Vdc

B.2.2 Recovery Critical LRUs (Class II)

Failure of any LRU on this list could prevent recovery of the RPV; available experience data are insufficient to permit evaluation of their operational reliability.

Ground launch interface control unit

Pod control unit

Flight control computer

Interface control unit

AHR electronic control amp

AHR displacement gyro

Throttle servo actuator

Main power control box

B.2.3 Mission Critical (Class III)

Failure of any LRU on this list could prevent mission completion; available experience data are insufficient to permit evaluation of the operational reliability of the LRU.

Normal accelerometer

Lateral accelerometer

Throttle position transducer

Digital processor unit

B.2.4 Cost Critical LRUs (Class IVb)

LRUs on this list have high predicted failure rates and/or maintenance costs; available experience data are insufficient to permit evaluation of their operational impact on the system.

Doppler velocity sensor

Loran

Recovery control unit

MCGS transponder

B.2.5 Non-Critical, No Test LRUs (Class IVc)

LRUs on this list are new or modified units that are not safety, recovery, mission, or cost critical (regardless of experience data availability). Reliability predictions for these LRUs may be used until experience data become available for assessment.

Battery, main

Battery, back-up

Radar altimeter

Telemetry

Tachometer

Fuel sensor

AC/DC frequency converter

Aft equipment comp. vent valve

Pressure/vacuum relief valve

Manual drain valve, vent system

Main tank fuel vent valve

RH & LH fuel pod quick disconnect

Voltage regulator

Air data subsystem (pitot-static & total air temp)

Pilot float operated valve

2-position 3-way solenoid

Fuel level control S.O. valve

Relay assembly - AC power control

("A", "C", & "E") transmitter cooling valve

Inverter 750 VA

Chaff pod selector box

Pilot float operate valve

Generator

ECM control box

Limiter assembly

"E" high & low control box

Umbilical dist. box

B.3 MINIMUM PROGRAM LRUs (LIST 3)

B.3.1 Personnel Safety Critical LRUs (Class I)

Failure of any LRU on this list would constitute a personnel safety threat; available experience data are insufficient to permit evaluation of their operational reliability.

Aileron servo actuator

Elevator servo actuator

Rudder servo actuator

Power module ±12 Vdc

B.3.2 Recovery Critical LRUs (Class II)

Failure of any LRU on this list could prevent recovery of the RPV; available experience data are insufficient to permit evaluation of their operational reliability.

Ground launch interface control unit

Flight control computer

Interface control unit

AHR displacement gyro

B.3.3 Mission Critical LRUs (Class III)

Failure of the LRU on this list could prevent mission completion; available experience data are insufficient to permit evaluation of its operational reliability.

Digital processor unit

B.3.4 Cost Critical LRUs (Class IVb)

LRUs on this list have high predicted failure rates and/or maintenance costs; available experience data are insufficient to permit evaluation of their operational impact on the system.

Doppler velocity sensor

Loran

Recovery control unit

MCGS transponder

B.3.5 Non-Critical, No Test LRUs (Class IVc)

LRUs on this list are new or modified items that were analyzed and found not to be safety, recovery, mission, or cost critical (regardless of experience data availability). Reliability predictions for these LRUs may be used until experience data become available for assessment.

- Battery, main
- Battery, back-up
- Radar altimeter
- Telemetry
- Tachometer
- Fuel sensor
- AC/DC frequency converter
- Aft equipment comp. vent valve
- Pressure/vacuum relief valve
- Manual drain valve, vent system
- Main tank fuel vent valve
- Main power control box
- RH & LH fuel pod quick disconnect
- Voltage regulator
- Air data subsystem (pitot-static & total air temp)
- 2-position 3-way solenoid
- Fuel level control S.O. valve
- Relay assembly - AC power control
- Door interlock switch
- Transmitter cooling valve (A, B, C)
- Inverter 750 VA
- Chaff pod selector box
- Pilot float operate valve
- AHR electronic control amplifier
- Generator
- ECM control box
- Limiter assembly
- High & low control box (E)
- Umbilical dist. box
- Pod control unit
- Throttle servo actuator
- Throttle position transducer
- Normal accelerometer
- Lateral accelerometer

B.4 NON-SELECTED LRUs (Class IVa)

LRUs on this list have sufficient operational assessment data available to permit realistic establishment of operational reliability without additional testing; LRUs excluded by ASD direction (denoted by asterisk).

- Wing assembly
- Wing tips, LH, RH
- Aileron assy
- Pylon assy, LH, RH
- Vertical stabilizer
- Horizontal stabilizer
- Rudder assy
- Elevator assy
- Nose module
- Nacelle
- Fairing
- Main chute container
- Drag chute container
- Engine
- Fuel control
- Prestart fuel valve
- Motorized fuel, expulsion valve
- Fuel shut off, solenoid valve
- Fuel sump drain valve
- Filter, engine bleed air
- Check valve, engine bleed air
- Solenoid valve, 2 position 3 way
- Fuel boost pump
- Air pressure regulator
- Hi pressure fuel adapter
- Pressure check quick disconnect
- Pressure/vacuum, relief valve (fuel vent)
- 25K fuel vent barometer
- Engine bleed air valve
- Engine anti bleed valve
- Fuel vent system tank
- Pressure/vacuum relief, valve pneumatic
- Oil tank vent shutoff, valve
- Pressure/vacuum, relief valve
- Oil filter
- Oil tank drain
- Tailpipe assembly
- Shroud, upper forward
- Shroud, upper aft
- Shroud, lower
- Clamp, V-band
- Tailpipe V-band clamp
- Refueling pressure regulator
- Thermocouples and harness
- LH & RH fuel pods*
- LH & RH fuel pod low level switches*
- LH & RH pod drain valves (2 ea)*
- Fuel expulsion control box*
- Barometric switch assembly*
- Door interlock switch*
- Stab chute switch*
- Cable cutter*
- Bulk storage unit*
- "D" band beacon
- "D" band antenna*
- "G" band beacon
- "G" band antenna*
- Environmental control module*
- Refrigerant storage bottle*
- Quick disconnect*
- Temperature gage*
- Pressure gage*

45K pressure baro switch
Quick disconnect*
Blower assembly
"C" transmitter*
"E" high transmitter*
"E" low transmitter*
"A" antenna*
C_1 and C_2 antenna*
"E" high antenna*
"E" low antenna*
Chaff pod R& & LH
Pilot chute*
Bridle*
Lanyard tie break*
Break tape*
Drag chute*
Deployment bag*
Reefing cutter* (Main Chute)
Engagement chute canopy*
Load line*
Reefing cutter*
Apex tie cutter*

Apex break cord*
Rocket motor*
Fwd. support assembly
Aft. support assembly
Main chute*
Deployment bag*
Reefing cutter* (Drag Chute)
Release mechanism*
Riser*
Rocket motor igniter element*
Thurst vector control element*
Antenna, radar altimeter*
MCGS antenna*
MCGS waveguide
MCGS waveguide filter
Main initiator
Drag initiator*
Resistor cans*
Strike payload LRUs*
RECCE payload LRUs*
Compass transmitter

APPENDIX C

REFERENCES

REFERENCES

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APPENDIX D
TEST DATA ANALYSIS CONSIDERATIONS

One objective of the BGM-34C reliability test program is to ascertain the length of time the system (or any of its LRUs) operates before it fails or requires repair. The pertinent test data will therefore consist of the time intervals representing the lifetimes of the failed test articles, and the operating time until test termination for the unfailed test articles. For the BGM-34C program, lifetime will be regarded in terms of time to failure.

The reliability calculations for the BGM-34C assume a constant failure rate for estimating the mean life, Θ, and for determination of the confidence interval of the test articles.

D.1 FAILURE-TRUNCATED TESTING

For the general case where test time has not been specified, the following method can be applied to determine test truncation at a given number of failures.

From analysis of BGM-34 flight test data[10], it was established that:

a. Hours of operation $\simeq$ 155

b. Number of failures $\simeq$ 85

The following equation (ref. 14, Section 2B6.2) yields the number of failures at which a test should be terminated:

$$r = \left\{ \frac{K_\beta + (\Theta_0/\Theta_1)K_\alpha}{(\Theta_0/\Theta_1) - 1} \right\}^2 \tag{1}$$

where

α = producer's risk

β = consumer's risk

Θ_0 = acceptable MTBF, considered in conjunction with α

Θ_1 = unacceptable MTBF, considered in conjunction with β

K = normal deviate

r = number of failures for test termination.

For a very accurate and hence lengthy test, applicable values of the constants in equation 1 might be:

$\alpha = \beta = 0.01$ (1%)

$\Theta_0/\Theta_1 = 1.1$

from which we have:

$$r = \left\{\frac{2.326 + 1.1(2.326)}{0.1}\right\}^2 = 2385.9 \tag{2}$$

If we assume the more commonly applied producer and consumer risks of $\alpha = \beta = 0.1$, the test time can be substantially reduced while providing high confidence in the results. That is,

$$r = \left\{\frac{1.282 + 1.1(1.282)}{0.1}\right\}^2 = 724.8 \tag{3}$$

By further assuming a commonly accepted value of 2/3 for Θ_1/Θ_0, the number of failures at which termination would occur would be 41.

Using the present flight data, the estimate for equipment MTBF is $\Theta = 155/85 = 1.8235$. From this value the expected test times would be:

r	Expected Test Time
2386	4351 hr
725	1322 hr
41	75 hr

Should more precise data for calculating equipment MTBF be available, revised calculations will be required.

D.2 TIME-TRUNCATED TESTING

Table D-1 gives MTBFs corresponding to one-sided confidence intervals for various numbers of failures occurring during a time-truncated test of 16,000 equipment hours. To obtain values for a test of time T, one must multiply by T/16,000.

TABLE D-1. ONE-SIDED CONFIDENCE LIMITS FOR 16,000-HOUR TIME-TRUNCATED TEST

No. of Failures	One-Sided Confidence Limit on Θ at Indicated Confidence Level			
	80%	90%	95%	99%
0	9937.89	5904.06	5333.33	3470.72
1	5333.33	4123.71	3375.53	2409.64
2	3729.60	3013.18	2539.68	1904.76
3	2898.55	2395.21	2061.86	1593.63
4	2388.06	2000.00	1748.63	1379.31
5	2020.20	1720.43	1523.81	1223.24
10	1145.31	1038.96	944.51	794.83
20	647.88	589.71	551.31	484.06
50	280.11	265.87	253.00	230.68
100	146.68	140.19	135.40	126.73
200	75.10	73.02	71.07	68.04
500	30.71	30.13	29.85	28.77

To illustrate the use of the table, consider the situation where 20 test failures have occurred. Thus the following probability statement can be made:

$$\Pr\left\{\Theta \geq 647.88 \,\middle|\, T = 16000,\ r = 20\right\} = 0.80 \qquad (4)$$

where

Θ = True but unknown mean time between failures

T = Time at which the test was truncated

r = Number of test failures

This table was generated under the assumption of a constant failure rate. The mathematical framework is detailed in reference 15, and the tables used in the calculation can be found in reference 16.

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