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ENVIRONMENTAL ACCEPTANCE TEST SPECIFICATION FOR THE FLIGHT MODEL UK-2/S-52 SPACECRAFT

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GODDARD SPACE FLIGHT CENTER

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ENVIRONMENTAL ACCEPTANCE TEST SPECIFICATION FOR THE FLIGHT MODEL UK-2/S-52 SPACECRAFT

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1. SCOPE

1.1 General. - This specification establishes the Environmental Acceptance Tests for the Flight Model UK-2/S-52 Spacecraft. The purpose of these tests is to demonstrate satisfactory performance of the spacecraft under the various environments it may be exposed to during its lifetime. These tests are intended to discover any defects in material or workmanship and to provide information relating to the unique characteristics of the spacecraft. Included also are those operations, such as dynamic balancing, which are necessary for the proper functioning of the spacecraft.

1.1.1 This specification is part of a series which, collectively, constitute a complete test program for the UK-2/S-52 Satellite. Final acceptance for flight of the Flight Model Spacecraft is subject to the satisfactory performance throughout this test program.

1.2 Responsibility for Administration. - The responsibility and authority for decisions relative to the requirements of this specification rests with the Test and Evaluation Division, subject to review by the Project Manager and the Reliability Assurance Council.

2. APPLICABLE DOCUMENTS

2.1 Electronic Test Procedures for the Environmental Design and Flight Qualification Testing of the UK-2/S-52 Satellite

3. GENERAL INSTRUCTIONS

3.1 Expected Environments. - The integrated flight model spacecraft shall perform satisfactorily under conditions no greater than that expected to exist during time of operation in orbit and to be able to withstand, with no permanent degradation, all environmental conditions expected to be encountered prior to orbiting including such conditions as storage, standby, and launch.

3.1.1 Simulation of Environment. - This specification is intended to provide for test conditions which will disclose quality and workmanship defects without aging or otherwise reducing the useful life of the spacecraft.

3.1.2 Selection of Alternate Test Limits. - Where an option or waiver in test limits is permitted, the applicable component specification shall specify the test limits.

3.2 Special Definition. - For purposes of this document, a "60-40 orbit" shall mean that the spacecraft will be operated in a manner simulating an orbit wherein the spacecraft is in sunlight 65 minutes and in darkness for 38 minutes. A "100% orbit" shall mean that the spacecraft is operated in a manner simulating an orbit wherein the spacecraft is in sunlight 100% of the time. These nominal times may be varied during a test, such as simulating a sunrise out of sequence, for the purpose of obtaining a more effective test.

3.3 Test Facilities. -

3.3.1 General. - The apparatus used in conducting tests shall be capable of producing and maintaining the test conditions required, with the equipment under test installed on the apparatus and operating or non-operating as required.

3.3.2 Volume. - The volume of the test facilities shall be such that the bulk of the equipment under test shall not significantly interfere with the generation and maintenance of test conditions.

3.3.3 Heat Source. - The heat source of the test apparatus shall be so located that radiant heat shall not fall from it directly on the equipment under test, except where application of radiant heat is one of the test conditions.

3.3.4 Standard Conditions for Test Area. - Laboratory conditions for conducting equipment operational checkout prior to or after an environmental exposure shall be as indicated below.

a. Temperature: 25° ± 3°C

b. Relative humidity: 55% or less

c. Barometric pressure: Room ambient (correct performance data to 760 mm Hg if so specified in the applicable equipment specification).

3.4 <u>Measurements</u>. - All measurements shall be made with instruments shich are appropriate for the category involved and for the environmental conditions concerned. The accuracy of the instrumentation and test equipment shall be certified and recorded before the test.

3.4.1 <u>Tolerances</u>. - The maximum allowable tolerances for test conditions shall be as follows, unless otherwise specified by the applicable test section in the environmental test specifications.

a. Temperature: Plus or minus 2°C (Exclusive of accuracy of instruments).

b. Relative humidity: Plus 3% minus 2% R.H.

c. Vibration amplitude: For Sinusoidal - plus or minus 10%. For Random - plus or minus 3 db between 20-2000 cps.

d. Vibration frequency: Plus or minus 2%.

e. Additional tolerances: Additional tolerances shall be as specified.

3.4.2 <u>Vacuum Gages</u>. - The vacuum shall be indicated by a vacuum gage whose sensing element is directly exposed to the environment of the chamber test space. The gage shall read the absolute pressure to which the equipment is exposed.

3.5 <u>Test Sequence</u>. - The test sequence shall be as outlined in this document, however, it may be varied as required with the concurrence of the Test and Evaluation Test Coordinator and the Project Management System Engineer.

3.5.1 The sequence shall be as follows:

a. Acceptance, Ozone Calibration, and Leak Test
b. Weight, Balance, Moment of Inertia, and Spin
c. Vibration
d. Leak Check and Ozone Calibration
e. Thermal Vacuum
f. Solar Simulation
g. Antenna Pattern Check
h. C.G. and Final Balance
i. Ozone Calibration
j. Magnetic Check.

3.6 Performance Record. - Prior to conducting any of the environmental tests specified herein, the equipment shall be subjected to a comprehensive operational checkout under the conditions specified in the reference of paragraph 2.1 and a record made of all data necessary to determine that performance of the equipment complies with the requirements of the applicable equipment specification. These data shall provide a basis for checking satisfactory performance of the equipment before, during, or after environmental tests. A chronological log shall be maintained indicating the duration of operation of the spacecraft and each subsystem. This log shall include all operational periods following assembly of the devices and shall be in a form suitable for reliability review.

3.7 Installation Check. - Following installation into the test apparatus and prior to exposure, the equipment shall be operated to insure that no malfunction or damage was caused due to faulty installation procedure or handling.

3.8 Criteria for Unsatisfactory Performance or Construction. - Deterioriation or change in performance of any component which could or does in any manner prevent the equipment from meeting functional, operational, or design requirements throughout the specified life shall provide reason to consider the equipment as having failed to comply with the conditions of the test to which it was subjected and shall be interpreted as a discrepancy.

3.9 Evaluation of Equipment. - When so directed in individual test procedures, the equipment undergoing test shall be operated to permit performance data to be obtained, and/or inspected for evidence of deterioration. Provision shall be included for checkout of redundant subsystems and where applicable , components of circuitry at the appropriate level of testing, to verify satisfactory performance. Any significant deterioration observed shall be evaluated by the cognizant design group.

3.10 Rejection and Retest. - Malfunctions occurring during the integrated spacecraft acceptance test program shall be reported to the Test Coordinator, the Systems Engineer, the Cognizant Design Agency, and the Quality Assurance Branch of the Test and Evaluation Division. The course of action shall be at the discretion of the Systems Engineer and the Test Coordinator. This includes the decision in regard to retest.

3.11 Substitution of Equipment. - If a component or subassembly is operated in excess of design life and wears out or becomes unsuitable for further testing during an acceptance test sequence due to causes other than design deficiencies, a different component or piece of equipment may be substituted. If, however, the substitution substantially affects the significance of results of the test sequence during which the part failed, that test sequence and any previously completed procedures which are affected shall also be repeated.

3.12 Use of Tested Equipment. - Subsystems subjected to design qualification tests for spacecraft and/or subsystems shall not be used in the flight system assemblies. Subsystems assembled into the flight unit being tested to this specification shall have been exposed previously to flight acceptance levels of environment. This requirement may be waived by agreement between the Systems Engineer and the Test Coordinator.

4. FLIGHT ACCEPTANCE TESTING

4.1 Flight Acceptance. - The Flight Acceptance Tests are intended to include a complete sequence of tests and exposures in which the flight spacecraft is subjected to environmental rigors which simulate actual environments expected during transportation, handling, pre-launch stand-by, launch, injection and orbit. The purpose of the flight acceptance tests is to reveal quality and workmanship defects and to provide information relating to the unique characteristics of the spacecraft. Satisfactory demonstration of the ability to withstand the environmental tests prescribed herein qualifies the spacecraft for flight.

4.2 Incoming Inspection. - Before beginning the environmental test program prescribed herein, the spacecraft shall undergo a complete systems check which shall include the determination of the functioning of the GSFC, Westinghouse, and United Kingdom equipment as prescribed in the reference of paragraph 2.1. This check shall be conducted at Westinghouse under the direction of GSFC Test and Evaluation Personnel and again upon receipt of the spacecraft at GSFC.

4.3 Ozone Calibration. - A calibration of the ozone experiment, both broadband and spectrometer, shall be conducted prior to commencing environmental tests.

4.4 Leak Test. - The only unit in the UK-2/S-52 Spacecraft to be leak tested is the tape recorder. Two types of test shall be conducted, one a "sniff" test wherein, a gross indication of leak may be detected, the other used to accurately determine leak rates. The tape recorder shall be charged with 100% helium during the entire flight acceptance program.

4.4.1 "Sniff" tests may be conducted with the tape recorder installed in the spacecraft. They may be conducted at anytime the tape recorder is installed in the spacecraft. If, during any of these tests a leak is detected, the unit shall be removed from the spacecraft and a more exact determination of leak rate shall be made using a Mass Spectrometer Leak Detector in a vacuum.

4.4.2 The leak rate of the tape recorder shall be accurately determined at three points during the flight acceptance program: (1) as part of the incoming inspection in the Test and Evaluation Division, (2) after the Vibration exposure, and (3) after the Antenna Pattern Check just prior to C.G. determination and Final Balance.

4.4.2.1 For these tests, the tape recorder shall be removed from the spacecraft and, having one atmosphere pressure of 100% helium, the leak rate shall be determined.

4.4.2.2 A Mass Spectrometer Leak Detector shall be used with a test pressure in the vacuum chamber of 1×10^{-3} mm Hg. A leak rate of 1×10^{-5} std. cc/sec. shall be considered acceptable.

4.5 Static and Dynamic Balancing. -

4.5.1 General. - Although not an environmental test, balancing is necessary for a spin stabilized payload. The accuracy of balance required shall be determined by consideration of the launch vehicle and orbital flight restraints. Balancing is chosen as the first operation so that the effect of testing on the balance weights and the effect of these weights on payload operation may be evaluated during the course of the subsequent testing.

4.5.2 The spacecraft, while turned off, shall be balanced prior to exposure to the prescribed environmental tests.

4.5.3 The spacecraft in its fourth stage spin-up and thrust configuration shall be dynamically balanced by spinning the body about the intended spin axis. During balance the spin rate shall not normally exceed that expected to occur during launch. Subsystems shall be shifted or permanent weights added in planes as approved by the Project Manager, to correct payload unbalance. Balance requirements dictated by the launch vehicle and prescribed adjustments are stated below.

a. Static unbalance of the flight unit with appendages folded shall not exceed 12 oz-in.

b. Dynamic unbalance of the flight unit with appendages folded shall not exceed 200 oz-in^2.

4.5.3.1 In order to meet requirements for orbital stability, the spacecraft shall be balanced to the following allowance:

Dynamic unbalance with appendages deployed shall not exceed 60 oz-in^2.

4.5.4 The balance measurements may be computed by operating upon the characteristics of the various parts of the spacecraft.

4.5.5 Spin Test. - Prior to and after these tests, the spacecraft shall be visually examined and functionally tested to assure correct performance. During these tests, the spacecraft shall be monitored via telemetry.

4.5.5.1 Launch Test. - The spacecraft in its launch configuration shall be subjected to a spin rate vs. time profile which corresponds to the expected roll rates in flight, as nearly as practicable. The spacecraft shall be in an operational status normal for powered flight during this test. This test may be conducted upon the dynamic balancing machine. The spin rate vs. time profile shall be as follows:

	Condition Simulated	RPM	Time
a.	Rotation after PET motor firing	160	15 min.
b.	Rotation after Yo-Yo deployment	70	60 sec.
c.	Rotation after boom erection	38.9	60 sec.
d.	Rotation after paddle erection	33.45	60 sec.

Booms, paddles, yo-yo, and similar items need not be present during this test.

4.5.5.2 Orbital Flight Test. - In the case of the UK-2/S-52, the spin test under orbital conditions shall be accomplished as portions of other parts of the environmental test program; in particular, the solar simulation. Due to the low nominal orbital rotational speed of the spacecraft, 5 rpm, it is considered not necessary to perform this test as a special operation.

4.5.5.3 Waiver of Spin Test. - Spacecraft operation checks during spin are not normally required on flight payloads. However, since balance and spin tests on the prototype have been deferred, the above spin requirements will be performed on the flight units.

4.6 Weight, Center-of-Gravity and Moments of Inertia. - The parameters of weight, center-of-gravity, and moments of inertia are used in predicting vehicle performance during launch as well as spacecraft orientation during injection and orbit. The center-of-gravity and moments of inertia shall be determined for the spacecraft in several configurations expected during launch, injection, and orbit, but not including the ABL-X248 fourth stage motor. The moments of inertia shall be determined about three orthogonal axes.

a. Yo-yo attached, booms and paddles tied down
b. Yo-yo off, booms and paddles tied down
c. Yo-yo off, booms deployed and paddles tied down
d. Yo-yo off, booms and paddles deployed
e. Orbit configuration (including calculation for the Galactic Noise dipole antenna)

4.6.1 The spacecraft in launch configuration shall be weighed with all booms and paddles and the separation mechanism to within ±114 grams.

4.7 Vibration Tests. -

4.7.1 The spacecraft performance shall be checked prior to exposure to vibration test. The spacecraft shall be attached to a vibration generator via a rigid jig fabricated to accept the spacecraft at the mounting device. Vibration shall be applied in each of three orthogonal directions, one direction being parallel with the thrust axis. The tape recorder shall be pressurized to two atmospheres absolute.

4.7.1.1 The spacecraft shall be operated in a duty cycle typical of that to be employed in actual launch and monitored for malfunctions in telemetering and all other systems which operate during boost. Antennas or other devices whose configuration changes during launch shall be in proper position relative to the vehicle program sequence when a particular vibration is introduced. For this purpose, sinusoidal vibration shall be considered to occur during X-248 motor operation, random vibration during launch, and maximum dynamic pressure during flight.

4.7.1.2 The telemetry antennas shall be deployed during all vibration tests.

4.7.1.3 For purposes of controlling vibration applied to the spacecraft, a calibrated accelerometer will be placed at the X-248 bottle-adapter interface. In addition, two other accelerometers, with sensitive axes mutually perpendicular with the first, shall be located near the interface (on the jig) to monitor uncontrolled lateral crosstalk.

4.7.2 Sinusoidal Swept Frequency. - This portion of the test shall be conducted by sweeping the applied frequency from the lowest to the highest frequency once for each range specified in the schedule. A sweep rate of four octaves per minute using a logarithmic scale shall be used.

Frequency Sweep Schedule

Vibration Axis	Frequency Range cps	Test Duration ≃ Min.	Acceleration g, 0-to-Peak
Thrust (Z-Z Axis)	5-50	0.83	1.5 *
	50-500	0.83	7.1
	500-2000	0.50	14.
	2000-3000	0.15	36.
	3000-5000	0.18	14. **
	Total ≃	2.5 Min.	
Lateral (X-X Axis) and Lateral (Y-Y Axis)	5-50	0.83	0.6 *
	50-500	0.83	1.4
	500-2000	0.50	2.8
	2000-5000	0.33	11.3 **
	Total ≃	2.5 Min.	(Each Axis)
	Grand Total ≃	7.5 Min.	

* Or within maximum amplitude limit of vibration generator.
** Or within maximum frequency limit of vibration generator.

4.7.2.1 Sinusoidal Vibration Records. - All accelerometer signals shall be recorded continuously on tape during all sinusoidal tests. Due care shall be exercised to calibrate the overall system for frequency response and amplitude linearity characteristics to values 1.25 times the maximum expected to be recorded during tests. Permanent records then shall be made and properly labeled to demonstrate conformance with this specification.

4.7.3 Combustion Resonance Dwell. - This test simulates a measured combustion oscillation condition observed in the S-248 solid-propellant rocket motor. The range of the sinusoidal vibration test is from 550-650 cps. The test is conducted by traversing this 100-cps-wide band at a logarithmic rate such that ¼ minute is consumed in moving from 550 to 650 cps.

4.7.3.1 Apparent Weight. - To determine control acceleration to be used for this test, the apparent weight of the spacecraft in the vicinity of 600 cps may be determined by measurement. This will require that both force and acceleration be measured at a point near the selected input interface, or the apparent weight may be deduced at this point, by measurement elsewhere. Apparent weight = applied force/g- acceleration (resolved at the spacecraft-jig interface). Control acceleration then is computed by dividing ±181 kg (±400 lbs.) force (thrust axis) or ±30 kg (±66 lbs.) force (lateral axes) by the apparent weight in kilograms averaged over the 550 to 650 cps range.

4.7.3.2 Force Programing. - A superior alternate method may be substituted wherein vibration force is programmed by servo-loop control of a suitable jig such that forces of ±181 kg (±400 lbs.) (thrust) and ±30 kg (±66 lbs.) (lateral) are applied at the spacecraft interface. If the jig is properly calibrated and control signals are compensated for jig-driving force, apparent weight of the spacecraft need not be determined.

4.7.3.3 Assumed Apparent Weight. - A second alternate method may be used wherein apparent weight of the spacecraft is assumed to be 3.2 kg (7 lbs.). Using this assumption, the control acceleration should be ±57g (0-to-peak) for thrust axis and ±9.4g (0-to-peak) for the lateral axes.

4.7.4 Random Motion Vibration. - Gaussian random vibration shall be applied with g-peaks clipped at three times the root-mean-square acceleration, according to the schedule given herein. With spacecraft installed, the control accelerometer response shall be equalized such that the Power Spectral Density values are within ±3 db everywhere in the frequency band. The filter roll-off characteristic above 2000 cps shall be at a rate of 40 db/octave or greater.

Random Vibration Schedule

Vibration Axis	Frequency Range cps	Test Duration Min.	PSD Level g^2/cps	Approx. Accel. g-rms
Thrust (Z-Z Axis)	20-2000	2	0.03	7.7 *
Lateral (X-X Axis) and Lateral (Y-Y Axis)	20-2000	2 (each axis)	0.03	7.7 *
	Total	6 Min.		

* Within amplitude limit of vibration generator.

4.7.4.1 Random Vibration Records. - During the random vibration tests, signals from the control accelerometer shall be passed through a bandpass-filter-type analyzer which has been adjusted to scan the test spectrum in the applicable test-duration time. The filter bandwidth shall be as narrow as allowed by the testing time and the length of the spectrum to be traversed. Permanent records shall be made during the specified random vibration tests and properly labeled to demonstrate conformance with this specification. Magnetic tape recordings may be used for data storage and analysis.

4.7.5 Performance. - Performance parameters shall be measured before and after the above vibration as appropriate. All components and subsystems in the spacecraft shall operate without failure, malfunction, or out-of-tolerance performance. A detailed examination for evidence of cracks, loose parts, and degradation shall be made. Any discrepancies in spacecraft structure or components shall be reviewed and action taken.

4.7.5.1 As part of the measurement of performance parameters, a check shall be made of the spectrophotometer units to determine that they have retained their calibration.

4.8 Leak Check. - A leak check of the tape recorder shall be conducted in accordance with paragraph 4.4.

4.9 Thermal Vacuum Tests. -

4.9.1 The spacecraft and subsystems shall have been visually examined and performance checked prior to commencing the test setup.

4.9.1.1 The equipment shall be supported with materials that will little influence thermal distribution as agreed upon by the Test and Evaluation Division and the Project Manager.

4.9.1.2 Thermocouples and/or thermistors and resistance wire thermometer shall be installed in critical thermal areas of equipment, and at specific reference locations as determined by a thermal analysis of design relative to launch and orbit environments.

4.9.1.3 During the thermal vacuum series of tests, the spacecraft shall be operated through the cold and hot cycles for a total minimum period of fifteen days. This time may include time spent in an undervoltage condition.

4.9.2 Low Temperature Tests. -

4.9.2.1 The spacecraft shall be installed in the test chamber and all wiring for determining payload operation and environmental conditioning while under test conditions will be connected.

4.9.2.2 Upon completion of the test setup, the chamber door will be closed and a complete spacecraft checkout conducted. If interference between chamber and spacecraft operation is noted, attempts will be made to minimize the effect.

4.9.2.3 Upon completing the above checkout, the spacecraft will be operated while evacuating the chamber to a pressure of 1×10^{-4} mm Hg. The spacecraft shall then be turned off. High tension sources shall be monitored to uncover corona or arcing.

4.9.2.4 While non-operative, the spacecraft shall be subjected to a chamber vacuum of 1×10^{-5} mm Hg or less and the chamber wall temperature shall be adjusted so that the spacecraft attains a temperature of $-5°C \pm 2°C$ (power off). This temperature shall be determined by monitoring thermocouples or thermistors located on the equipment in the expected low temperature areas. After the temperature in the non-operative state has stabilized, it shall be operated and chamber wall temperature maintained constant. The test shall continue and equipment operated through at least three days. The temperature of each subsystem shall be monitored during this test. At no time shall the temperature of the tape recorder go below -15°C.

4.9.3 <u>High Temperature Tests</u>. -

4.9.3.1 If this test does not, for any reason, follow the Cold Temperature Test above, the procedures of thermocouple installation and spacecraft checkout outlined above shall be followed prior to starting the following procedures.

4.9.3.2 While non-operative, the spacecraft shall be subjected to a chamber vacuum of 1×10^{-5} mm Hg or less and the chamber wall shall be adjusted to $+50° \pm 2°C$ (power off temperature). This temperature shall be determined by monitoring thermocouples located on the spacecraft in the expected high temperature areas. After stabilization of the spacecraft at the non-operative temperature, the spacecraft shall be operated while maintaining the chamber wall temperature constant. The test shall continue and the spacecraft operated through at least three days (excluding undervoltage). The temperature of each subassembly shall be monitored during this test.

4.10 <u>Solar Simulation - Vacuum Tests.</u> -

4.10.1 The spacecraft shall be mounted in the 7 x 8 chamber on a gimbal system so that the vehicle may be rotated at 5 rpm ±10% about the longitudinal axis in order to simulate orbital motion. The mounting shall be made as to provide the least significant heat transfer path practicable. With the spacecraft operating, the chamber pressure shall be reduced to 1×10^{-5} mm Hg or less. The chamber walls shall then be cooled to -175°C or less. During this period, radiant energy shall be applied to the spacecraft from the direction corresponding to that of the sun in space. The radiant energy distribution shall approximate the solar spectrum and be the equivalent of one solar constant.

4.10.1.1 During the Solar Simulation-Vacuum Tests, the spacecraft shall be operated through a minimum total period of five days. This may include an undervoltage condition.

4.10.2 Experiment excitation shall be from an RF source and the Solar Simulator.

4.11 Antenna Pattern Check. - The flight spacecraft shall be taken to the antenna range where the pattern of the telemetry antennas will be determined by the Flight RF Systems Branch.

4.12 Center of Gravity and Final Balance. - Launch vehicle requirements for static and dynamic balance shall be as stated below except that when feasible, these tolerance values should be halved to provide a margin of safety for disassembly which is often required for checkouts at the launch site.

4.12.1 Maximum center-of-gravity offset should be less than 0.13 mm (.005 in.). If offset is 0.13 mm or greater, static balance shall be performed to come within 0.13 mm.

4.12.2 The tilt of the spacecraft principal axis should be less than 0.008 radian with respect to the spin axis and the product of inertia shall be as stated below. If tilt is 0.008 radian or greater, dynamic balance shall be performed to come within 0.008 radian.

$$P < .001\ (I_R + C)$$

P = Product of inertia of the spacecraft about the spin and pitch axis, gram-cm^2.

I_R = Roll moment of inertia of the spacecraft about spin axis, gram-cm^2.

$C = 6.1 \times 10^7$ gram-cm^2

(1 slug-ft^2 = 1.3558 kilogram-meters^2)

(1 slug-ft^2 = 1.3558×10^7 gram-cm^2)