SOUTHWEST RESEARCH INSTITUTE

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Department of Applied Electromagnetics

DOCUMENT NO. VP-2
REVISION A

VERIFICATION PLAN

FOR THE

M172 BODY MASS MEASUREMENT DEVICE

FLIGHT HARDWARE

PRELIMINARY - NASA APPROVAL PENDING

3.0 DESCRIPTION OF BODY MASS MEASUREMENT DEVICE

The top assembly drawing (SwRI drawing number 2837-001-01) illustrates the features of the body mass measurement device (BMMD).

The body mass measurement device consists of a mechanical subsystem and an electronics subsystem. This device is completely self-contained with the exception of requiring a nominal 28 vdc power source and a plane, stable mounting surface.

To operate the device, the subject to be measured lowers himself into the seat and fastens the body restraint straps. The "mass/off/temp" switch of the electronics subsystem is put in the "mass" position, and the digital display is cleared by actuating the reset switch. A control lever is then pushed forward to unlock the seat. The subject tenses his muscles, holds his breath (breath will be held for about ten seconds) then releases a sear and the seat begins to oscillate.

An electro-optical transducer sends a signal to the device's logic circuit each time the seat crosses the equivalent midpoint in its oscillating cycle. After two cycles have been completed, the total elapsed time for the next three cycles, in tens of microseconds, appears on the device's digital display. The device is shut down by actuating the control lever, which moves the seat to the offset position, latches the sear, and finally locks the seat. The period reading, shown on the digital display, is recorded. The "mass/off/temp" switch is put in the "temp" position, the reset switch is actuated, and the temperature, shown on the digital display, is recorded. The electronics is then de-energized. The recorded readings (i.e., temperature and period of oscillation) are used to obtain mass values by reference to a calibration curve, conversion chart, or equation.

3.1 Description of Mechanical Subsystem

The subsystem drawing (SwRI drawing number 2837-100-01) illustrates the features of the mechanical subsystem of the body mass measurement device.

The main components of the mechanical subsystem are the frame, springs, seat, seat lock, restraint system, and sear mechanism.

The frame forms the structure of the device, and the seat is suspended from the frame by means of springs. When the device is not in use, the seat is locked to the frame by the seat lock. Protection to the springs is provided in the locked configuration because the mass of the seat is no longer suspended on the springs, therefore forces accidentally applied to the seat are not transmitted to the springs.

The springs are plate-fulcra type, and consist of a pair of identical flat plates, one at each side of the frame. One end of each spring is rigidly attached to the frame, and the other end of each spring is rigidly attached to the seat, one at the front and the other at the rear. This arrangement suspends the seat from the frame on the springs, and allows relative motion between the seat and frame during the measurement cycle.

The restraint system consists of body restraint straps which couple the seat and the subject whose mass is to be measured. After the subject lowers himself into the seat, these restraint straps are fastened around his body and attached to the seat. This couples the subject to the seat, preventing relative motion during the measurement cycle.

The sear mechanism serves to hold the seat an exact distance from its neutral position, in preparation for the measurement cycle. In this position the springs are also offset. In operation, a control lever is first used to unlock the seat. When the subject is ready for mass measurement, he releases the sear, and the restoring force of the springs causes the seat to oscillate. After the mass measurement is completed, the control lever is actuated in the reverse direction. This moves the seat and springs to the offset position, latches the sear, and locks the seat.

3.2 Description of Electronics Subsystem

The electronics subsystem (SwRI drawing number 2837-700-01) consists of five separate functional components. These components are the power regulator, the temperature sensor, the electro-optical transducer, the clock and digital logic, and the digital display. Figure 3.2-1 is a block diagram of the electronics subsystem.

The five components are encapsulated into a single module. The SMMD and BMMD electronics subsystems are identical. Following is a brief description of each component:

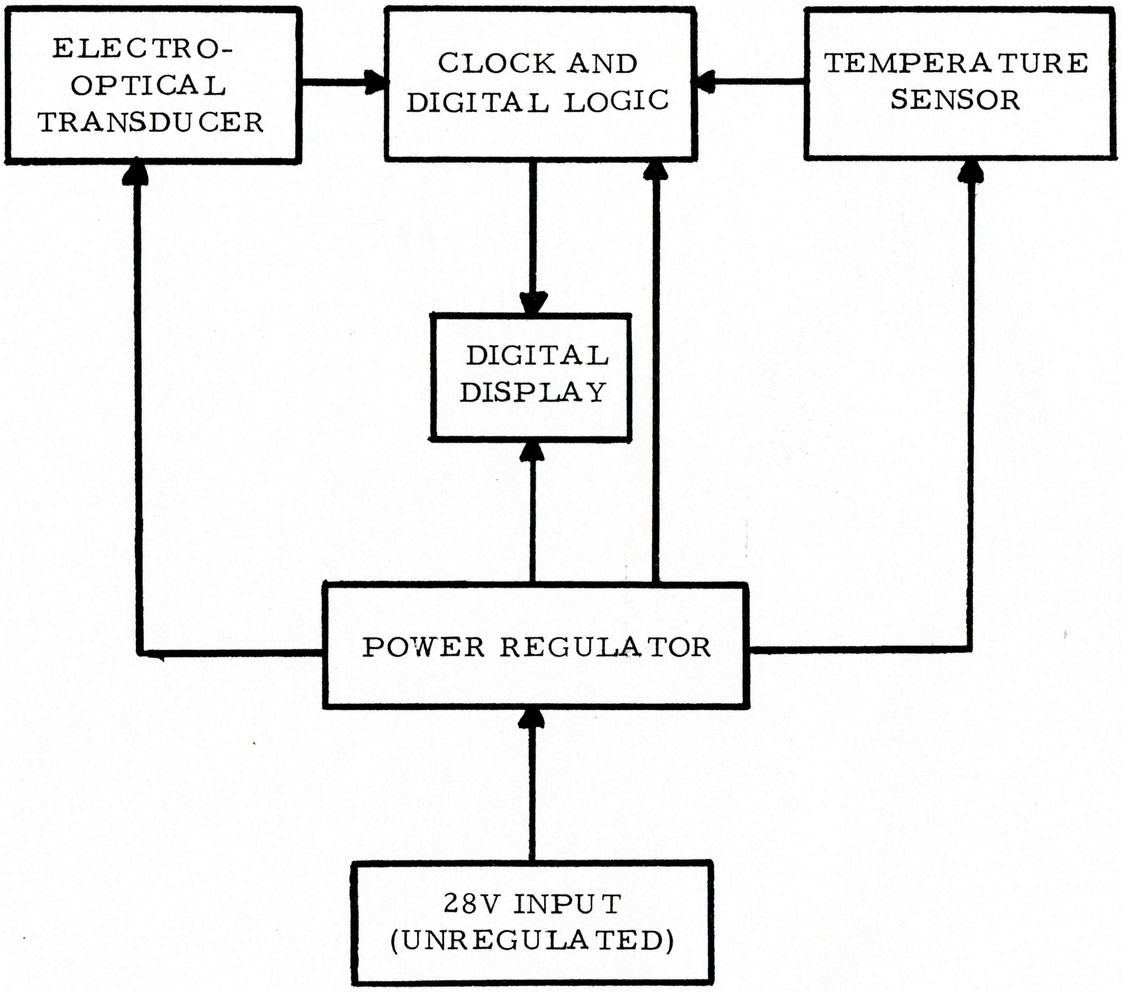

FIGURE 3.2-1 - ELECTRONICS SUBSYSTEM BLOCK DIAGRAM

a. Power Regulator

Voltage regulation of the spacecraft-supplied power is accomplished by a "switching" regulator, which provides maximum efficiency in voltage regulation. Pulse current is supplied to a storage element as required to maintain the desired + 5 volts dc output. A balanced filter is incorporated in the input section to reduce conducted EMI on the input lines and to provide protection against transients from the spacecraft source.

The power regulator supplies power necessary to operate the electronics subsystem and derives its power from the unregulated power supply by the spacecraft.

b. Electro-Optical Transducer

The electro-optical transducer component senses the passage of the specimen tray or seat through its equilibrium position. The first two periods of oscillation are ignored by the logic circuitry in order to allow any transients produced by the release mechanism to dissipate. The beginning of the third period signals a start count to the clock and digital logic component, and the beginning of the sixth period signals a stop count to the clock and digital logic component.

The optical source consists of a solid state light emitting diode in the 900 nanometer wavelength range, while the sensor consists of a solid state photosensitive device. The electro-optical transducer operates on power furnished by the power regulator.

c. Temperature Sensor

The temperature is sensed by a thermistor probe. The probe determines the "on time" of an integrated monostable multivibrator, which in turn controls the input to the clock and digital logic component. Temperature is displayed to the nearest degree by two of the six digits in the digital display. Accuracy is $\pm$ 1° F between 65°F and 80°F. The temperature is displayed continuously when the function switch is in the "Temp" position and may be updated by depressing the "Reset" switch. The temperature sensor operates on power furnished by the power regulator.

d. Clock and Digital Logic

The clock and digital logic component consists of a 1 MHz oscillator, seven integrated circuit up/down decade counters, and six BCD to 7-bar converters. The control logic necessary to perform the functions for mass and temperature measurements is also contained in the clock and digital logic component.

When measuring mass, the counter will "count up", and the period of 3 specimen tray oscillations is displayed on the digital display component.

As the thermistor has a negative temperature coefficient, the counter will "count down" from a pre-set number when measuring temperature, and the temperature can be read directly from the digital display.

The clock and digital logic component operates on power furnished by the power regulator.

e. Digital Display

The digital display component is composed of six 7-bar light emitting diode numerical displays. The signals processed by the clock and digital logic component are displayed in digital form by the digital display component.

The digital display component operates on power provided by the power regulator.

4.0 VERIFICATION METHODS

The methods which will be used to verify that the hardware design meets the technical requirements of Section 3.0 of the End Item Specification (EIS) are listed in the Verification Matrix shown in Figure 4.0-1.

Satisfactory verification by implementation of the verification methods or the satisfactory completion of the tests indicated on the approved verification matrix of the Verification Plan will be used as the basis for acceptance of the hardware design. The verification methods and test types are as follows:

a. <u>Verification Methods</u>

Similarity
Analysis
Inspection
Demonstration
Test

b. <u>Test Types</u>

Qualification
Acceptance
Preinstallation
Other tests (Developmental Evaluation)

Requalification of previously qualified hardware may be required when: changes have been made to the design of the hardware, fabrication, or process operations; the source of procurement has changed; articles have repeated failures; or inspection, test or operational data indicate the need for requalification. When one of the above conditions occurs, Southwest Research Institute will:

a. Provide the Manned Spacecraft Center Contracting Officer with information on the existing conditions and remedial and preventive action to be taken, and

b. Specify the need for, and extent of requalification testing, and

c. Obtain Manned Spacecraft Center Contracting Officer approval prior to conducting requalification testing.

4.1 Similarity

Verification by similarity will be used when it can be shown that the article is substantially similar or identical in design, manufacturing processes and quality control to another article that has been previously qualified to equivalent or more stringent criteria. Verification by similarity may pertain to characteristics such as material, configuration, functional element or assembly, and can be applied selectively for applicable environments. Previous qualification tests conducted on other articles will be applicable provided:

a. There are no changes in:

(1) Design and specifications including operating limits, weight, dimensions, materials, performance and tolerance, reliability, and quality.

(2) Fabrication methods

(3) Inspection techniques

(4) Manufacturing environment and tests up to the point where qualification tests would normally be initiated.

b. Present articles are from the same manufacturing continuous-built lot as the qualified article.

c. Present articles are interchangeable with previously qualified articles.

A change in any of the above provisions must be reported by the manufacturer. Validation is required, by an engineering analysis or test report, that the change does not adversely affect the qualification of the article. A certification of compliance is required from the manufacturer confirming the items listed in the preceding paragraphs.

Verification by similarity shall be used to show that all electronic modules are interchangeable per EIS, subparagraph 3.1.1.2.2 and that the flight hardware and backup hardware meet all requirements which will be checked by qualification tests on the qualification test hardware.

Specification to assure operational suitability in the anticipated environments. Qualification test hardware will be used for qualification testing and shall be identical in configuration and production processing to flight hardware or similar as established in accordance with the requirements of subsection 4.2.1. Qualification test hardware will not be used as flight hardware or backup hardware. Qualification Test Procedures will be prepared and submitted for review. A formal report of test results will be submitted for approval at completion of qualification tests. Disapproval will be a constraint upon acceptance of the flight hardware. Consequently, the qualification test program must be scheduled such that there is sufficient time to allow for possible failures, rework during testing, preparation of the final test report, and review and approval after submittal.

4.5.1.2 General Requirements

a. Qualification tests will be conducted on the entire end item; acceptance tests will be conducted on qualification test hardware prior to qualification tests being conducted.

b. One test article will be subjected to qualification testing.

c. Sequence of qualification tests will follow the same order as listed in the test procedures document.

d. A functional test to determine whether the qualification test hardware is performing within specification tolerances will be conducted before and after each environmental exposure. The same tests will be performed during the exposure period if the flight hardware will be required to operate in that environment. If the tests are conducted in series with no significant time interval between tests, the tests after an environmental exposure may serve as verification of proper performance before the succeeding environmental exposure.

e. Qualification test hardware will be mounted in a manner simulating the actual mounting in the flight vehicle for all qualification tests wherein the flight hardware is expected to be affected by the mounting.

f. Qualification tests will be performed under strict control of environments and Test Procedures. Recalibration of Qualification Test Hardware will be permitted during tests inasmuch as it is a part of normal in-service operation.

g. If the design configuration or manufacturing processes are changed after acceptance tests on qualification test hardware are initiated, any differences existing between the qualification test hardware and the flight and backup hardware will invalidate verification.

h. Qualification tests will be completed prior to the delivery of flight and backup hardware.

i. It is not considered necessary to perform any disassembly after testing is completed to determine margins of safety and potential failure modes.

j. Personnel performing the qualification tests will be thoroughly familiar with all assembly, acceptance test, and qualification test procedures. Southwest Research Institute will assign a single individual as a test monitoring engineer to control all qualification test operations, maintain a complete test operations log, assure that all tests are conducted properly and thoroughly as required in the applicable Qualification Test Procedure and control the qualification test area.

4.5.1.3 Test Environments and Methods

MIL-STD-810, Section 3, will apply in the establishment of the qualification test program. The specific test environments and methods applicable to the qualification test hardware will be the environments and test methods in the following sections.

4.5.1.3.1 High Temperature

MIL-STD-810, Method 501, Procedure I, will apply, except that the internal chamber temperature will be raised to 160°F and maintained for a period of not less than four hours after stabilization of the temperature of the test article.

4.5.1.3.2 Low Temperature

MIL-STD-810, Method 502, Procedure I, will apply. The internal chamber temperature will be lowered to -40°F and maintained for a period of not less than four hours after stabilization of the temperature of the test article.

g. If the design configuration or manufacturing processes are changed after acceptance tests on qualification test hardware are initiated, any differences existing between the qualification test hardware and the flight and backup hardware will invalidate verification.

h. Qualification tests will be completed prior to the delivery of flight and backup hardware.

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4.5.1.3.3 Shock

MIL-STD-810, Method 516, will apply, Procedure II will be used to test hardware. During Procedure II, the BMMD will be in the ground shipping mode.

4.5.1.3.4 Pressure (Positive)

The BMMD will be placed in a chamber and the chamber pressurized for a period of not less than 15 minutes at a pressure 1.1 times 1345 mm Hg.

4.5.1.3.5 Acceleration

MIL-STD-810, Method 513, Procedure I, will apply. The longitudinal and lateral axis test levels will be 4.7 and 2.0 g's respectively. For these tests, the longitudinal and lateral axes are with respect to the launch vehicle and the BMMD will be mounted to simulate the mounting position of the flight hardware at time of launch. This test will be performed with the BMMD in the stowed mode.

4.5.1.3.6 Vibration

a. Sinusoidal resonant search - A resonance frequency search will be conducted prior to any other vibration test. Resonant frequencies of the test specimen will be determined by sweeping through the frequency range of each of the three mutually perpendicular axes of the test specimen from 20 to 2000 Hz at a 3 g peak. The amplitude of excitation will be modified at each resonant point, applying only sufficient energy to allow determination of the frequency of resonance. The search will be a logarithmic sweep from 20 to 2000 Hz at a sufficiently slow rate, no faster than 2 minutes per octave, so that all significant resonances may be recognized and recorded. The identity of each resonance will be given in terms of the part in resonance, its natural frequency and observed amplification factor (Q). The sinusoidal resonant search will be made with the BMMD in the stowed mode.

b. Sinusoidal cycling - MIL-STD-810, Method 514, figure 514-6, will apply using the cycling time of Time Schedule IV of Table 514-II. A resonant dwell test will not be conducted. The case or crate will be included in the test setup. This test may be eliminated if proof of adequate packaging and crating can be demonstrated.

c. Random vibration - The random vibration spectrum and test duration per axis will be specified in Table 4.5.1.3.6-1. The hardware will be subjected to the spectrum in each of three orthogonal axes. One of the axes will be the one considered the most critical for the hardware. Random vibration system equalization will be accomplished and demonstrated by using "random spectrum analysis" technique, using 50 Hz or less analyzing filters. Peaks and notches may not deviate more than $\pm$ 1.5 db below 300 Hz, and $\pm$ 3 db from 300 Hz to 2000 Hz. These tolerances are increased in the roll off regions of the spectrum by $\pm$ 0.1 db for every one db down from the maximum level specified. During random vibration testing, the input to the power amplifier will be clipped to prevent overdriving or otherwise distorting the input to the shaker. The clipping will be maintained at three sigma. Reduction of the clip level to less than three sigma, but greater than two sigma, may be allowed only in those instances where the shaker system is marginal and the RMS acceleration level can be increased by doing so. The concurrence of the test manager is required in these circumstances. The random vibration will be performed with the BMMD in the stowed mode.

4.5.1.3.7 Altitude

MIL-STD-810, Method 500, Procedure II, will apply. The test chamber internal temperature will be lowered to the lowest temperature at which the test article is designated to operate instead of $-65^{\circ}F$, and maintained until temperature stabilization of the test article is reached. The test chamber internal pressure then will be lowered to at least 1×10^{-6} torr. Only a specimen of the BMMD seat will be subjected to this test.

4.5.1.3.8 Atmosphere Compatibility

The equipment will be operated in a test chamber atmosphere of 100 percent oxygen at a continuous pressure of 6.2 psia for 24 hours. The BMMD will be operated through one duty cycle immediately prior to completion of the exposure period. The temperature will be maintained at laboratory ambient level during the first 16 hours and then raised to $120^{\circ}F$ and maintained for eight hours. There will be no visible burning, creation of toxic gases or obnoxious odors, or deterioration of seals or lubricants during the exposures. If the flight hardware will be required to operate in an oxygen environment prior to launch (such as during prelaunch tests), the same procedure will be followed except that the chamber pressure will be 16.5 psia.

Lift-Off Random (1 min/axis)

Flight Axis

20 - 30 Hz @ 0.10 g^2/Hz
30 - 1000 Hz @ -3 db/oct
1000 - 2000 Hz @ 0.0030 g^2/Hz

Composite - 4.1 grms

Lateral Axes

20 - 100 Hz @ 0.10 g^2/Hz
100 - 2000 Hz @ -3 db/oct
2000 Hz @ 0.0050 g^2/Hz

Composite - 6.2 grms

Boost Random

Flight Axis

20 - 30 Hz @ 0.025 g^2/Hz
30 - 1000 Hz @ -3 db/oct
1000 - 2000 Hz @ 0.00070 g^2/Hz

Composite - 1.7 grms

TABLE 4.5.1.3.6-1 - RANDOM VIBRATION SPECTRUM

4.5.1.3.9 Electromagnetic Interference Test

The BMMD will be tested to the requirements of MIL-STD-461, equipment class 1D.

4.5.1.3.10 Moisture and Contaminants

The intrinsic requirements of the M172 Experiment dictate a hardware design which, by necessity, has certain components which are quite delicate and susceptable to accidental damage. It is not feasible, and perhaps impossible, to protect these delicate components from all the many eventualities which could happen during the life of the instrument. Therefore, the only recourse is to design and test the instrument to a group of requirements which represent the more likely occurrences.

During ground handling and shipping the BMMD will be environmentally protected at all times against moisture and contaminants by either a controlled laboratory environment or by a plastic bag which has been purged with dry nitrogen. Consequently, no requirement or test is necessary for adverse ground environments of unusually high moisture or corrosive contaminants such as salt fog.

Table 3-IA of document MSC-KW-E-69-11 indicates a design requirement for high and low humidity during operation and/or orbital storage. Therefore, a humidity test will be conducted in accordance with MIL-STD-810, Method 507, Procedure I except that the minimum temperature will be 68°F and the maximum temperature will be 120°F.

Table 3-IA of document MSC-KW-E-69-11 also indicates that corrosive contaminants, oxygen and humidity (CCOH) will be present in combination during orbital and experiment operation. Since Skylab will have a positive air movement system, it is not believed that accidental spills of corrosive fluids such as urine will produce floating clouds of urine droplets that will deposit over the interior surfaces. Also accidental spills of urine or foodstuffs are likely to occur in the waste management area which is some distance away from the BMMD. It is certain that the BMMD surfaces will be touched by the astronauts who are likely to leave perspiration deposits on the touched surfaces. Therefore, the design requirement for corrosion protection will be met by suitably coating all touch areas producing a corrosion resistant surface. Verification

of the corrosion protection will be accomplished by conducting a developmental CCOH test on samples of the suitably protected touch area materials. A report of this test will be submitted to NASA.

4.5.2 Acceptance Tests

Acceptance tests, combined with other verification methods and tests, will verify that each item of experiment hardware meets the requirements of Section 3.0 of the End Item Specification and is acceptable. Acceptance tests will be conducted on all end items of experiment hardware. Acceptance Test Procedures will be prepared and submitted for review. Data sheets will be prepared showing the results of acceptance tests performed on each set of hardware. Acceptance testing will be accomplished in accordance with the following general requirements:

a. The severity, duration, and number of tests will not result in overstressing or degradation of the hardware performance capability.

b. Where possible, all normal, operational modes will be tested.

c. The BMMD will be calibrated and aligned prior to conducting acceptance tests.

d. Acceptance tests will be performed under strict control of environments and test procedures. Adjustment or tuning of hardware is not permitted during acceptance testing.

e. Any repairs, modifications or replacements after completion of acceptance tests will require retesting to assure the acceptability of the change. The degree of retest necessary will be proposed and submitted for approval.

f. The Acceptance Test Procedures will consist of the following tests, inspections, and demonstrations as referenced in section 3.0 of the End Item Specification.

EIS Subparagraph	Subject
3.1.1	Mass measurement test
3.1.1.1	Accuracy and resolution

4.5.2.1 Thermal Cycling

The BMMD will be thermally cycled from 20°F to 120°F. The test will be conducted by stabilizing the unit at 70°F, raising the temperature to 120°F and allowing the unit to stabilize, holding for one additional hour, lowering the temperature to 20°F, raising the temperature back to 120°F and then reducing the temperature to 70°F. Functional tests will be conducted before and after the temperature cycling test.

4.5.3 Preinstallation Tests

Preinstallation tests will be conducted on each end item of experiment hardware after receipt by a contractor or a NASA Center for installation. These tests will be designed to verify that the hardware was not damaged during handling or shipment after the acceptance tests were conducted, and that the performance capability has not deteriorated. Only a minimum amount of functional testing will be accomplished. Preliminary Preinstallation Test Procedures will be prepared by Southwest Research Institute. The preliminary procedures will be submitted to the contractor or NASA Center responsible for installation of the hardware for use in the preparation of final Preinstallation Test Procedures. The final procedures will be reviewed by the contractor or activity who prepared the preliminary specification and procedures to assure the adequacy of the tests.

The preliminary preinstallation tests will consist of examinations for damage during shipment and checking the calibration of the BMMD.

6.0 TEST FACILITIES AND LOCATION

The test facilities and location will be as specified in the test procedures document. All test facilities will be located at Southwest Research Institute, except some environmental test facilities located at General Testing Laboratories, Springfield, Virginia.

7.0 TIME PHASING

It is anticipated that acceptance testing will be initiated on the qualification test hardware on or about 9 January 1971. Qualification testing will be initiated on or about 15 January 1971 and will be completed on or about 15 March 1971. Acceptance testing of the remaining flight and backup hardware will be initiated approximately one week prior to the delivery dates which are 1 April and 30 June 1971 respectively.