MICROFICHED

MAY 18 1972

B4.L1
T72-13724
C1
CR151302

I M B L M S

ITEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM

DEFINITION REPORT - TASK I

TECHNICAL LIBRARY
BUILDING 45
MAY 9 1972
Manned Spacecraft Center
Houston, Texas 77058

IL 14, 1969

CONTRACT NASW-1631
AMENDMENT NO. 2

(NASA-CR-151302) IMBLMS - INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM (Lockheed Missiles and Space Co.) 404 p

N77-77564

Unclas
00/12 28541

BEST AVAILABLE COPY

T72-15724
C1

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM

TECHNICAL LIBRARY
BUILDING 45
MAY 1 8 1972
Manned Spacecraft Center
Houston, Texas 77058

DEFINITION REPORT - TASK I

April 14, 1969

G. A. Albright - Program Manager

W. M. Helvey - Manager, Biotechnology

LOCKHEED MISSILES & SPACE COMPANY
Sunnyvale, California

MAY 1977
RECEIVED
NASA STI FACILITY
INPUT BRANCH

28541

NOTICE

These design concepts and requirements represent an important part of the Lockheed competitive position and as such should only be used for the benefit and future implementation of the NASA IMBLMS program. Any other use of this material must be mutually approved by NASA and LMSC.

Foreword

Lockheed Missiles & Space Company (LMSC) is submitting this report covering Task I to the National Aeronautics and Space Administration (NASA) in compliance with the requirements of NASA Contract NASW-1631 Amendment 2, dated Dec. 23, 1968.

This report defines the design and performance requirements for the IMBLMS Functional Breadboard (FBB) Design. Along with descriptive definitions and associated block diagrams, these requirements are intended to be the "Breadboard Specifications". Measurement techniques and equipment which require crash development are identified to supplement and improve FBB techniques for use in the flight IMBLMS.

Contents

Section		Page
	FOREWORD	
I	INTRODUCTION	
II	MEASUREMENT REQUIREMENTS	
III	DESIGN AND PERFORMANCE REQUIREMENTS - DESCRIPTIVE DEFINITIONS AND BLOCK DIAGRAMS	
	A. FBB SYSTEM	
	B. CONSOLES	
	C. CLINICAL EVALUATION	
	APPENDIX	
	D. DYNAMIC PHYSIOLOGICAL MONITOR (DPM) SUBSYSTEM	
	APPENDIX	
	E. VASCULAR DYNAMICS SUBSYSTEM	
	APPENDIX	
	F. RESPIRATORY SUBSYSTEM	
	APPENDIX	
	G. METABOLIC & NUTRITION SUBSYSTEM	
	APPENDIX	
	H. BEHAVIORAL SUBSYSTEM	
	APPENDIX	
	I. BIOCHEMICAL PREPARATION & ANALYSIS (BPA) SUBSYSTEM	
	J. DATA MANAGEMENT SUBSYSTEM (DMS)	
	APPENDIX	

INTRODUCTION

1.0 INTRODUCTION

The National Aeronautics and Space Administration is conducting studies of an Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS). The goal is to develop a highly flexible, state-of-the-art, flight system capable of accepting a wide variety of biomedical experiments designed to extend the knowledge of man's capability of operating in space.

The purposes of the Phase B3 effort are to define, design, fabricate, assemble, and test an IMBLMS functional breadboard (FBB) prior to installation at the NASA Manned Spacecraft Center, and to generate preliminary requirements for an IMBLMS engineering development unit (EDU). The FBB consists of a physiological and behavioral data management (PBDM) station, biochemical and preparation analysis (BPS) station, suxiliary respiratory equipment, cryogenic freezer, video recorder, and support equipment. Non-deliverable measurement and simulating equipment to be employed during the test phase at Lockheed includes a simulation control and data system (SCADS) and associated computer facility, tape recorder, ergometer, mass measurement systems, and lower body negative pressure chamber.

This Task I report defines the Design and Performance Requirements for the Functional Breadboard. These requirements and associated block diagrams are intended to be the "Breadboard Specifications".

Section II Measurement Requirements identifies the recommended FBB and Flight IMBLMS measurements and measurement techniques and equipment requiring crash development.

Section III Design and Performance Requirements - Descriptive Definition and Block Diagrams, presents the intended Breadboard Specifications. The format of these requirements is in general accord with the Apollo Applications Program Experiment Overall Requirements. (MSC-KA-D-68-1). This system engineering approach to documentation benefited from LMSC previous B2 effort with the development of measurement functional flow diagrams and preliminary Requirements Allocations Sheets.

The FBB overall system document is supported with 10 subsystems requirements. Related descriptive definitions and block diagrams are presented with each subsystem to explain and convey information as to how the FBB will be designed and will function to meet the design and performance requirements.

Certain subsystems include applicable appendices e.g., Measurements Requirements Data Sheets, Clinical Evaluation Checkoff List, Behavioral Measurement Procedures, Measurement Display Requirements, to clarify and summarize medical/engineering measurement and equipment characteristics.

MEASUREMENT REQUIREMENTS II

SECTION II

IMBIMS/FUNCTIONAL BREADBOARD
MEASUREMENT REQUIREMENTS

MEASUREMENT REQUIREMENTS

1.0 INTRODUCTION

2.0 MEASUREMENTS AND TECHNIQUES REQUIRING CRASH DEVELOPMENT

- 2.1 FBB Measurements/Techniques
  - 2.1.1 Systolic and Diastolic Blood Pressure
  - 2.1.2 Limb Plethysmography
  - 2.1.3 Cardiac Output
  - 2.1.4 Total Body Water
  - 2.1.5 Respiratory Measurement/Equipment
  - 2.1.6 RBC and WBC Counts
  - 2.1.7 Colorimetry-Conductivity Test Cell for Erythrocyte Osmotic Fragility
  - 2.1.8 Preservation Equipment
- 2.2 Flight IMBLMS Measurement Techniques
  - 2.2.1 Central Venous Pressure (Derived)
  - 2.2.2 Inflight Bone Densitometry
  - 2.2.3 Endoradiosondes
  - 2.2.4 Radial Immunodiffusion
  - 2.2.5 Electrophoresis
  - 2.2.6 Fluorometer
  - 2.2.7 Radioisotopic Measurements and Equipment
    - 2.2.7.1 In-flight Labeling of Erythrocytes
    - 2.2.7.2 In-flight Labeling of Albumin
    - 2.2.7.3 Liquid Scintillation Counter
  - 2.2.8 Urine Volume Measurement Device
- 2.3 Preservation for Post Flight Analysis
- 2.4 The Evaluation of Reliability and Validity of Behavioral Measurements
- 2.5 Data Management Techniques
  - 2.5.1 Color Telemicroscope
  - 2.5.2 4-Channel Cathode Ray Tube

1.0 MEASUREMENT REQUIREMENTS

The IMBLMS measurements are required to assess the clinical status of the astronaut in terms of his general health, cardiovascular and musculoskeletal effects of weightlessness, and environmental effects from radiation, oxygen toxicity, microbial and chemical contamination, and crew interpersonal relationships. In addition, the IMBLMS measurements should provide research data to (1) determine unknown effects of spaceflight, (2) develop predictive indexes, (3) establish tolerance limits, (4) develop and optimize countermeasure equipment and (5) advance medical knowledge.

Measurement priorities and spacecraft measurement program objectives will vary from flight to flight depending on previous flight data, trend analyses, and updated mission objectives. However, a comprehensive flight biomedical capability designed on a modular basis to permit ease of maintenance, replacement, substitution, and growth is required to meet the needs of manned space exploration in the 1970's.

The previous phases of the IMBLMS program have identified measurements and measurement techniques considered for the Flight IMBLMS. A representative measurement capability has been defined for the B-3 Functional Breadboard phase to demonstrate state-of-the-art space qualifiable measurement techniques, application of a computer controlled data management system, centralization of related controls and displays, preliminary subject-operator equipment interfaces, and measurement test data analyses. Feasible FBB measurements, AAP measurements, and successfully developed advanced measurement techniques will be included in the Flight IMBLMS.

1.1 IMBLMS Measurements

Table I lists all the recommended FBB measurements as well as those established during the B-2 Phase of the program. The unmarked measurements will be included in the FBB, although several of those may require development, refinement, or validation. The measurements marked with a single asterisk (*) will be considered for addition in the Flight IMBLMS, while those marked with a double asterisk (**) are presently considered only for pre and post flight analysis. The only NASA recommended FBB measurement which is not recommended for either the FBB or the Flight IMBLMS is inflight viral culturing. LMSC feels that presently used techniques are far too complex, requiring a high degree of subject training, to be performed on board. It is, therefore, recommended that the Flight IMBLMS shall contain only provisions to preserve appropriate samples for post-flight analysis. ~~IMBLMS~~

It is recommended for the FBB and Flight IMBLMS that determinations normally made on serum be made on plasma. Difficulty has been experienced in the separation of serum from whole blood under simulated weightlessness (varied gravitational fields) because of failure of the clot to remain completely coalased. Whether this difficulty will persist in true weightlessness is unknown. Blood collected with sodium heparin as the anticoagulant can be used

TABLE I

IMBIMS MEASUREMENTS

I. Neurological

Clinical evaluation
- Electronystagmogram (2-channels)
- Electroencephalogram (2-channels)
- Electromyogram (1-channel)
- Level of consciousness assessment
- *Ocular counterrolling
- *Oculogyral illusion
- *Visual task with head rotation
- *Angular acceleration threshold
- *Agravic perception of personal and extrapersonal space

II. Cardiovascular

- Clinical evaluation
- Clinical electrocardiogram (12-leads)
- Reference electrocardiogram (sternal or axillary)
- Heart rate
- Vectorcardiogram (Frank's lead system)
- Impedance cardiogram (Kubicek method)
- Phono-/vibrocardiogram
- Arterial blood pressure
- Peripheral venous pressure
- Arterial pulse contour
- Venous occlusion plethysmrography
- Pulse wave velocity
- Response to inflight exercise
- Response to LBNP exposure
- *Ballistocardiogram
- *Central Venous Pressure (Derived)

III. Respiratory

- Clinical evaluation
- Respiratory rate
- Lung volumes
- Ventilation
- Breathing mechanics
- Gas distribution, consumption, and production with breath-by-breath sensitivity
- Diffusion capacity
- *Alveolar-arterial gradient

IV. Metabolism and Nutrition

Clinical Evaluation
Energy metabolism (Cat. II)
Ear canal temperature
Average skin temperature
Muscle size and strength
Body mass
Specimen mass
Total body water
Caloric intake (preflight assays)
Balance studies
*Inflight bone densitometry
*Gastric pH
*Gastric pressure

V. Endocrinology (see Category IX)

Clinical Evaluation

VI. Hematology (see Category IX)

Clinical Evaluation
Capillary fragility (Rumple Leede)

VII. Microbiology and Immunology

Clinical Evaluation
Body microflora
- bacterial
- fungal
- *viral

Environmental microflora
- bacterial
- fungal
- *viral

VIII. Behavioral Effects

Clinical Evaluation
Sensory test battery
- visual
- auditory

Psychomotor
- Fine Motor
- Cross Positioning
- Cross body movement
- Continuous Control

Complex Behavior
- Perceptual Cognitive
- Monitoring
- Complex Mental Processes
- Work

Individual and Interpersonal Behavior

IX. Clinical Laboratory Evaluations

Urinary Ca, P, Na, K, and Cl
Urinary color, specific gravity, pH, glucose, protein, bile, blood, and microscopic
Plasma volume
Plasma electrolytes (Ca, Na, K, Cl, and P)
Total protein - plasma
Blood glucose
Ca and PO_4 - plasma
pH, pO_2, and pCO_2 - blood
Hemoglobin
Hematocrit
Blood cell morphology (RBC, WBC, and differential; platelets)
Reticulocyte count
RBC fragility
RBC mass and survival
Bleeding and coagulation times
BUN
Ketones
Bilirubin
*Methemoglobin
*Carboxyhemoglobin
*Clot retraction
*Uric acid
*LDH
*CPK
*SGOT
*SGPT
*Alkaline phosphatose
*Bilirubin (colorimetric)
*BUN (colorimetric)
*Creatinine
*Cholesterol
*Lipids
*Magnesium
*Immunoglobulins
*Protein electrophoresis
*LDH isoenzymes
*Prothrombin time
*Bicarbonate
*T-3
*Fibrinogen
*Transferrins
**Sulfate
**Aldosterone
**Mucoproteins
**Hydroxyprolines
**Pryophosphates
**Total amino acids
**Creatine

**ADH
**17-hydroxysteroids
**17-ketosteroids
**VMA
**Metanephrines
**Catecholamines
**Histamine
**Serotonin (5-OHIAA)
**TSH
**Growth hormone
**Parathormone
**Insulin assay
**Calcitonin
**Glucagon assay
**Free thyroxin (T-4)
**TBPA
**Lymphocyte karyotyping
**Platelet adhesiveness
**Fibrinolytic activity
**Phospholipids
**Complement titration
**Antibody titration
**Prothrombin consumption
**Leucocyte mobility

X. Environmental Measurements

yes

Temperature
Pressure
Humidity
Atmospheric composition (O_2, CO_2, N_2)
*Spacecraft motion
*Toxic contaminants

interchangeably with serum for essentially all classes of determinations. In addition, carefully separated plasma reveals consistently less hemolysis than serum. The only potential interferences might be in the performance of electrophoresis in the Flight IMBLMS, where fibrinogen contributes an extra peak to the electrophoretic pattern. It is not felt, however, that this will prove to be a significant problem.

2.0 MEASUREMENTS AND TECHNIQUES REQUIRING CRASH DEVELOPMENT

2.1 FBB Measurements/Techniques

Several measurements, although included in the FBB, will require further development outside the B3 Phase to improve their technique, to enhance their accuracy, or to simplify their operational procedures.

2.1.1 Systolic and Diastolic Blood Pressure. - Nearly all indirect methods to measure arterial blood pressure employ the Riva-Rocci principle and are, therefore, inherently limited in accuracy. However, the ability to measure relative pressure changes reliably in lieu of absolute accuracy provides a useful measurement. The susceptibility of automatic blood pressure measurements to movement and ambient noise artifacts can be improved with further development. The use of multiple motion artifact cancellation circuits and/or the ultrasonic technique developed by Southwest Research Institute (AMRL- TR-67-201, Vol. 1) warrant further evaluation.

Various methods of indirect nonocclusive measurement of blood pressure have been proposed, but severe problems facing the transducer development have, until recently, limited the use of these techniques to rigidly controlled laboratory applications. One technique (pulse sensing) employs a direct force-balance probe which, when placed against the temporal artery, responds to the arterial pressure wave. Although still developmental, this method holds promise for possible space application as a continuous nonocclusive measurement of temporal arterial blood pressure. Accurate positioning of the sensor, and maintaining this orientation under exercise conditions may prove to be very difficult.

2.1.2 Limb Plethysmography. - An extensive review of limb plethysmography techniques for regional blood flow has shown that the Whitney mercury strain-gage method is still the most reliable and accurate technique. Replacement of the mercury with another electrolyte will have to be further investigated. LMSC will utilize the mercury strain gage bridge and amplifier developed by Brakkee and Vendrik * for the FBB because of its accurate electrical calibration and wide range of adjustment features.

* J. Appl. Physiology 21 (2) 1701-704, 1966

LMSC has done some development work on an ultrasonic technique. This unit performs very well from an electronic point of view, but considerable difficulties may occur in developing a suitable method of coupling the transducer crystals to the limb, while simultaneously maintaining unimpaired expansion of the tissues. The capacitance plethysmograph of Fewings and Whelan * has the advantage that the resting volume of the limb segment being measured can be calculated. Initial calibration is a rather complex procedure. To maximize measurement accuracy, individually molded capacitance cages would be required for both lower legs of each subject. Being rather delicate mechanically, storage of these cages or sleeves would take up considerable volume.

To perform venous occlusion plethysmography, inflation of the cuffs will be done manually in the FBB. For the Flight IMBLMS, an automatic method is recommended.

2.1.3 Cardiac Output. - Two methods will be used on the FBB: the Kubicek technique of impedance cardiography, and the CO_2 rebreathing technique of Fick. Both methods have their shortcomings and require considerable further development and experimentation before either can be regarded suitable for spaceflight use. The impedance technique is very sensitive to motion artifacts and accidental grounding of the subject; the CO_2 method requires maintaining a very stable steady-state condition of metabolic activity throughout the measurement cycle to obtain a reliable value. The invasive dye dilution technique such as cuvette densitometry, although considered to be the most accurate, is not recommended for in-flight use.

Determining cardiac output by the use of external counting of a radioactive indicator ** rather than a dye or the Fick principle is another technique which requires further study. The planned use of radioiodinated human serum albumin (RISA-125) to determine plasma volume affords the opportunity to determine cardiac output by simply placing a suitable radiation detector over the heart when the RISA injection is given. The count rate versus time data recorded as the RISA bolus passes are analyzed in a manner similar to the concentration-time data obtained using the dye injection-arterial sampling techniques. The amount of tracer to be injected for cardiac output determination is 10-20 microcuries of Iodine-125. A thin crystal scintillation detector and recorder are required. A state-of-the-art detector has dimensions of 10" x 1" and weighs 175 grams.

* J. Appl. Physiology 21 (1) 334-340, 1966

** Gorten, Ralph J. M. D., The Use of Iodine for Precordial Counting, Journal of Nuclear Medicine 6:129-174, 1965, Durham, North Carolina

2.1.4 Total Body Water. - If the accuracy of the recommended breath ethanol total body water technique is inadequate, consideration should be given to the tritiated water method. Use of tritiated water would require the development of a special scintillation counter. Problems in separation of the contaminated urine if drinking water is reclaimed from urine must be investigated. An alternate procedure of using radioiodinated iodoantipyrine requires serial determinations.

2.1.5 Respiratory Measurement/Equipment. -

2.1.5.1 Exercise Oxygen Consumption - Carbon Dioxide Production. - The accuracy and clinical acceptance of the open circuit system employing integrating flowmeters and rapid response gas analyzers is rapidly being improved and established. The accuracy of averaging multiple rapid measurements of volume and gas concentration on a breath-by-breath basis, while inherently less accurate than close spirometric techniques, has been aggravated by the slow response time and drift of previously available gas analyzers and errors in the flow integrators. The use of improved gas analyzers for the FBB and the development of a suitable mass spectrometer for the Flight IMBLMS should provide acceptable accuracy for these metabolic measurements.

2.1.5.2 Flight-Qualified Mass Spectrometer. - Development of a flight-qualified mass spectrometer would substantially reduce the weight and bulk of gas analysis equipment to be used in conjunction with the respiratory measurements and is mandatory for the measurement of trace contaminants. The instrument would require near-simultaneous measurement capability for the six respiratory parameters (O_2, CO_2, N_2, He, CO, and H_2O), and a rapid scanning feature for trace contaminant measurements.

2.1.5.3 Turbine Flowmeters. - The use of turbine flow meters offer excellent linearity over a wide range of flow velocities for relatively slowly changing flow rates. Presently available unidirectional turbine flow meters have technical problems in eliminating the inertial "coasting" of the rotor after the flow has stopped. Even at relatively low flow rates this coasting continues for approximately 10 seconds.

An electromechanical anti-coasting device, actually a switch placed upstream of the rotor, has been developed. This highly sensitive switch disconnects the rotor signal from the processing electronics when no flow is present. However, it does not eliminate rotor coasting. Similar technical problems will have to be solved before a bi-directional turbine flow meter currently under development can be recommended for the Flight IMBLMS.

2.1.6 RBC and WBC Counts. -

Although it would be quite possible to continue to perform erythrocyte and leucocyte counts microscopically, it would be preferable to develop a small impedance counter, capable of operation in a zero gravity environment. The manual performance of these tests, while providing valuable information, is very tedious, time consuming, and relatively inaccurate. An impedance counting technique would overcome these objections to the measurement and could be operated in either an automated system or as an independent unit.

2.1.7 Colorimetry-Conductivity Test Cell for Erythrocyte Osmotic Fragility. -

The determination of erythrocyte osmotic fragility is usually performed by placing a constant volume of cells in a series of hypotonic saline solutions and visually or spectrophotometrically estimating the level of hemolysis occuring at each of the saline concentrations. An accurate estimation of the fragility requires the use of several salt concentrations; the smaller the decrements, the more accurate the definition of the hemolysis curve. The number of solutions and manipulations involved make the technique rather undesirable for flight use. At least one device that performs this measurement by correlating the degree of hemolysis with salt concentration, during the continuous diffusion of the salt across a semipermeable membrane, is commercially available. A similar instrument developed for flight applications could save substantial amounts of time for the astronaut-investigator. It would also require less storage space than would prepackaged reagents for each saline concentration, and would reduce the amount of specimen required.

2.1.8 Preservation Equipment. -

2.1.8.1 Cryogenic Freezer. - The preservation and storage of blood, urine and fecal samples requires development of a flight oriented cryogenic freezer. Major problems are concerned with maintaining -100°C with a minimum expenditure of temperature control over a long period. Cryogenics offer a semi-passive system requiring a minimum expenditure of power. Pressure relief valves would have to be provided for handling solid to gas phase change.

2.1.8.2 Refrigeration. - Refrigeration and incubation are required for in-flight medical experiments during prolonged missions. The major disadvantage of conventional techniques is the continuous power expenditure. Development of a combined refrigerator-incubator employing the thermoelectric effect offers a solution to this problem for the required temperature range (34°F to 100°F).

2.2 Flight IMBIMS Measurement Techniques

The successful performance of all the measurements identified in Table 1 for the flight IMBIMS will require the crash development of certain measurement and data handling equipment/techniques.

2.2.1 Central Venous Pressure (Derived). -

Measurement of the time interval between the P-wave of the electrocardiogram and the A-wave of the jugular pressure pulse appears to have some merit to indirectly determine central venous pressure. Several problems have to be solved before this technique can be used as a practical monitoring method. These include the control of the timing in the respiratory cycle which causes large variations in the measurement from beat to beat, automatic measuring of the time occurrence of the low amplitude P-wave of the ECG, and automatic measuring of the time occurence of the A-wave in the V, A, and C wavetrain of each pressure pulse.

2.2.2 Inflight Bone Densitometry. -

Development of a flight qualifiable method to perform inflight bone densitometry can be expected to require a considerable effort, particularly so if no X-ray equipment is available. The difficulties in providing accurate calibration of a radioactive γ-ray source appears to be grossly under-estimated. Even in the ground based laboratory standardization of the X-ray source to provide an exact exposure of 167 $\pm$ 2 milliroentgen, in order to be able to compensate for minute differences in film characteristics, developer reagents, and development time, is an extremely exacting and time consuming procedure. The densitometric analysis of these X-rays requires very elaborate electronic equipment to obtain quantitative values, almost necessitating post flight analysis. Fogging of the films during long duration flights may become a severe problem unless heavy shielding is provided during storage.

2.2.3 Endoradiosondes. -

The use of endoradiosondes to measure intestinal motility, pressure, and pH has encountered several technical problems. Once the sonde has passed through the stomach, there is no accurate way of determining its location without the use of either fluroscopic examination or complex triorthogonal antenna arrays. An abdominal belt antenna does not permit localization of the sonde. Further development effort is required before the use of endoradiosondes can be included in the Flight IMBIMS.

2.2.4 Radial Immunodiffusion. -

Radial immunodiffusion offers the opportunity to analyze many specific proteins at the present time, and the promise of many more in the near future. Relatively little difficulty is anticipated with the adaptation of currently available radial immunodiffusion technology to operation in zero gravity. It may be necessary to incorporate suitable wicks into the serum reservoirs if capillarity proves inadequate for specimen containment.

2.2.5 Electrophoresis. -

The development of an electrophoresis system that will function in an environment of zero gravity presents some unusual difficulties. It should, nevertheless, be feasible to develop systems that will permit good resolution of serum proteins and LDH isoenzymes. The major problem to be overcome would appear to be the containment of the buffer solutions while providing electrical continuity in the support matrix. It is not considered necessary to develop immunoelectrophoretic technology, since immunologic analyses can be more readily performed by radial immuno-diffusion.

A device similar to that developed for the staining of differential and reticulocyte smears can be utilized for clearing and staining the protein electrophoretograms and the localization of LDH isoenzymes.

Quantification of separated components could be performed after transmission of a television image, or, if accuracy would be significantly impaired by this technique, a small reflectometer could be developed for the purpose.

2.2.6 Fluorometer. -

Certain of the enzyme systems included in Table I, require the presence of nicotinamide-adenine dinucleotide (NAD). Lactic dehydrogenase, for example, catalyzes the reversible oxidation of hydroxy acids to α - keto acids and α, γ - diketo acids in the presence of NAD. The enzyme will catalyze the oxidation of lactate to pyruvate, while simulataneously reducing the NAD.

$$\text{Lactate} + \text{NAD} \overset{\text{LDH}}{\rightleftharpoons} \text{Pyruvate} + \text{NADH} = \text{H}^{+}$$

The rate of conversion of lactate to pyruvate, or NAD to NADH is proportional to the concentration of LDH, and the amount of NADH formed during a given period of time can be used as an index of LDH activity. The amount of NADH formed may be estimated by measuring the intensity of native fluorescence after excitation by ultraviolet light. Systems utilizing this method are relatively simple to quantify because the absorbance maximum of NADH is at 340 nm while NAD, at that wavelength, has no absorbance and virtually no fluorescence.

This system can be used to estimate the activity of other enzyme systems as well. Methods have been published for oxalacetic transaminase, glutamic pyruvic transaminase, creatine phosphokinase and other parameters that can be estimated using certain enzymes, e.g. hexokinase for glucose.

Fluorescence has also been utilized to estimate other parameters of interest, e.g. cortisol, calcium, magnesium, etc. The development of this instrument would significantly enhance the measurement system capability.

2.2.7 Radioisotopic Measurements and Equipment. -

2.2.7.1 In-flight Labeling of Erythrocytes. - The determination of red cell mass and red cell survival is probably best carried out using ^{51}Cr as the chromate. The half-life of ^{51}Cr is only 28 days. This poses a serious problem of bringing on-board a sufficient quantity to last one year. The energy at around 300 kilovolts is high enough to require considerably greater shielding. A more serious problem is that it is important that excessive quantities of chromium be avoided during the labeling process. - That is, the specific activity of ^{51}Cr has to be adequate. The longer the ^{51}Cr preparation decays, the lower the specific activity becomes, and one has to be concerned about the possibility that red cells might be damaged during the course of labeling.

For these reasons, it appears necessary to provide an in-flight capability for cell labeling. The ^{51}Cr can be carried in concentrated form and the citrate buffer can be prepackaged. This will require the development of methodology that will permit the maintenance of specimen sterility. Also, since the labeled material will be reinjected, there is an absolute requirement for the complete exclusion of gas from the specimen since any gas, if injected, could lead to the formation of dangerous emboli.

2.2.7.2 In-flight Labeling of Albumin. - Plasma volume determinations are probably best done by using ^{125}I or ^{131}I- Albumin. However, since the iodination of protein probably limits the biologic integrity of the labeled material to a period of about three weeks, it is clear that taking labeled material on board at the onset of the flight could not satisfy the requirement to perform repeated determinations of plasma volume.

Since the half-life of ^{125}I is about 60 days, and the isotope for labeling is available in large doses but requiring minute volumes for iodination, it is entirely feasible to take on-board a sufficient quantity for iodinating protein for at least six months and probably a year.

In-flight labeling of the protein presents the same problems as red cell labeling, i.e., sterility and gas exclusion, with the additional requirement for column purification of the material prior to injection.

The availability of a protein iodination system offers the additional advantage that one could perform a number of radioimmunoassays on-board, since iodination is the basic first step in radioimmunoassay procedures. By this method it would be possible to assay the following materials in plasma: TSH, glucagon, growth hormone, parathyroid hormone, and insulin. It is likely that in the near future immunoassays will be available also for ACTH, thyrocalcitonin, and angiotensin. The basic steps in all of these radioimmunoassays are essentially similar and may be performed by a skilled technician.

The essential features of the radioimmunoassay are as follows: one must first procure the pure hormone for labeling, specific potent antibody to this hormone prepared in rabbits or some other animal, and antigammaglobulin specific for the animal which has been used to make the antihormone. Its greatest advantage is its sensitivity, since it can measure quantities of hormones in plasma which are undetectable by other methods. The fundamental principle involved is that the labeled hormone reacts with its antibody and forms an insoluble complex. If a fixed amount of antibody is present, then the addition of nonlabeled hormone will compete for the binding sites on the antibody and, therefore, the amount of labeled material which is precipitated will diminish in proportion to the cold material present. Essentially it is a competition type assay which involves labeling, incubation at cold storage, centrifugation, removal of a supernatant, and radioactive counting, followed by rather simple calculations.

2.2.7.3 Liquid Scintillation Counter. - The miniaturization and flight qualification of this type of equipment would permit the use of tritiated water for total body water determinations as discussed under FBB measurements. In addition, studies with ^{14}C-labeled compounds could be made. ^{14}C has a long half-life (many years) and so might be thought to be a dangerous tracer. However, in many instances the compound under study is rapidly metabolized by the body and the ^{14}C is emitted as $^{14}CO_2$ in the breath. Such breath analysis, when combined with urinary and blood measurements, enables one to conduct metabolic studies of such substances as glucose, lactate, proprionic acid, etc.

2.2.8 Urine Volume Measurement Device. -

An adequate urine volume measurement device is required for the Flight IMBLMS. The device must be integrated into the Spacecraft's waste management system, allow for individual collection and transfer of all or a small representative sample of a urine specimen which can be identified and time coded. The device must be hygienic and permit intermittent sterilization procedures to prevent microbial contamination.

2.3 Preservation for Post Flight Analysis

Table 2 presents a list of parameters proposed for post flight analyses, together with estimates of storage stability. Since few of the parameters have been subject of a definitive study, the storage intervals are estimates rather than known quantities. Stability studies should be conducted over the required intervals to quantify the effect of freezing (-75-100°C) and preservatives.

Certain measurements where preservation is doubtful are those dependent on the integrity of the cell wall, e.g. leucocyte mobility, platelet adhesiveness, and viscosity. Others are questionable, e.g. certain specific clotting factors, blood serotonin, RBC enzymes, karyotyping and mucoproteins.

Mineral and nitrogen balance studies normally require analysis for these elements in all the waste products of man. The bulk storage requirements for freeze preservation of all the urine and feces produced during an extended period (weeks) places an inordinate design constraint on the on-board preservation system and the spacecraft recoverable payload capability.

Development work is recommended to determine if the effects of vacuum drying those waste products on the parameters of interest is consistent and quantifiable. If small representative waste samples would be preserved by freezing and the remainder vacuum dried and a corrective factor applied for the elements lost during the vacuum drying, balance studies could be performed in extended flights with minimum engineering penalties.

2.4 The Evaluation of Reliability and Validity of Behavioral Measurements

A measurement technique must be proven reliable and valid. Prior to flight use the IMBLMS behavioral measurement techniques must be evaluated as a composite test battery with regard to these characteristics. Successful utilization will require establishing population standards and baselines of performance. Since the test battery is a composite of many previously separate measurement techniques, standardization of this particular group of tests is essential. Furthermore, the sensitivity of these measures and their efficacy over long periods with repeated measurement must be evaluated. Finally the relationship of these performance measure to physiological indices must be established and this is possible only through empirical determinations.

TABLE 2

STORAGE OF SPECIMENS FOR
POST-FLIGHT ANALYSIS

PARAMETER		PROBABLE STORAGE STABILITY -75 to -100°C	REFERENCE
1.	Catecholamines	Indefinitely--acidify	1,2
2.	Metanephrines	Indefinitely--inferred	1,2
3.	VMA	Indefinitely--inferred	1,2
4.	5-HIAA	>45 days, or acidify	2
5.	17-ketosteroids	>45 days, or acidify	2
6.	17-OH-steroids	>45 days, or acidify	2
7.	Hydroxyproline	>45 days	
8.	Amino acids	>45 days	
9.	Creatine	>45 days, or acidify	2
10.	Aldosterone	>45 days, or acidify	2
11.	ADH	>45 days, or acidify	2
12.	ACTH	>45 days, or acidify	2
13.	Pyrophosphates	>45 days, or acidify	2
14.	Antibody Titrations	>45 days	2
15.	Prothrombin Consumption	>45 days	2
16.	Clotting Elements	>45 days (VIII 17 months)	2,3
17.	Blood Rheology	Doubtful	
18.	Fibrinolytic Activity	>45 days	2
19.	TSH	>45 days (inferred)	2
20.	Growth Hormone	>45 days (inferred)	2
21.	Parathyroid Hormone	>45 days (inferred)	2
22.	Insulin	>45 days (deamidation when frozen in acid)	3
23.	Glucagon	>45 days (inferred)	2
24.	Calcitonin	>45 days (inferred)	2
25.	Complement Titration	>45 days	2
26.	Mucoproteins	Questionable	2,3
27.	Sulfate	> 45 days	2
28.	Phospholipids	> 45 days	2
29.	Histamine	Unknown	
30.	Leucocyte mobility	Doubtful	2
31.	Lymphocyte Karyotyping	May perform culture on-board, Stopping Growth at Metaphase	
32.	Platelet Adhesiveness	Doubtful	2
33.	TBPA	> 45 days	2
34.	T4	> 45 days	2
35.	RBC Enzymes	Unknown, use preservatives before freezing	
36.	Serotonin	Unknown, Freezing plus preservatives	4

References:

1. Syllabus of Laboratory Examinations in Clinical Diagnosis
   Edited by L. B. Page and P. J. Culver
   Harvard Univ. Press, 1962 pp 332-334
2. Fraser, T. M., Storage of Biological Samples
   Aerospace Medicine 39: 146-152 (1968)
3. Davies, D. F., Effects of Freezing and Thawing on Selected Quantitative Recoveries, Cryobiology 5: 87-95 (1968)
4. Specialized Diagnostic Laboratory Tests, 7th Edition
   Bio-Science Laboratories

2.5 Data Management Techniques

2.5.1 Color Telemicroscope. -

Lockheed has performed early laboratory evaluation of the potential use of three color filters, in conjunction with its black and white telemicroscope television system, to provide an ultimate (after ground based processing) color rendition of the microscopic slides being viewed; all within the bandwidth constraints of black and white TV signal transmission. The results of these early experimentations were sufficiently promising to warrant a recommendation that further development be programmed to achieve this three color capability for the Flight IMBIMS. The basic problem appears to be a lack of enough spectral response at the red end of the spectrum. A potential solution would be the use of a monitor screen with a lower color temperature characteristic and, if necessary, a special vidicon tube with extended red response.

2.5.2 4-Channel Cathode Ray Tube. -

Although one type of cathode ray tube (CRT) has been developed for space use, as part of a Gemini experiment package, it will be necessary to extend this basic design knowledge into a device with a larger viewing surface plus a dual-persistence screen. Laboratory development will be required to evaluate the several approaches to both long and short term persistence, including varying phosphors, use of filters and/or electronics. The IMBIMS CRT should be able to be used both for analog waveform display and as a video monitor.

SECTION III-A

IMELMS FUNCTIONAL BREADBOARD (FBB) PERFORMANCE/DESIGN/TEST REQUIREMENTS

FBB SYSTEM

FBB SYSTEM

1.0 INTRODUCTION

1.1 Functional Breadboard (FBB) Scope
1.2 System Definition
1.3 Organization of Requirements Documentation

2.0 APPLICABLE DOCUMENTS

2.1 Specifications
2.2 Standards
2.3 Other Documents

3.0 TECHNICAL REQUIREMENTS

3.1 Performance
3.1.1 Functional
3.1.1.1 Overall System Requirements
3.1.1.1.1 Measurement/Technique Requirements
3.1.1.1.2 Medical/Engineering Operational Requirements
3.1.1.1.3 Data Management Requirements
3.1.2 Operability
3.1.2.1 Reliability
3.1.2.2 Maintainability
3.1.2.3 Useful Life
3.1.2.4 Natural Environment
3.1.2.5 Transportability
3.1.2.6 Human Engineering
3.1.2.7 Safety
3.2 Interface Requirements
3.2.1 Experiment Equipment/Measurement Station Interfaces
3.2.1.1 Experiment Equipment/PBDM Station Interfaces
3.2.1.2 Experiment Equipment/Clinical Measurement Station Interfaces
3.2.2 Measurement Station/Support System and Facilities
3.2.2.1 PBDM Station/Support Systems
3.2.2.2 PBDM Station/Facilities Interface
3.2.3 MSC Laboratory Interface with the FBB
3.2.3.1 MSC Laboratory Configuration
3.2.3.2 LMSC Installation Requirements
3.2.3.3 Data Processing
3.3 Design and Construction
3.3.1 Mechanical
3.3.1.1 Modules Sizing Requirements
3.3.1.2 Structural Requirements
3.3.1.3 Display and Controls

(continued)

3.3.2 Electrical and Electronic
3.3.2.1 Electrical Connectors and Circuitry
3.3.2.2 Calibration
3.3.2.3 Power
3.3.3 Fluid (Gas & Liquid)
3.3.4 Test Provisions
3.3.5 Materials, Parts and Processess
3.3.6 Electromagnetic Interference

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

5.0 TEST REQUIREMENTS

1.0 INTRODUCTION

1.1 Functional Breadboard (FBB) Scope

This part of the FBB documentation establishes the overall performance, design, and test requirements of IMBLMS Functional Breadboard (FBB). The FBB shall be designed to carry out each specified measurement and test completely and with essentially the same procedural sequence as projected for the flight IMBLMS.

The FBB design requirements have been established to provide guidelines for component and system development and to assure that interfaces between the FBB and the observer/subject will be met. These requirements will be reviewed and when approved by NASA will form the Functional Breadboard Specifications.

Various NASA, military and industry specifications particularly pertinent to the FBB design served as basic guides in the following discussion of these requirements. In particular design requirement format as outlined in NASA Apollo Applications Program Experiment General Requirements, MSC-KA-D-68-1, NASA-MSC, March 15, 1968 has been followed to expedite subsequent flight requirements establishment.

1.2 System Definition

The IMBLMS Functional Breadboard (FBB) will be designed to fulfill several major design and performance goals. These goals include the capability to conduct each measurement and test with essentially the same procedural and data handling sequences as planned for the flight IMBLMS; to determine measurement feasibility and accuracy under operational constraints; to demonstrate centralized experimenter control; and to evaluate the handling, storage, and display of measurement data.

The IMBLMS FBB system as illustrated in Figure 1, comprises the following elements: A Physiological/Behavioral/Data Management (PBDM) Station; Major peripheral measurement equipment; Subject measurement equipment; Biochemical Preparation and Analyses (BPA) Station; Peripheral electronic equipment such as recorders, etc.; and Computer and Supporting Interface Simulation and Control and Data System (SCADS). In conjunction with a general purpose computer, SCADS will provide a simulation of the IMBLMS flight-processing capability for automatic data routing, onboard data computation, and data compression. Interface requirements for nondeliverable equipment (e.g., LBNP, ergometer, mass measurement system, specimen mass measurement system, analog tape recorder, auxillary pen recorder, and SCADS/Computer system) will be delineated.

1.3 Organization of Requirements Documentation

Ten requirements documents will be developed based on the FBB System Definition. The top document - System Requirements of which this document pertains, with the remaining documents concerned with Consoles, PBDM Station requirements, Biochemical Preparation and Analysis Station requirements, and Data Management requirements.

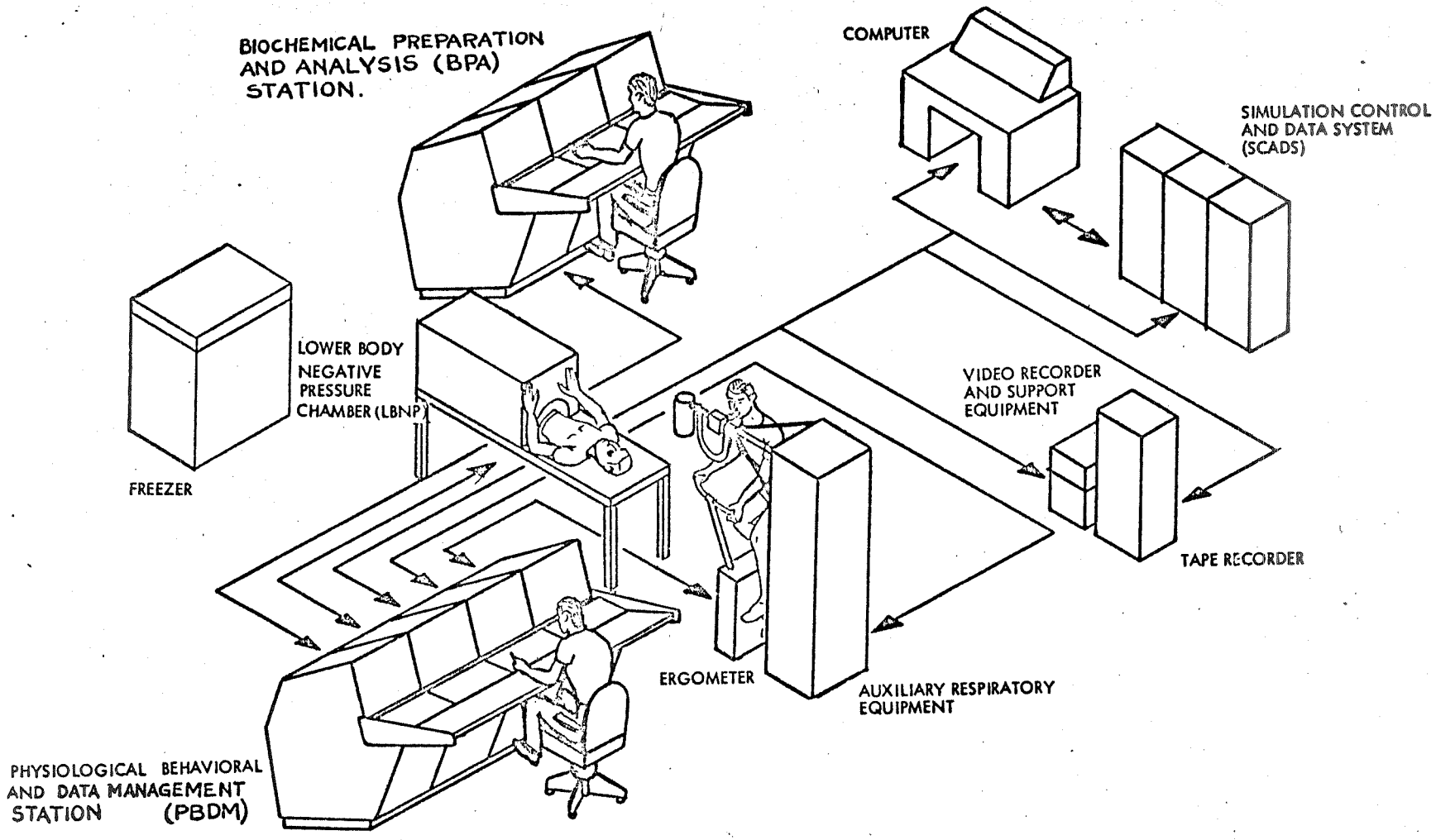


Fig. 1 IMBLMS Functional Breadboard System

Requirements documentation is as follows:

- o FBB System
- o Consoles
- o PBDM Station
  - Clinical Evaluation
  - Dynamic Physiological Monitor
  - Vascular Dynamics
  - Respiratory
  - Metabolism and Nutrition
  - Behavioral
- o Biochemical Preparation and Analysis
- o Data Management

Incorporated in the requirements documents are the descriptive definitions and block diagrams associated with FBB.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this General Requirements document and will be used to furnish design guidelines. Any subsequent revisions to these documents which will be applicable will be defined in the Engineering Development Unit (EDU) Requirements to be developed under Task VII.

2.1 Specifications

2.1.1 Military

Number	Title	Date
MIL-A-9067C	Adhesive Bonding, Process and Inspection Requirements for	3-16-61
MIL-C-27500 (USAF)	Cable, Electrical, Shielded and Unshielded, Aircraft, and Missile	12-27-60
MIL-D-5480D	Data, Engineering and Technical: Reproduction Requirements for	2-5-59
MIL-D-9412D (USAF)	Data for Aerospace Ground Equipment	9-27-61
MIL-W-6858C	Welding, Resistance: Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resisting Alloys, and Titanium Alloys; Spot and Seam	10-20-64
MIL-W-22759B (WP) With Supplement 1 dated 10-28-65	Wire, Electrical, Fluorocarbon-Insulated, Copper and Copper Alloy	10-28-65

2.12 Federal

J-C-98	Cable and Wire, Insulated; Methods of Sampling and Testing	9-11-51

2.2 Standards

Military Number	Title	Date
MIL-STD-100	Engineering Drawing Practices	3-1-65
MIL-STD-130B With Notice 1 dated 2-7-64	Identification Marking of U. S. Military Property	4-24-62
MIL-STD-453 With Change Notice 1 dated 9-4-63	Inspection, Radiographic	10-29-62
MIL-STD-461	Electromagnetic Interference Characteristics, Requirements for Equipment	7-31-67
MIL-STD-701F With Supplement 1 (USAF) dated 2-6-67 and Notice 1 (USAF) dated 1-23-67	Preferred and Guidance Lists of Semi-Conductor Devices	1-11-67
MIL-STD-1472	Human Engineering Design Criteria for Aerospace Systems and Equipment - Part 1. Aerospace System Ground Equipment	1-27-64
MIL-STD-1472	Human Engineering Design Criteria for Aerospace Systems and Equipment - Part 3. Aerospace Vehicles and Vehicle Equipment	5-19-67
MIL-STD-810A (USAF)	Environmental Test Methods for Aerospace and Ground Equipment	6-23-64

2.3 Other Documents

2.3.1 NASA

Number	Title	Date
KMI 1710.1 Attachment A	General Safety Plan Kennedy Space Center	10-4-66
M-DE 8020.008B	Natural Environment and Physical Standards for the Apollo Program	4-65 revised through 8-15-66
MSC-NA-D-68-1	Nonmetallic Materials Design Guidelines and Test Data Handbook	11-27-68
MSCI 1860.1A	Radiological Control - Exposure of Astronauts to Ionizing Radiation	7-11-67
NPC 200-2	Quality Program Provisions for Space System Contractors	4-62
NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services	4-62
NPC 200-4	Quality Requirements for Hand soldering of Electrical Connections	8-64
NPC 250-1	Reliability Program Provisions for Space System Contractors	7-63
RA-006-013-1A	Procedure for Failure Mode, Effects, and Criticality Analysis (FMECA)	8-66

2.3.2 Military

Number	Title	Date
AFETRM 127-1	Range Safety Manual Air Force Eastern Test Range	11-1-66
MIL-HDBK-5A	Metallic Materials and Elements for Aerospace Vehicle Structures	2-8-66
MS 24123A (USAF)	Plate, Identification	1-21-60
MS 33586A (ASG)	Metals, Definition of Dissimilar	12-16-58
AFSCM 80-9 Volume IV	Handbook of Instructions for Aerospace Systems Design - Electromagnetic Compatibility	4-20-66 revised through 4-20-67

2.3.3 Other

Unnumbered	Atomic Energy Act of 1954
Unnumbered	Title 10, Code of Federal Regulations, Chapter I, Part 30
H4-1	Federal Supply Code for Manufacturers (Name to Code)

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional.

3.1.1.1 Overall System Requirements. - The IMELMS functional breadboard designed to fulfill several major design and performance goals. These goals include the capability to conduct each measurement and test with essentially the same procedural sequence as planned for the flight IMELMS; to determine measurement feasibility and system accuracy under operational constraints; to demonstrate centralized experimenter control; and to evaluate the display, storage, and handling of measurement data. This section will list general overall system requirements that have been established to implement the FBB design.

Measurement techniques must be applicable for use in a zero g environment within a post Apollo spacecraft or space station. Measurement equipment must be flight qualifiable within practical limitations of weight, power, volume and cost, although no special efforts will be made to miniturize the FBB. Simplicity of individual measurement procedures and equipment along with centralization and utilization of controls and displays must facilitate multi-discipline experiments with small crews and optimize crew task assignments. Experiments must be safe, elicit the required degree of motivation and crew cooperation and provide reliable and clinically useful measurement data.

3.1.1.1.1 Measurements/Techniques Requirements. - The measurement/techniques selection for the FBB is based on the ten measurement categories established by NASA. Although the LMSC listing of the measurements (See Table I) follows the ten NASA categories, for reasons of making maximum use of comonality of equipment, to obtain logical control and display lay-outs, and to simplify operator-and subject-/equipment interfaces, LMSC has regrouped the measurements to fulfill these requirements.

The neurological measurements have been pooled with the vital signs and the more basic measurements in the cardiovascular group to facilitate centralized control on the Dynamic Physiological Monitor (DPM), which also displays the simple derived values such as heart rate, respiration rate, and systolic and diastolic blood pressure.

The more complex measurements in the cardiovascular group, such as cardiac output (impedance cardiogram), and those requiring the use of or used in conjunction with the LBNP or the ergometer, and which rely on the computer to perform the necessary calculations, are displayed on the Vascular Dynamics panel. Energy metabolism in terms of oxygen consumption and carbon dioxide production from Category IV, Metabolism and Nutrition, are included in the Respiratory Subsystem measurements, whereas ear canal temperature and average skin temperature from this same category, are measured at the DPM. The measurement of capillary fragility (Rumple Leede technique) from Category VI, Hematology, has also been included in the cardiovascular group, mainly because it uses a blood pressure cuff used for other measurements in that group. All

TABLE 1
IMBLMS MEASUREMENTS

Clinical Evaluation	
	History and physical examination.
Dynamic Physiological Monitor	
Cardiovascular:	ECG, VCG, sternal leads, heart rate, PCG/VbCG. Arterial blood pressure, pulse wave contour. Respiratory rate; ear canal and average skin temperature.
Neurological:	EEG, ENG, EMG. Level of Consciousness assessment.
Vascular Dynamics	
Cardiovascular:	Venous pressure (direct and indirect method). Pulse Wave velocity. Limb plethysmography. Cardiac output (impedance cardiogram).
LBNP	
Ergometer	
Respiratory	
Lung volumes:	Inspiratory capacity, expiratory reserve capability, vital capacity, residual volume, functional residual capacity, total lung capacity.
Ventilation:	Respiratory rate, Tidal volume, minute tidal volume, dead space, alveolar ventilation.
Breathing mechanics:	Maximum breathing capacity, timed vital capacity, maximum inspiratory flow, maximum expiratory flow, lung compliance airway resistance, minute alveolar volume.
Gas distribution, etc. comsumption:	Nitrogen washout.
	Alveolar pO_2, pCO_2
	O_2 consumption - breath-by-breath, continuous.
	CO_2 production - breath-by-breath, continuous.

(Table 1 Continued)

	Respiratory exchange ratio.
	Diffusion capacity (CO).
Arterial blood gases:	pO_2, pCO_2, pH
	Alveolar - arterial pO_2 gradient for air and 100% O_2.
	Capillary pO_2, pCO_2, pH.
Cardiac output:	CO_2 rebreathing technique.
Environmental measurements:	Temperature, pressure, pCO_2, pH_2O.
<u>Metabolism & Nutrition</u>	
	Caloric intake (data input).
	Muscle size and strength.
	Body Mass.
	Total body water.
	Capillary Fragility (Rumple Leede)
<u>Behavioral</u>	
Sensory motor:	Visual.
	Auditory.
	Psychomotor.
Complex behavior:	Monitoring.
	Complex mental processes.
	Complex perceptual processes.
	Work behavior.
	Individual and Interpersonal Behavior.

(Table 1 Continued)

Chemical Preparation & Analysis

Specimen identification and handling:	Blood, urine, microbiol smears.
Ion-specific electrodes:	Blood - pH, pO_2, pCO_2, Bicarbonate.
	Plasma - Sodium, potassium, chloride.
	Urine - Sodium, potassium, chloride.
Colorimeter:	Blood - Osmotic fragility, hemoglobin.
	Plasma - Glucose, calcium, phosphorus.
	Urine - Calcium, phosphorus.
Impedance:	Blood - Hermatocrit.
Refractometer:	Plasma - total protein.
	Urine - Specific gravity.
Test tapes:	Urine - pH, protein, glucose, blood, bile.
Radio-isotope Counter:	RBC mass and survival.
	Plasma volume.
Microscopy:	Blood - RBC, WBC, WBC differential, Reticulocytes,
	Cell morphology.
	Urine - Urinary sediments.
	Other microbial smears.
Miscellaneous:	Blood - Bleeding time, Coagulation time.
	Urine - color.

biochemical, hematological, microbiological, and immunological measurements have been pooled together in Category IX, Clinical Laboratory Evaluation. Since all FBB measurements of environmental parameters (Cat. X) are of major concern in the respiratory measurements, the equipment required is considered part of the Respiratory Subsystem.

3.1.1.2 Medical/Engineering Operational Requirements. - This subsection presents the functional operational interface requirements for the medical operator and subject utilizing the FBB console, rack equipment, and test apparatus. Requirements specified herein are applicable for both the PBDM and BPA stations.

User Personnel. - The FBB system will be designed to accommodate the 5th to 95th percentile population for the following equipment items: (1) consoles: (2) equipment racks; (3) Lower Body Negative Pressure Device (LBNP) chamber; (4) Ergometer; and (5) patient bed. Sensors, harness, masks, etc., will be designed for the 50th percentile population with provisions for adjustment to accommodate varying percentile ranges.

The FBB will be designed to be operated by personnel with a general background and training similar to that of an astronaut. This will correspond to individuals of intelligence levels and technological skills similar to astronaut - physicians and astronaut-pilot-engineer.

Equipment Location. - The PBDM and CMS consoles and supporting equipment and racks will be designed to permit their installation in a designated NASA/MSC facility. The location of test subject apparatus, LBNP, ergometer, and stowage enclosures will permit operator (physician) visual surveillance during appropriate periods of the experiment run (see Fig. 2).

Equipment that consists of expendable supplies will be located remotely from the stations. A freezer that is being used to preserve specimens may be located some distance from the operational station since it will be used infrequently and it will be mounted on wheels so that it can be moved easily to any designated area.

Some equipment will never be used at the same time with other equipment. An example of this is the Ergometer and the LBNP. If convenient this equipment should be remotely located from the operational station until actually required during the experiment run. The Mass Measurement devices are used infrequently and can be treated similarly. The vest/wiring harnesses that comprise the cardiovascular measurement system are worn individually with the possible exception of inclusion of the Neurological Harness with one of the other harnesses. These harnesses can be stored remotely until such time that they are required for a specific experiment run. An important consideration is for the consoles to be designed to permit operator (physician) see-over for viewing of subjects and test

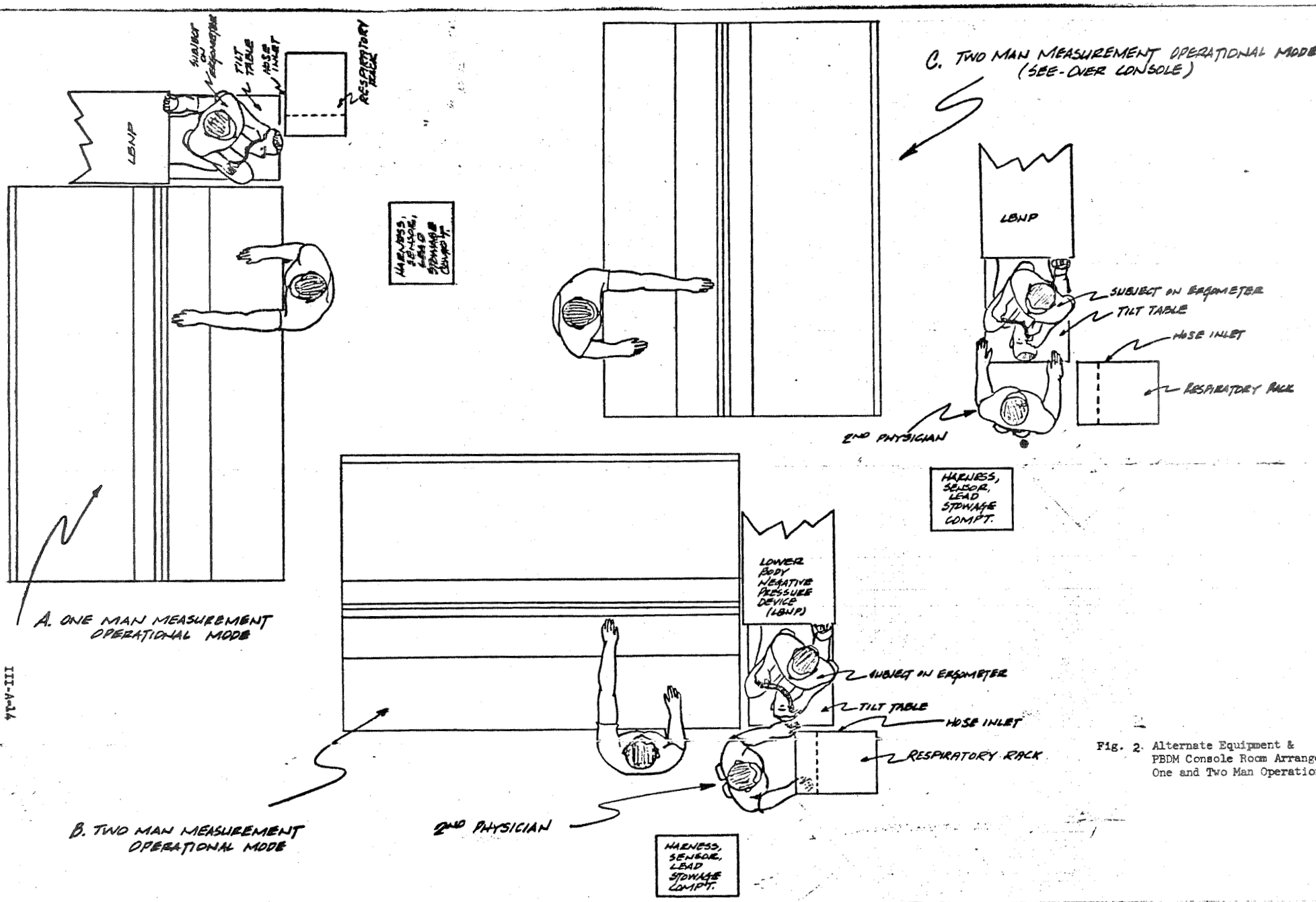


Fig. 2. Alternate Equipment & PBDM Console Room Arrangements-One and Two Man Operation

apparatus located behind the console. Location of the LBNP and ergometer will be within immediate reach/access of the seated console operator (physician). All biochemical support equipment required for BPA operator utilization during a measurement run will be located within the seat movement range of the operator. Cables for support equipment and test apparatus will be sufficiently long to permit the console operator to move these items into a "convenient" utilization position prior to measurement runs. Equipment design will permit alternate arrangement possibilities while providing sufficient maintenance access (at the console or rack, or equipment removal/replacement).

Measurement Operational Mode. - Three primary measurement subsystems will be included in the FBB program and are: (1) Physiological; (Behavioral, and (3) Biochemical. These three measurement areas will be supplemented by a data management subsystem for data input, output, handling, processing and display. The physiological and behavioral measurement subsystems, and the data management subsystem will be integrated into one operational station area including support equipment. This station area will be known as the PBDM station. The biochemical measurement subsystem will be integrated into a second area including support equipment and will be designated the Biochemical Preparation and Analysis. The operational mode for the PBDM station area will be designed for a one man operator and one subject. The operational mode for the BPA station will be designed for a one man operator with or without a subject. Biochemical samples may be taken prior to the measurement run.

Additional individuals associated with the checkout activity will be employed as test support or measurement monitoring personnel only and will not be included in the actual station operational measurement procedural run.

Console Display/Control Panels and Work Surfaces. - Operation of numerous measurement equipments will require specific displays and controls be provided the operator in a convenient work place layout. Therefore, dedicated display and control panel zones will be required in a console for operator utilization. The operator will require an area to place logs, procedures, work sheets, etc., and additionally, an area to rest his arms, elbows, or hands during routine operations. A workshelf area will, therefore, be provided to accommodate this requirement. Figure 3 presents the required operational display, control and workshelf area relationship to the operator. This figure also presents general design requirement limitations for panel and workshelf area combinations. Reach envelope requirements are presented in Figure 4 for a console configured to accept standard 19 inch rack equipment mounting. Figure 5 presents visual cone envelope requirement limitations for viewing control and display areas for a typical four (4) bay console configuration and equipment location scheme.

Console Configuration. - Requirements for FBB consoles have been established above; therefore, the layout of the PBDM and BPA console will be in accord with the Crew Systems design objectives and requirements listed in Table 1. The general console configuration requirement, and the capability for console see-over is presented in Figure 6. The console will be composed of multiple bays, each of which can accommodate standard equipment racks of 19 inch modules. The PBDM station console will be composed of four (4) bays and the BPA station will be composed of three (3) bays. Both consoles will incorporate groth space in the panel areas and within the console shell to provide for subsequent display/control equipment addition as deemed necessary.

REACH INCREASE

	ARM POSITION 0°	45°	90°
• SHOULDER EXTENDED	4"	3"	2"
• SHOULDER EXTENDED & TRUNK ROTATED	6"	4"	2"
• SHOULDER EXTENDED, TRUNK ROTATED, & TRUNK BENT	16"	12"	8"

REACH DECREASE

• PUSH BUTTONS	0"
• TOGGLES	2"
• SMALL ROTARY SELECTORS &TD	4"
• LARGE ROTARY SELECTORS	4.5"
• HAND GRASP	5"

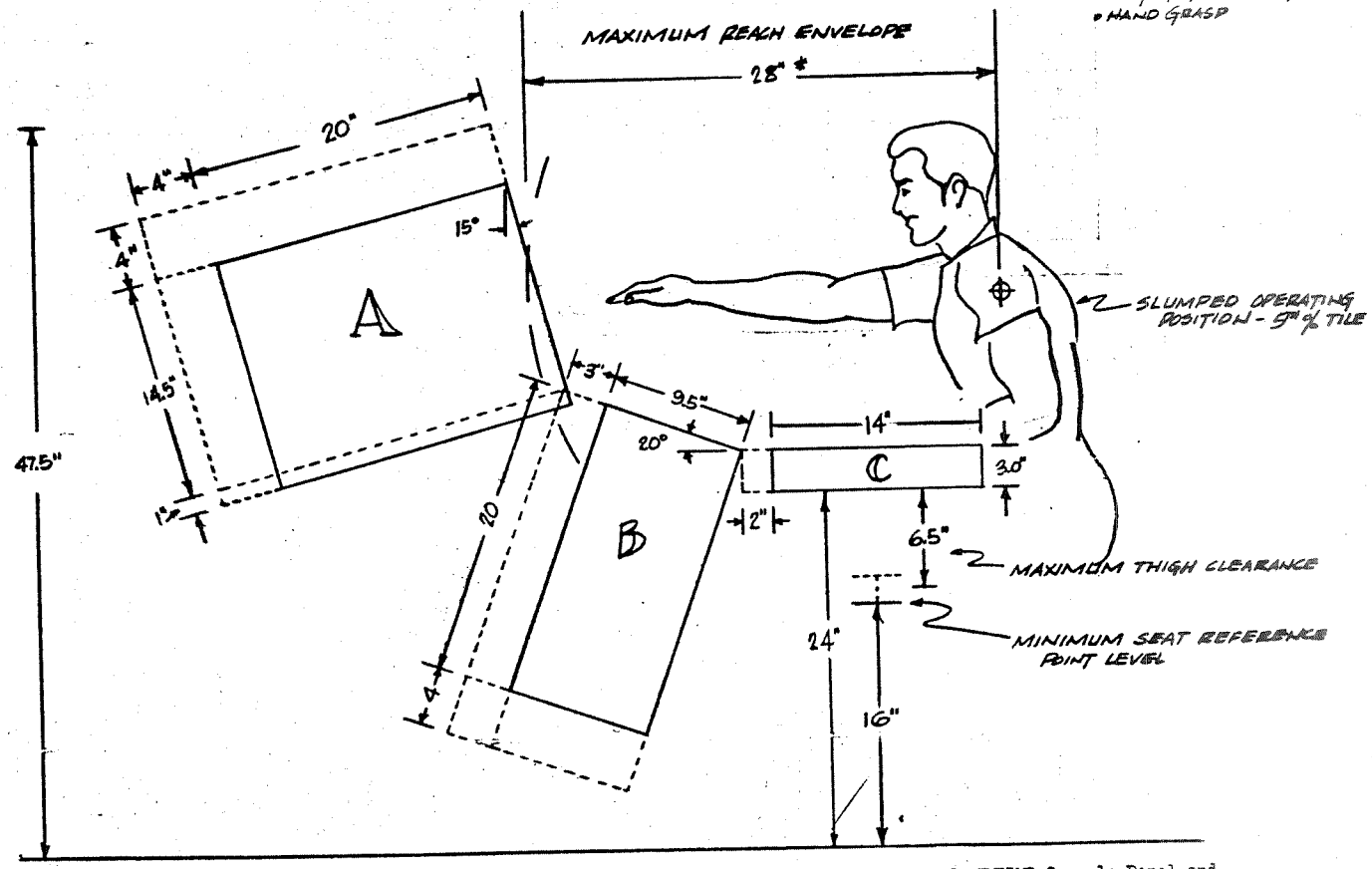


Fig. 3 IMPINS Console Panel and Workshelf Arrangement Requirements

* THIS DIMENSION NOT TO SCALE

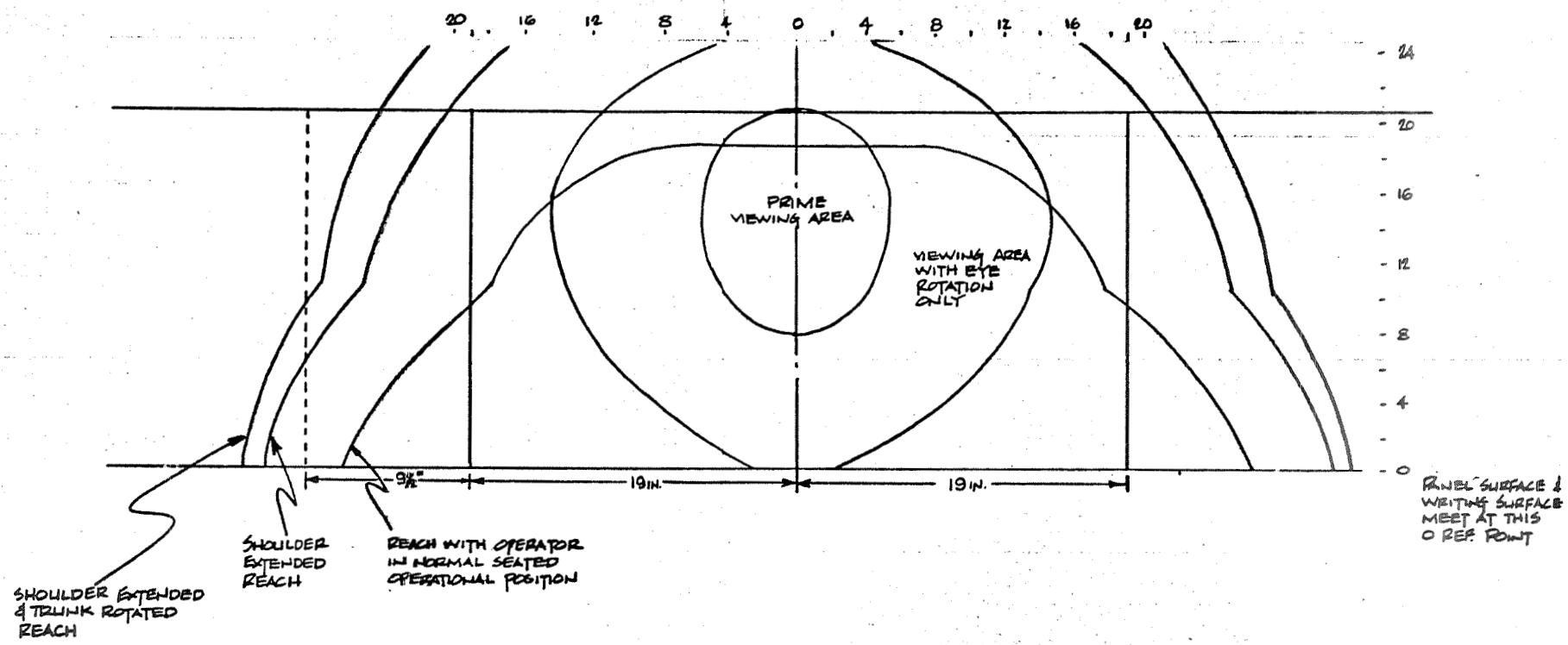
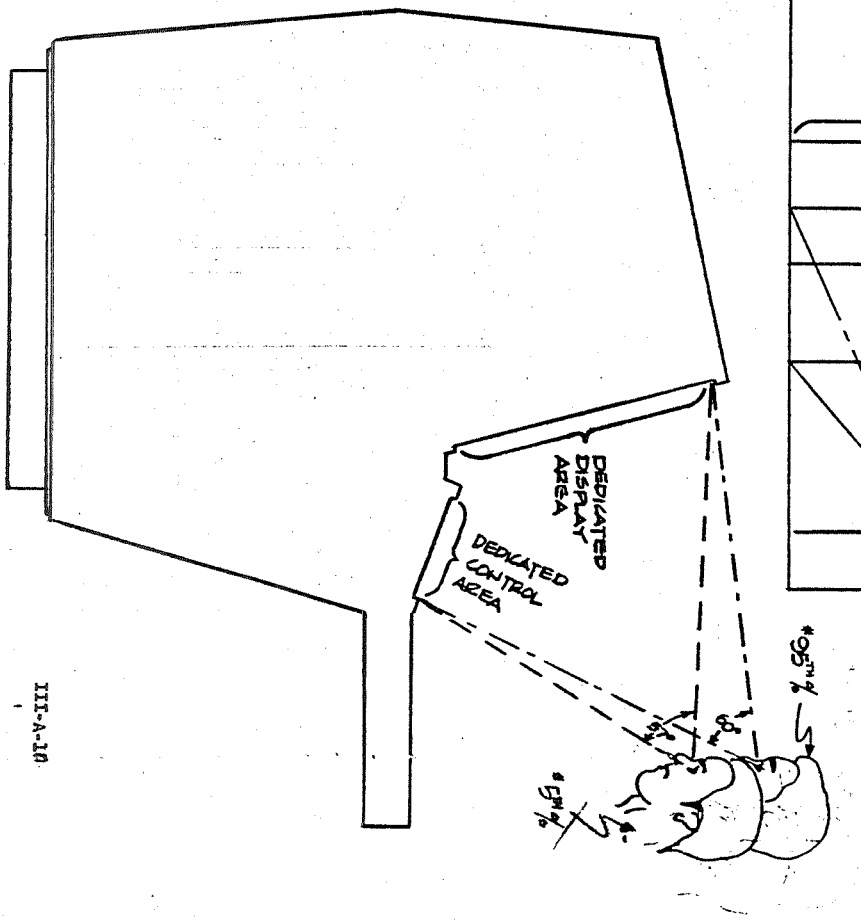
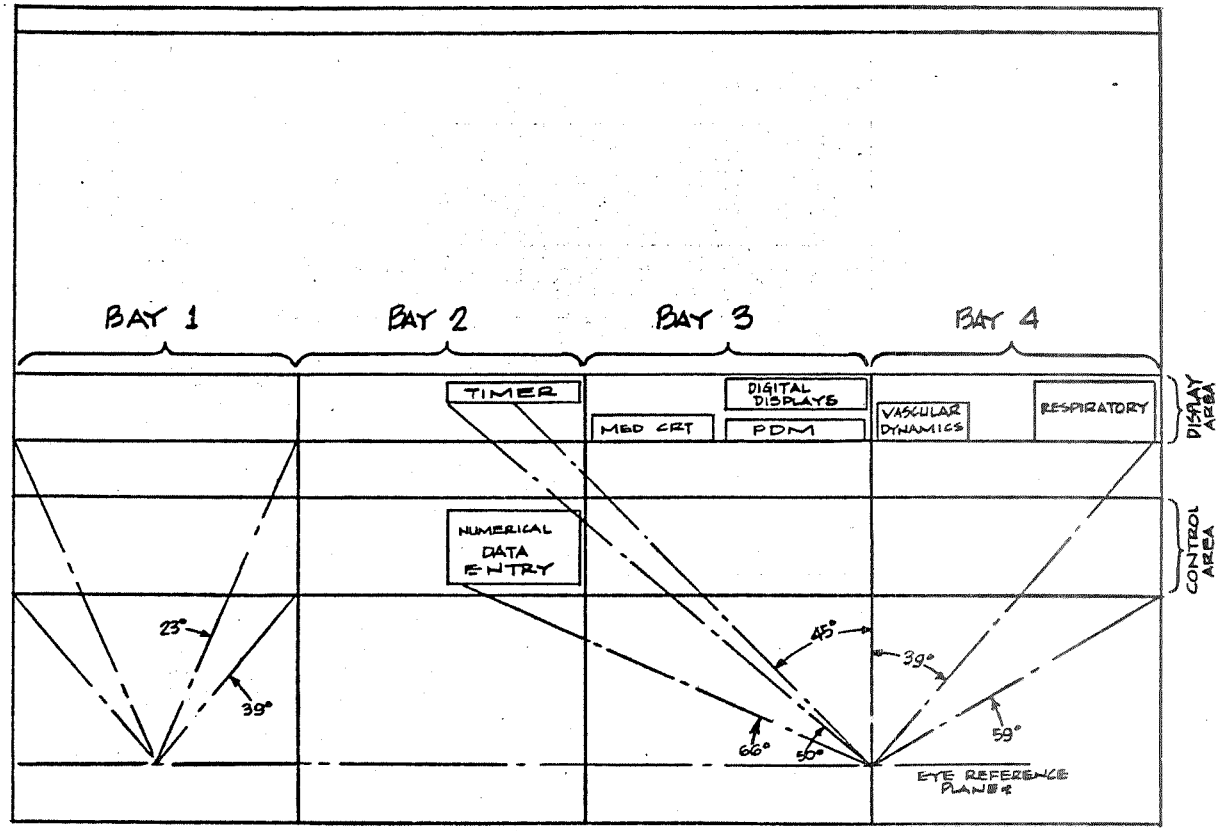


Fig 4. Operator Reach Limitations



*Slumped sitting position (2 inch decrease from erect position)



Viewing Angles for the Seated, Standing, and Supine Positions

Body member rotated	Direction	Lateral angle** Opt.	Lateral angle** Max.	Direction	Vertical angle** Opt.	Vertical angle** Max.
Head only	Left	0	60	Up	0	50
	Right	0	60	Down	0	50
Eyes only	Left	15	35	Up	0	25
	Right	15	35	Down	30	35
Head and eyes	Left	15	95	Up	0	75
	Right	15	95	Down	30	85

**In deg from the line of sight, which is assumed to be horizontal. Any shift in the line of sight from the horizontal will rotate these dimensions by a similar amount.

Fig. 5. Panel Layout Viewing Angles

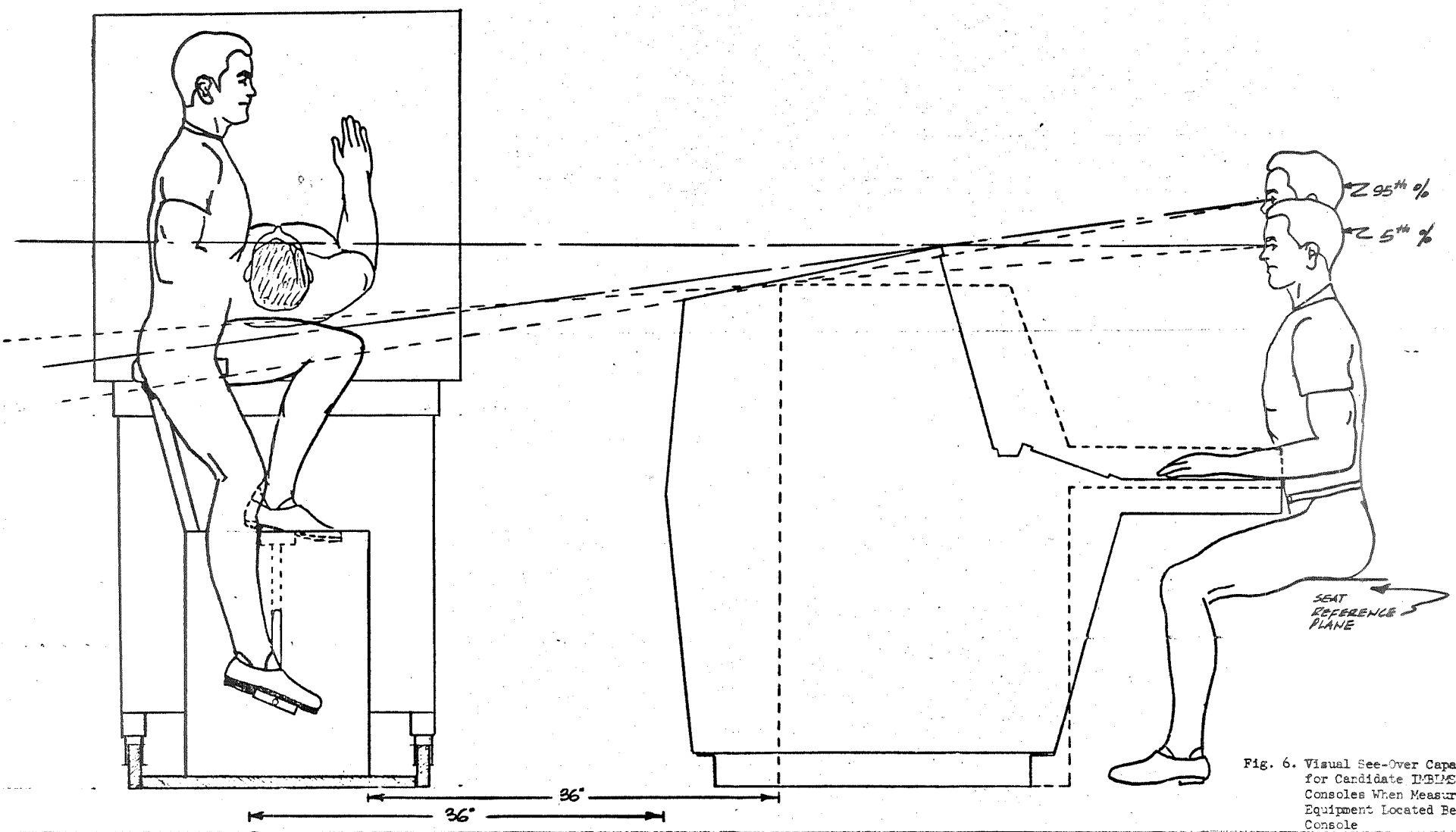


Fig. 6. Visual See-Over Capability for Candidate IMBIMS Consoles When Measurement Equipment Located Behind Console

Communication. - The console operator will be provided with an insert earphone headset (one ear only) and attached boom mike. The headset will provide adequate signal to noise ratio and the dynamic range, without appreciable distortion will be at least 40 db with power-handling capacity adequate to receive the peaks of the amplifier output. Earphone/mike cable will be lightweight and the cable will terminate in a male plug to permit plug-in into the console input jack plug.

3.1.1.1.3 Data Management Requirements. The IMBLMS functional breadboard will provide, in addition to dedicated display equipment, several media of data presentation and data entry, plus a capability for data storage, data evaluation/computation, and data routing. These various general purpose modes of data handling and presentation will constitute the Data Management Subsystem (DMS).

Inputs. - The DMS will provide a programmable input signal switching matrix. This matrix, either directly or indirectly, will permit each measurement having an analog output signal (except audio signals) to be made available to the system computer, regardless of its need for further evaluation. Signal degradation, if any, will be within the accuracy envelope specified under Accuracies.

The DMS will be capable of accepting input analog signals through its switching matrix, or directly, for purposes of recording in an analog medium, and/or converting such signals into a digital format for further computation, digital recording and (if required) output.

The DSM will be capable of accepting coded digital information, manually entered via a pushbutton keyboard with associated logic and from "digit-dial" switches with associated logic, for computation, analysis, recording, etc.

The DMS will provide the capability for video observation and recording of visual data; from both a microscope and astronaut observation.

Accuracy. - The DMS will provide an overall accuracy of 0.5 percent for measurements converted into, and displayed, in a digital format. The DMS will provide an overall accuracy of 2.0 percent for measurements accepted and displayed, or recorded, in an analog format; each accuracy requirement is exclusive of the accuracies of the biodata transducers used to obtain these measurements.

Recording. - The DMS will provide the capability to record incomcing data, converted data, evaluated data and analyzed data, in both an analog and digital media. The DMS will provide a capability for recording voice signals simultaneous with analog and digital data. Additional "scratch-pad" or memo recording of voice signals, with immediate playback capability, will be provided. Since the Functional Breadboard will not have complete mobil plug-in capability for voice intercommunication, small portable voice recorders may be used to simulate this maximum flexibility.

Simultaneous data recording and display (e.g., pen recorders) may be used to verify and/or compare test results with other visual display capabilities. Independent video data recording and/or simultaneous display will be provided by the DMS.

Display. - The DMS will provide the capability to display up to four simultaneous analog signals on a variable persistence oscilloscope. This oscilloscope will be capable of z axis modulation for effective three dimensional presentations. Analog data for display on the oscilloscope may be obtained from biodata transducers, via the switching matrix, from previously recorded analog data, or from analog signals generated in the Systems computer and routed through digital-to-analog converters. The oscilloscope will be provided with manual controls to: vary the amplitudes, vary the sweep speeds, vary the persistence, calibrate, and perform other manual tasks considered standard for this equipment.

The DMS will provide displays to indicate its current operating configuration, including manual input keyboard status. The DMS will provide the capability to display, on an effective simultaneous basis, up to five separate digital values; with an appropriate display of an abbreviated identification for each value. Each identification readout will have the capability of presenting 24 different preselected alphanumerics.

The DMS will provide the capability for an alphanumeric (minimum total of 64 different characters) printout of: numerical data being entered into the system, results of computer evaluations, and preprogrammed simulated ground instructions for measurement variations, etc.

There will be a capability to display video data, either in real-time or from a video recorder. The latter function will provide the capability for simulating ground playback, and observation/evaluation, of video data previously relayed to the ground via a spacecraft's communication system.

Backup Operation. - The Data Management System will have sufficient logic and internal electronics to permit the operation of its programmable (input) switching matrix via the input keyboard, exclusive of the availability or services of an external system computer. The system will also be capable, under this same configuration, of the recording display, and playback of analog input signals. Alphanumeric readouts, except for data manually entered, and digital (or digital-to-analog converted) data will not be available in the backup mode of operation.

Computation. - The DMS, via a peripheral digital computer system, will provide: a capability for semi-automatic operation of the Functional Breadboard, measurement analysis and evaluation through stored reference information and arithmetic computations.

3.1.2 Operability

3.1.2.1 Reliability. - The IMBLMS Functional Breadboard will be designed to operate under ground laboratory conditions. Attainment of the maximum probability of proper IMBLMS FBB functioning during test operation will be a primary consideration in the design, fabrication, and utilization of the FBB. Limited operating life tests will be performed on critical elements. The reliability goal for the FBB based on its intended laboratory environment use shall be 1,000 hr MTBF.

3.1.2.2 Maintainability. - General maintainability design guidance will conform to Paragraph 5.4 of MIL-STD-470, and MIL-STD-1472. Provisions for

service and maintenance which may be performed during pre-test or post-test shall be considered in the design of the FBB. Such maintenance will consist of removal of console access panels and removal and replacement of critical components or subsystems. In some cases, slide-out racks will be furnished which will permit access to alignment or adjustment mechanism. Access covers not completely removable will be hinged metal covers with captive quick-opening fasteners capable of manual operation with simple opening tools.

Preventive maintenance will not be required during on-line operation of the FBB. Preventive maintenance, when required, will be performed at intervals of not less than 720 hours of operation.

Field maintenance will be limited to replacement of removable units and repair or replacement of fasteners and access panels.

3.1.2.3 Useful Life. - Estimates of time-line testing and equipment use indicate that a target useful life of 3 years is reasonable with reasonable servicing and maintenance. The shelf life of 5 years under normal warehouse conditions will be the design goal.

3.1.2.4 Natural Environment. - The FBB will endure, without performance degradation, the natural environment of pre-test operations and checkout, transportation, storage, and operating at NASA-MSC laboratory. Normal operational environment is considered as air-conditioned with temperature at 70°F ± 8° and a relative humidity of 35 to 60%. Natural environments designed for are:

	Pretest, Checkout Transportation and Storage	Operating
Temperature	32°F to + 120 F	70°F ± 8°
Humidity, Relative	47-70%	35 to 60%
Atmosphere	Normal Air	Normal Air

3.1.2.5 Transportability. - Full design recognition shall be given to the durability requirements of the FBB for the pre-test, checkout, and test operations. Whenever possible, the equipment shall be designed to be transported by common carrier with a minimum of special handling. Special packaging and electronic transportation methods shall be used for transfer of FBB from LMSC-Sunnyvale to NASA-MSC. Mass and physical envelope of the FBB (Electronic consoles, equipment racks, measurement equipment harnesses, etc.) will be limited to one-man handling capability wherever possible. Sharp corners, and protruding components will be eliminated.

Items of assemblies which will require special handling during transport will be identified.

Equipment in this category will include items or assemblies which exceed normal transportability parameters; which will have hazardous or dangerous characteristics; which will require special consideration as to sensitivity to shock, vibration or attitude during transportation; or which will have unusual characteristics such as temperature, pressure or humidity limits requiring environmental control or electrical source requirements.

3.1.2.7 Human Engineering. - The FBB accessibility, geometry, and packaging will be compatible with an observer/subject requirements. All controls and displays will be compatible with human engineering standards and will not interfere with normal test operations. MIL-STD-1472 (Supersede MIL-STD-803A-1 & 3) will be used as a design guide.

3.1.2.8 Safety. - The FBB including all its components will not present a hazard to the operating personnel or subjects. Circuits will be afforded complete protection from electrical malfunctions. Overloads caused by short circuits, etc., will be controlled with solid-state power regulation devices. Fault isolation maintained at the module level will be demonstrated in one equipment module. Safety analysis will be carried out in accordance with the major provision of MIL-S-38130. LMSC Safety Engineering and Industrial Safety Organization will be required to carry out safety analysis and safety verification and assurance.

Loss of electrical power will cause the equipment to assume a fail-safe condition and all equipment containers will be equipped with electrical interlocks as well as a feedthrough grounding and electrical bonding system from one equipment to the next.

3.2 Interface Requirements

Interface requirements and constraints of the FBB are due to functional, physical, and procedural relationships between experiment equipment, operator/subject and all systems, equipments and facilities required to accomplish FBB Test objectives.

3.2.1 Experiment Equipment/Measurement Station Interfaces.

3.2.1.1 Experiment Equipment/PBDM Station Interfaces. - The PBDM station will provide suitable interconnection, distribution, and control of measurement signals originating from external sources such as harnesses, signal conditioners, verbal data, etc. Additionally, it will provide suitable electrical/mechanical interconnection to experiment equipment used as periphal support such as the Ergometer and LBNP. Utility support such as power, water, air, oxygen and vacuum will be provided as needed.

Interface terminals will be provided for the transmission of data to computer processing. Control of this interface will be at the PBDM station.

Checkout and calibration functions will be provided by the PBDM station for the experiment equipment.

3.2.1.2 Experiment Equipment/BPA Station. - The BPA station will provide suitable handling and measurement facilities for the experiment equipment. It will provide equipment for identifying and labeling all samples and specimens. Preservation and storage of urine and blood samples at cryogenic temperatures will be provided. Waste disposal facility will be provided at the station. Utility support such as power, water, chemicals, etc., will be provided as needed.

Provisions will be provided for transporting material, experimental results, test samples, etc., to the PBDM station for permanent recording, transmission, or for computational purposes.

3.2.2 Measurement Station/Support Systems, and Facilitie s Interfaces.

3.2.2.1 PBDM Station/Support Systems. - PBDM Station support systems are identified as auxiliary respiratory equipment, environmental monitoring, calibration, audio, analog/digital and video tape recording. The support systems will have proper stowage and operational positions in relationship to the station. Special precautions will be taken to package support equipment and provide adequate interface in terms of electrical/mechanical fittings. The support equipment will be located in such a way as to be easily available to the operator both visually as well as for mechanical operations if required.

The envelope of the su pport equipment will be limited to conform when assembled with the NASA facility capability.

The weight of the support equipment will be limited wherever possible to a one man handling operation. In cases where the support equipment is rack mounted, wheels will be provided for mobility.

3.2.2.2 PBDM Station/Facilities Interface. - Facilities will be made available at LMSC for the FBB Test that are compatible with the space and utilities requirements defined for NASA-MSC. The FBB PBDM Station will interface with the LMSC Simulation Control and Data System which links digital and analog general-purpose computers. The system will be required to perform real-time data collection, conversion, reduction, and scaling for display at the PBDM. Computer support will be provided by the SEL 810 computer and peripheral equipment, e.g., tape control and magnetic tape units paper tape reader, and a digital input/output control unit.

3.2.3 MSC Laboratory Interface with the FBB. - NASA/MSC will prepare a conceptual layout for the IMBLMS FBB checkout facility. This layout will be based on NASA requirements, and the LMSC requirements as presented below.

3.2.3.1 MSC Laboratory Configuration. - The LMSC FBB will be installed in Building 8, second floor, room 270. The room is an enclosed area approximately thirty-two (32) feet long by twenty (20) feet wide. Ceiling height is approximately eight (8) feet. The floor is concrete with tile covering. Walls are plaster board, while the ceiling is acoustical tile contining numerous flush mounted illumination fixtures. There are two doors, approximately thirty (30) inches in width which provide access to the room. Standard 110 volt wall sockets and telephone plugs are available. Adjacent to the main room are smaller rooms which interconnect through doors and may be available for desk space, cabinets, computer installation, maintenance equipment, etc.

3.2.3.2 LMSC Installation Requirements. - Three principal requirements areas have been established: (1) Operation, (2) Interface, and (3) Maintenance.

Operation. - Major peripheral equipment such as the ergometer, mass measurement, REVS chair, and LBNP must be located in an experiment area which is observable to the PBDM console operator. Equipment cabinets containing items associated with the PBDM station and the BPA staion must be located within

reasonable access distances of the console work stations. The consoles, equipment cabinets, and test apparatus must be positioned such that there can be adequate personnel traffic flow both for normal operations and for emergency situations.

The total room db noise (NCA) level, exclusive of experiment apparatus, will be no greater than 25 db. Illumination will be no less than 25 foot candles at the console work top surface. Dimming control will be provided to reduce overhead light intensity and to aid in reducing glare levels. A normal air-conditioned office environment will meet FBB operating requirements.

Interface. - Cabling and Utilities. -The PBDM provides an Input-Output connection panels for the various cables used to interconnect measurement harnesses, peripheral test equipment, recorders, computers, etc. Cable trays or troughs must be provided for minimizing interference during experiment runs. Interconnection is also required between the PBDM and the BPA stations. A vacuum source line should be provided for the BPA console to be utilized in the waste management system. Filter sources and debris trap should be provided near the console interface point with the vacuum line. An air pressure source (15 psi) and lead-in hose must be provided for interconnect to the PBDM console or to the subject during remote operation.

A summary of the utility requirements is as follows:

Power	110 v 60 Hz (single phase)
Air	100 psig (breathable)
Oxygen	Commercial bottles
Vacuum	Stokes Microva Pump, Model 412H-10
Light	Variable illumination levels
Water	Hot and cold (local supply)
Waste Disposal	Acid Drain and Biological Waste Drain Accommodation
Ventilation	Standard room air conditioning

Interface. - Subject and Equipment Heat Loads. - Both the PBDM and BPA consoles will be provided with blowers for internal heat dissipation within the consoles. Normal air flow is through the bottom rear filters up past equipment with air discharge through the louvers into the room downward and to the rear of the two consoles. The heat production anticipated from operation of the two stations together with one exercising subject and three observers is estimated to be as follows:

1 Subject - Ergometer exercise program	27.3 BTU/Min
3 Observers - Light activity	45.0 BTU/Min
PBDM & BPA Stations (Incl. Blowers)	79.4 BTU/Min
Freezer duty cycle - 1 HP	42.0 BTU/Min
Total Heat Load	193.7 BTU/Min

Maintenance. - Commercial equipment requiring maintenance will be defined in the Operating Procedures. Repair or modification of this type of equipment will be normally handled by removal of the unit from the Station and serviced by maintenance laboratory. Special type equipment such as mouthpieces, pulmonary

valve, etc., that require special handling after use to prevent bacterial growth will be maintained on site. Electronic equipment such as a monitoring oscilloscope will be provided with extendable support mounts that permit trouble shooting without removal of the entire unit. Lamp removal for the various readouts will be normally accomplished by front access. The station consoles permit access from front or rear for checkout or maintenance. Normally there will be no maintenance required during operation of the FBB.

3.2.3.3 Data Processing. - An interface terminal, or space for such a termination, will be provided for the transmission of data in digital form to a "within the state of the art" automatic data processing complex located at MSC. The terminal will be provided upon NASA's definition of such a complex, within the framework of the overall program schedule. Should the timing of this definition fall outside of program schedules, space will be allocated for a future terminal installation. A second termination will be provided for interface with a Lockheed owned computer complex, for operation of the FBB at Lockheed. Compatibility of software between the Lockheed processing complex and the MSC complex will be strived for, within the limits of similarity between such complexes, and timely knowledge of the MSC equipment.

The FBB data processing complex at MSC must approach the following capabilities:

Main Frame Computer

- Organization - binary, parallel words
- Memory - 8000 to 64,000 word core (1 Peripheral Tape Deck required if in the range of 32K-64K words; 2 Peripheral Tape Decks required if in the range of 8K to 16K words)
- Word Length - 12 to 16 bits per word
- Cycle Time - 1.9 sec
- Add Time - 3.8 sec
- Multiply Time - 6.46 sec
- Divide Time - 17 sec
- Programming - Fortran assembler with Boolean capabilities

Peripheral Equipment

- Magnetic Tape Unit(s) - 45 inches/second, including controller
- Digital I/O Capability
- Input/output teletype printer and keyboard
- Paper tape reader
- Paper tape punch

In addition to the above processing equipment, the following recording capabilities will be used for FBB operation at Lockheed, and similar capabilities will be required for complete FBB operation and evaluation at MSC.

- 16 Channel Pen Recorder wit h differentially connected high input impedance (1 megohm or higher) amplifier/attenuators

- 14 track Analog Magnetic Tape Recorder with differentially connected high input impedance (1 megohm or higher) amplfiers for both recording and playback. 12 tracks to be recorded in an FM modulated mode, and 2 tracks to be recorded in a direct mode. A remote recorder control panel would be desirable for utilization of this device.

3.3 Design and Construction

3.3.1 Mechanical.

3.3.1.1 Modules Sizing Requirements. - A primary requirement for the FBB is to group related displays and controls. The modular arrangement requirement based on this criterion establishes a basic module size of 19 x 19 inches (frontal area). This permits rack-mounting using conventional electronic consoles and further permits incorporation of standard rails so equipment can be easily moved out for servicing, calibration, or removal. Variations of the basic module size are permitted; however, only the basic module or a one-half module (1-1/2 x 9-1/2 inches) will be on slide rails and removable. Other non-standard modules will be hard-mounted and removable by conventional techniques such as quick-opening fasteners, screws, etc.

3.3.1.2 Structural Requirements. - Removable modules will be provided with electrical cables of sufficient length and flexibility and further be provided with a protective coating over the length which is expected to be handled during ins ertion and removal operations. The design of the modules and its rack shall include provisions to align the modules in such a manner that accurate alignment can be checked and possible adjustments can be performed without the removal of components, cabling or plumbing.

Equipment containers will be provided with sufficient screen covered holes in the structure to prevent excessive pressure buildup and to provide an adequate path for air flow. In addition, the vent holes in the structural body will be provided with a fine mesh filter screen to prevent debris from entering into the interior of the module.

3.3.1.3 Display and Controls. - Time displays required for the FBB will utilize only the following standardized intervals: days (24 hours), hours (60 minutes), minutes (60 seconds), and seconds. Time measurement indicators will be of the digital-readout type, except when presentation is used primarily for rate determination, or when frequent resetting is required.

FBB controls which require tool(s) for actuation, alignment, etc., will have provisions whereby the position of the control is readily apparent to the operator without the tool in place. Normally any adjustments will be easily

available to the operator from his operational position. Exceptions to this requirement are in cases where commercial equipment is designed to be serviced and/or aligned by rear access. In this case, the equipment must be extendable, thus permitting alignment from a front position.

Switches requiring cover guards will have the cover guard designed so that the position of the switch can be determined without moving the cover guard.

3.3.2 Electrical and Electronic.

3.3.2.1 Electrical Connectors and Circuitry. - Protection against reverse polarity and/or improper electrical inputs will be obtained by careful assignment of connector pins and connector key variation. To prevent short circuits, electrical circuits will not be routed through adjacent pins of an electrical connector. The connection pattern in the mounting brackets will be configured such that only the right modules can be inserted. Disconnected electrical circuits will be protected against short circuiting or compromising of other circuits by providing dead end female connectors or caps to the mounting brackets of the module. Prior to removal of a module from the mounting bracket, the disconnected pigtail is plugged in to dead end or dummy connectors.

3.3.2.2 Calibration. - All measurements that can be calibrated by an electrical signal generation will be performed either with a built-in capability or by employing a portable calibration unit before and after a Pressure and temperature transducers will be calibrated using standard laboratory calibration units on a one time only basis. The portable calibration unit will have the following characteristics:

Frequency accuracy	0.1% 1 Hz - 10kHz
Amplitude accuracy	0.25% 20 Hz to 10kHz
Frequency range	.001 Hz to 100,000 Hz
Voltage range	100 μv - 5v

3.3.2.3 Power Requirements. - The FBB will be designed to operate off of 115 v ± 10%, 60 Hz. DC-DC converters will be provided together with suitable power regulation equipment to provide correct input DC regulated power. AC power input cables will not ground the neutral to the equipment chassis or cabinet. The chassis to AC power grounding will be through the green ground wire on the interconnection cable. A copper ground bus bar will be provided for DC grounding. 115 v AC and 28 V DC power outlets will be provided.

3.3.3 Fluid (Gas and Liquid). The service points for the fluid systems of the FBB, including those for filling, draining, purging or bleeding will be located and designed such that:

- Exposure of equipment to spillage of fluids is prevented
- Servicing of fluid systems can be accomplished without damage to the service points

The service points will be designed with positive protection by means of location, connector type or size, etc., to prevent connection to incorrect fluid service lines.

The fluid system will be designed to permit complete flushing and draining. The system will be free from dead ended piping or passages through which flushing fluid cannot be made to flow. Drain ports will be provided at the low point in the system.

Positive measures will be taken to prevent incorrect installation of fluid line components whose function is dependent on direction of flow. Where feasible, the design of these fluid line components will incorporate end fittings or connections whose dimensions or configuration will not permit incorrect installation. The direction of fluid flow will be clearly indicated with permanent markings of the exterior of the component and the parts and lines to be mated with it. Where feasible, flow checks will be made after each installation or change.

3.3.4 Test Provisions. - Consideration will be given to incorporating test points in certain critical electrical and fluid subsystems. A demonstration of test checkout will be performed. Test equipment will be identified and a list prepared containing descriptions, functions, accuracies, test identity, use, costs, and delivery schedules.

3.3.5 Materials, Parts and Processes. - Materials, parts and processes used in the FBB will be of the highest quality compatible with technical requirements specified herein.

3.3.5.1 Toxicity of Materials. - Materials will not be used in the FBB test area which, when operating at temperature up to the maximum anticipated in the laboratory environment, will generate toxic or noxious fumes, or dust, in such concentration as to impair operator/subject performance or safety. Fluids which can produce toxic fumes will not be used in systems within the FBB if a substitute with equivalent performance exists.

3.3.6 Electromagnetic Interference. - The requirements of MIL-STD-461 will be used as guidelines for the FBB electronic, electrical and electromechanical equipment. LMSC will follow the EMI Plan developed under Phase B Section II NASA-W-1631 and reported in LMSC 680517-III, 16 February 1968, Vol. III, Medical and Engineering Reports and Trade Studies, pages 3-230 through 3-240.

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

4.1 Conceptual Design

4.1.1 Design Objective. - The IMBLMS Functional Breadboard (FBB) will be designed to fulfill several major design and performance goals. These goals include the capability to conduct each measurement and test with essentially the same procedural and data handling sequences as planned for the flight IMBLMS; to determine measurement feasibility and accuracy under operational constraints; to demonstrate centralized experimenter control; and to evaluate the handling, storage, and display of measurement data.

4.1.2 Design Concept. - The Lockheed design is based on a centralized Physiological/Behavioral/and Data Management (PBDM) Station and a separate Biochemical Preparation and Analysis (BPA) Station. The FBB system will incorporate sensors and signal conditioning equipment, simulation control and computer services (non-deliverable), test support equipment (deliverable and non-deliverable), and certain standard laboratory test measurement equipment (non-deliverable).

4.2 Block Diagrams

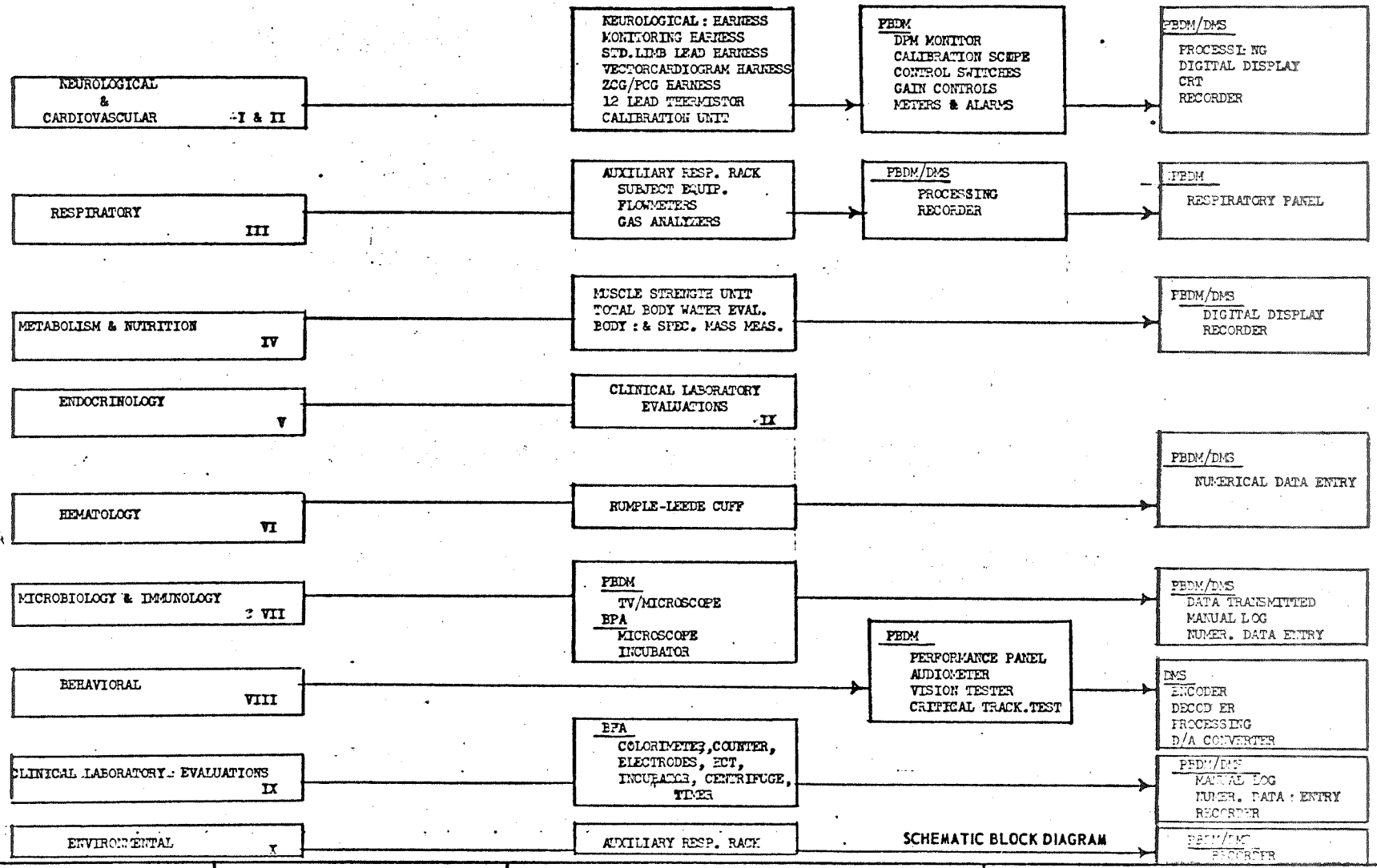
4.2.1 Equipment Elements. - The FBB System is comprised of equipment designed to perform the measurements specified in the ten NASA measurement categories. Two major display and control consoles - a four bay console for the PBDM Station - a three bay console for the BPA, are utilized. An Auxiliary Rack is required to house peripheral respiratory equipment. A storage cabinet will be supplied to house support equipment such as vest/wiring harnesses, signal conditioners, and expendable supplies. A freezer will be provided for preservation of specimens.

4.2.2 Functional Operation. - Figure 7 illustrates the equipment associated with the ten NASA measurement categories. As shown the combination of Neurological and Cardiovascular measurements require six harnesses which are connected to the PBDM Station and led directly to the Dynamic Physiological Monitor (DPM). There calibration display and analog meter presentation of data occurs. Signal outputs from the DPM are transferred to the Data Management Subsystem (DMS) for processing, recording, etc.

The Respiratory measurement equipment at the Auxiliary Rack consist of subject interface equipment such as mouthpiece, valves, etc. Data output from the Auxiliary Rack can go either to the Respiratory Panel at the PBDM Station or to the DMS for processing.

The Metabolism & Nutrition equipment signal output is led directly to the DMS for processing.

Endocrinology measurements, certain metabolic and nutrition measurements and hematological measurements, have been included in the Clinical Laboratory Evaluation Category IX.



ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 7 INTERIM FUNCTIONAL BREADBOARD SYSTEM		
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO.	REV
SUPV		APPD				
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B / SH / OF	III-A-31	

Form LMSC 26208

Capillary Fragility measurement is accomplished with a Rumple-Leede cuff and data entered to the DMS through the numerical data entry keyboard.

Microbiology and Immunology measurement equipment consist of a TV-Microscope installed at the PBDM Station. A direct transmission of this data can be effected. The microscope can be removed from the PBDM Station and utilized at the BPA Station when required. Data is manually logged and entered into the DMS via the numerical data entry keyboard. An incubator is provided at the BPA for culturing and controlling specimens.

The Behavioral equipment consist of the Performance Panel at the PBDM Station, and peripheral testing equipment which may be brought to the PBDM Station and operated. This peripheral equipment consists of the Audiometer, Vision Tester, and Critical Task Tracking Unit. Signal outputs from these devices are led to the DMS for processing, evaluation, and recording. The TV unit at the PBDM can be used for subject monitoring during work tasks.

Clinical Laboratory Evaluations comprise the majority of the BPA Station measurement. Equipment at the BPA Station consists of; Colorimeter, Counter, Electrodes, HCT, Incubator, Centrifuge, and Timer. Normally data obtained is logged and entered the DMS through the Numerical Data Entry Keyboard at the PBDM Station.

Environmental measurements are accomplished with equipment located in the Auxiliary Respiratory Rack. Data is fed to the DMS for recording.

5.0 TEST REQUIREMENTS

Acceptance tests will verify that the FBB system meets the technical requirements specified in the requirements documentation.

Where appropriate and practical, realistic operational conditions will be employed. However, tests will not be performed under reduced atmospheric pressure conditions or in an enriched oxygen environment; nor will flight or space suits be used. Astronaut translation and restraint problems associated with weightlessness will not be simulated. Measurements that would normally require the injection of foreign substances into the body will be simulated using specially prepared samples to represent low, normal, and high values of the parameters of interest. The effect of weightlessness on liquid/gas phase separation problems will be simulated by having gravity or varied gravitational forces work against the procedure involved. Specific acceptance testing criteria shall be established in accordance with the following requirements:

- Acceptance testing shall be performed to verify that all requirements, materials, construction, workmanship, dimensions, design and performance are met. Tests shall be made under laboratory conditions and room ambient environments.

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

- Where possible, all normal, alternate, redundant and emergency operational modes shall be tested.

- The hardware shall be calibrated and aligned prior to conducting Acceptance Tests.

- Adjustment or tuning of hardware is not permitted during acceptance testing unless it is normal to in-service operation.

- The degree of retest necessary in event of failure shall be specified. A failure is defined as the inability of the test article to perform its required function within specified limits under the conditions, and for the duration specified in the Acceptance Test Criteria specifications.

- Any repairs, modifications or replacements after completion of Acceptance Tests shall require retesting to assure the acceptability of the change.

5.1 Acceptance Test Procedures

Operating procedures developed during Task II will be employed during checkout of the FBB, which will be performed at the component, subsystem, and system levels. Detailed checkout will follow verification of the operational readiness

of the various commercial items of equipment immediately after application of input power. After verification of the readiness of the commercial equipment, stimulus will be applied (principally from the calibration unit) to the appropriate FBB input terminals, and routed to the proper display module, through manual activation of the processor keyboard. External equipment will then be connected individually and operation of the FBB, including the processor simulator and digital equipment, will be verified. Processor self-check programs, activated through the processor keyboard, will complete the testing and establish the data management system readiness for final integrated system checkout tests.

5.2 Acceptance Test Failure Criteria

The acceptance tests shall demonstrate stated measurement accuracies, repeatability, subject and experimenter suitability, and present resultant data in a usable form. Where applicable, test accuracies will be compared to standard methods and techniques for further evaluation.

Up to two errors or failures during any complete FBB acceptance test run-through will necessitate a demonstration of acceptability of that specific item of equipment causing the error or failure. More than two errors or failures will require an entire re-run of all equipment having any relation to the test being performed.

The amount of time between system tests, to demonstrate repeatability is directly related to the inherent stability of the equipment being tested and the amount of time required to perform an equipment calibration. Lockheed, in general, will demonstrate a successful measurement repeatability within a maximum period of 8 hours of equipment on-time. Obviously, some equipments will not require such a long on-time to demonstrate repeatability and a written justification of an applicable shorter period of time will be part of the test procedure and/or subsystem design specifications.

CONSOLES III-B

SECTION III-B

IMBLMS FUNCTIONAL BREADBOARD (FBB) SYSTEM PERFORMANCE/DESIGN REQUIREMENTS

CONSOLES

CONSOLES

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

3.1 Performance
3.1.1 Functional Characteristics
3.1.1.1 Exterior Profile
3.1.1.2 Console Equipment Panel Areas
3.1.1.3 Writing Surface
3.1.1.4 Equipment Cooling
3.1.2 Operability
3.2 Interface Requirements
3.2.1 Interconnection Cables and Connectors
3.2.2 Grounding
3.2.3 Power Outlet Box
3.2.3.1 Power Circuit Connections
3.3 Design and Construction
3.3.1 General Design Features
3.3.1.1 General Appearance
3.3.1.2 Console Reconfiguration Capability
3.3.1.3 Console End Caps
3.3.1.4 Rear Access Doors
3.3.1.5 Front Access Panel
3.3.1.6 Console Color
3.3.1.7 Equipment and Floor Loading
3.3.1.8 Console Deflection and Lifting
3.3.1.9 Console Floor Mounting

1.0 INTRODUCTION

This part of the FBB documentation establishes the requirements for performance and design of the equipment identified as the IMBLMS FBB Operator Equipment Console, hereinafter referred to as the Console. The Console is used to provide a mounting facility for individual control, display and supporting equipment in a functional enclosure. The Console provides the primary interface for an instrumented subject and a test operator.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this requirement and will be used to furnish design guidelines:

SPECIFICATIONS

Military

Mil-S-38130A 6 June 1966	Safety Engineering of Systems and Associated Subsystems and Equipment, General Requirements for
Mil-S-267A 31 January 1966	Human Engineering Design Criteria

STANDARDS

Federal

FED-STD-595 1 March 1956	Federal Standard Colors

Military

Mil-STD-130B (1) 7 February 1964	Identification Marking of U. S. Military Property
Mil-STD-470 21 March 1966	Maintainability Program Requirements for (Systems and Equipment)
Mil-STD-1472 9 February 1968	Human Engineering Design Criteria For Military Systems, Equipment & Facilities
Mil-STD-454 10 June 1968	Standard General Requirements For Electronic Equipment

SSD (LMSC)

63-3 24 June 1963	Engineering for Transportability

Drawings (LMSC)

5504148 5504601	Console, Envelope Drawing Interface, Electrical and Mechanical

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional Characteristics. - The development, design, manufacture, installation and test of the Console will be in accordance with Military Standard 1472.

3.1.1.1 Exterior Profile. - The Console envelope will conform to LMSC Drawing 5504148 which defines profile, styling and envelope dimensions. The Console will be designed so that it can be increased or decreased by unit bay widths of 19 inches.

3.1.1.2 Console Equipment Panel Areas. - The Console will be divided into three panel areas according to specific function and are: display; control; and support areas.

The display area will be the upper portion of the Console front surface. The display area will be capable of accepting rack-mount type equipment up to 19 inches wide, by the insertion of vertical supports.

The control area will be the portion of the Console front immediately above the writing area. The control area will be capable of accepting rack-mount type equipment by the insertion of vertical supports.

The support area will be the lower portion in the rear of the Console. The mounting of the 19-inch wide panels will be within each unit bay width.

3.1.1.3 Writing Surface. - A horizontal modular writing surface shall be incorporated which is consistent with a one or two bay unit width (approximately 19 or 38 inches) and will consist of a fixed, laminated plastic covered top and a structural support unit to support the required weight. Each writing surface module will be removable from the remainder of the Console with common hand tools for ease of transporting. Writing surface end pieces will be provided.

3.1.1.4 Equipment Cooling. - Blowers will be provided for equipment cooling. The blower assemblies will be in accordance with LMSC Drawing 5504148-31 with typical operating and structural characteristics as follows:

a. Performance: Nominal rating CFM range, with air-vanes positioned for vertical discharge:

186 CFM @ 600 RPM
480 CFM @ 1550 RPM

b. A standard filter will be used and will be mounted so that it is readily accessible.

c. Air discharge deflectors will be provided. These deflectors will be adjustable to 45 degrees in each direction of vertical and 90 degrees to the

adjustable scrolls rotation. The angle of discharge will be continuously adjustable within this range.

The Console will contain at least one blower assembly if heat producing equipment is installed therein. The blower will be mounted in the lowest position in the support areas of the Console, and will not exceed one blower assembly per bay. Ducts will be provided with each blower to assure that only room ambient air is brought into the blower inlet. Air discharge through the louver into the room will be downward and to the rear of the Console.

The Console, with blower(s) operating, blank panel installed, doors and panels closed, will meet an NC-40 noise level.

3.1.2 Operability. - Section III-A System Requirements document contains applicable operability requirements.

3.2 Interface Requirements

The Console will satisfy the electrical and mechanical interface requirements as shown in LMSC Drawing 5504601.

3.2.1 Interconnection Cables and Connectors. - AC power input cables will use plugs which do not ground the neutral to the equipment chassis or cabinet.

3.2.2 Grounding. - Signal grounding will be accomplished with a copper ground bus bar in each bay. The bus bar will be insulated from cabinet or chassis grounds, and will contain tapped holes and provisions for jumpering to an adjacent bay ground bus.

Chassis-to-A.C. power grounding will be accomplished with an extension of the green wire from each bays A.C. power distribution bos; of sufficient length to permit a single point of contact between all green wires and one of the bay walls. Each bay will then be electrically interconnected to adjacent bays with a short ground strap to provide complete bay/chassis grounding.

It will be possible to interconnect, or disconnect, the signal ground bus bar with/from the single point of green wire-to-chassis A.C. power ground.

3.2.3 Power Outlet Box. - An AC power outlet box with at least 6 receptacles, a circuit breaker and an "on-off" switch to control the receptacles will be provided in each bay.

3.2.3.1 Power Circuit Connections. - The power circuits will be single phase at 115 V $\pm$ 10 V, 60 Hz. Three wire cables will be used, of which the hot wire shall be black, the neutral wire white, and the ground wire green. Each of the cables will be provided with a plug that will fit a standard Hubbell 5352 duplex outlet.

3.3 Design and Construction

Design and construction shall be in accordance with LMSC Drawing 5504148, Mil-STD-454, and the following paragraphs.

3.3.1 General Design Features.

3.3.1.1 General Appearance. - All fasteners, screws, rivets, etc., shall be flush with the exterior shell of the Console. The general appearance of the Console shall be esthetically attractive. Door, panel and module sections shall be flush fitting.

3.3.1.2 Console Reconfiguration Capability. - The Console shall be designed in such a manner that it can be reconfigured to a different number of bay units including the writing surface, within 8 hours. The reconfiguration shall be within the capability of the average technician using common hand tools.

3.3.1.3 Console End Caps. - The Console end caps shall be designed as removable sections to provide for expanding and decreasing the bay unit size of the Console.

3.3.1.4 Rear Access Doors. - Flush rear access doors in each bay shall be hinged or removable. The door release latch shall be flush and shall not require any tools to operate.

3.3.1.5 Front Access Panel. - Front access panels shall be provided in each bay unit and shall be of flush design. Each panel shall provide adequate access to interior of the Console. The fasteners shall be flush and shall not require any tools to operate.

3.3.1.6 Console Color. - The colors of the Console shall be in accordance with FED-STD-595.

3.3.1.7 Equipment and Floor Loading. - With a maximum installed equipment weight of 300 pounds per bay, the total weight per bay excluding end caps, shall not exceed 500 pounds. The total distributed floor load per bay, including Console bay and equipment, shall not exceed 200 pounds per square foot.

3.3.1.8 Console Deflection and Lifting. - A three or four bay unit Console, with end caps, shall suffer no damage when supported at the other edge of the end bays with 300 pounds of dead weight in each bay and vertical supports installed at increments of 19 inches. The Console shall be capable of being supported by the horizontal surface where the life locating holes are without damage, with 300 pounds of dead weight in each bay.

3.3.1.9 Console Floor Mounting. - Floor fastener holes shall be provided in the base of the Console for the purpose of floor mounting.

SECTION III-C

IMBLMS FUNCTIONAL BREADBOARD PERFORMANCE/DESIGN REQUIREMENTS

CLINICAL EVALUATION

CLINICAL EVALUATION

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

- 3.1 Performance
  - 3.1.1 Functional
    - 3.1.1.1 Overall System Requirements
    - 3.1.1.2 Questionnaire Organization
    - 3.1.1.3 Data Entry and Retrieval
  - 3.1.2 Operability
- 3.2 Interface Requirements
  - 3.2.1 Physician-Subject Interface
  - 3.2.2 Data Management Interface
- 3.3 Design and Construction
  - 3.3.1 Mechanical
  - 3.3.2 Displays and Controls

APPENDIX

1.0 INTRODUCTION

This document establishes the overall performance and design requirements for the Clinical Evaluation Subsystem. All the clinical Evaluations for each of the NASA designated measurement groups have been combined in a single medical history and physical questionnaire. The information will be coded so that it can be entered into the Data Management System via the Numerical Data Entry Keyboard.

2.0 APPLICABLE DOCUMENTS

Section III-A System Requirements Document contains all the applicable documents.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional. -

3.1.1.1 Overall System Requirements. - The clinical evaluation questionnaire will provide an across-the-board evaluation of the mental as well as the physical status of the crew members. Emphasis will be placed on the particular phenomena which are considered spaceflight specific or which may occur during prolonged flights. Many abnormal or disease states, the probability of whose occurrence in healthy subjects is unlikely will not be evaluated in the questionnaire Should it become necessary to include additional remarks or observations particularly in relationship to the effects of trauma, the on-board physician will record these on a voice channel for direct or delayed transmission to ground control.

Measurements of vital signs perse, which are taken very frequently as part of the routine monitoring using other IMBIMS measurement equipment will not be included, although these can be verified manually whenever considered necessary, using the equipment contained in the physician's flight kit.

3.1.1.2 Questionnaire Organization. - The history and physical questionnaire will be combined in one form with a logical progression from general to more specific information consistent with the classical physician's review of body systems. Such an arrangement will facilitate the entry of only pertinent data similar to a physician's progress note.

3.1.1.3 Data Entry and Retrieval. - The questionnaire must be present to the physician in a manner to facilitate the "checkoff" of positive finding with coded information available so that the data can be entered into the DMS. A five digit coding system will indicate the major category, a more specific category, a more precise location of the finding or complaint, its nature and its severity or frequency. The DMS must provide a permanent record which identifies both the narrative information and its code. This will markedly facilitate the subsequent entry of follow up data.

3.1.2 Operability. -

Section III-A FBB System Requirements Document contains all the applicable Operability requirements.

3.2 Interface Requirements

The interface requirements of the Clinical Evaluation Subsystem involve the performance of a physical examination under weightlessness and the entry and retrieval of this questionaire type data via the Data Management Subsystem.

3.2.1 Physician-Subject Interface. -

The history and physical examination will be conducted concurrently requiring facilities that provide reasonable volume, privacy and quiet. Weightlessness may necessitate that both the physician and subject be positioned in some type of restraint devices so that a proper orientation can be maintained. A restraint device for the physician's flight kit may also be necessary. With proper training the physician would probably not need to refer to the questionnaire during the actual examination. Specific information that cannot be remembered can be entered into the memo recorder via the headset and mike for subsequent playback at the PBDM Station. The physician must refer to the questionnaire to obtain the proper code number to enter positive findings.

3.2.2 Data Management Interface. -

The data obtained from the History and Physical Examination Questionnaire are entered into the Data Management System at the FBB in the following manner:

- The appropriate code is entered on the Processor keyboard to make the Numerical Data Entry Keyboard available to the DMS.
- The physician sets Astronaut Number, Mission Day, and Mission Time with the thumbwheel switches on the Numerical Data Entry Keyboard. The Organ System switch is set to 0, and the appropriate Test Number, identifying the History and Physical Examination, is entered at the Test No. switches.
- Starting with the first history and physical examinations entry, he sets the appropriate five digit code in the Test Value block. After visual verification, he pushes the "Enter" button.
- He proceeds in the same manner until all code numbers have been entered.
- The "Record" button is now activated, which will record all codes previously entered on tape.
- To obtain a printed copy the physician pushes the "Print" button on, and the line printer will print out the data that was recorded on the DMS tape.

3.3 Design and Construction

The scoring and marking of the questionnaire is based on a five digit system, as follows. The first digit represents one of the major categories:

0 General Status
1 Head and Neck
2 Eyes
3 Ears, Nose, and Throat
4 Lungs
5 Heart
6 Abdomen and Rectum
7 Genitolurinary
8 Upper Extremities
9 Lower Extremities

The second digit indicates the major subdivision within each of these categories (Range 0-9). The third digit provides either a class of symptoms, or a more precise location of a finding or complaint. The following designations are used:

0 Entire area
1 Left Side
2 Right Side
3 Left and Right Side
4 Upper Half
5 Lower Half
6 Upper and Lower Half
7 Number (of tooth)

The fourth digit delineates the nature of the finding or complaint, or provides further details regarding the second or third digit(s). (Range 0-9). The fifth digit indicates the frequency or severity, or gives another descriptor, of the finding or complaint. A range of 0 through 4 was established, whereby 0 = None, 1 = Normal, and 2, 3 or 4 represents an increasing progression in severity or frequency, unless some other descriptor has been assigned to these numbers. Ordinarily all entries scored 0 or 1 simply will be deleted and will not be recorded and transmitted. However, ground control, in response to a periodic physical examination report received earlier, may request the on-board physician to check specific parameters, in which case the latter can positively reconfirm a "none" or "normal" finding.

Appendix III-C contains the complete History and Physical Examination Questionnaire. It should be noted that where applicable all possible or most likely used combinations of the first three digits have been indicated as a complete group. This reminds the physician that he has to make a selection of the appropriate third digit number before proceeding to the fourth and fifth digits. Each positive finding always consist of a complete five-digit number. For instance, to report moderate itching and severe lacrimation in both eyes, requires the sequential entry of codes 20363 and 20354.

3.3.1 Mechanical. -

The questionnaire contained in Appendix III-C will be presented in a logbook at the PBDM station so that the physician can enter the positive findings into the DMS in the proper code.

The hard copy results will be placed in the measurement data logbook.

3.3.2 Displays and Controls. -

Applicable display and control requirements are specified in Section III-J.

SECTION III-C

APPENDIX

MEDICAL HISTORY & PHYSICAL EXAMINATION QUESTIONNAIRE

The Medical History & Physical Examination Questionnaire has been arranged according to General Status and Body Elements. The scoring and marking of the questionnaire is based on a five digit system and is discussed in Section 3.3.

APPENDIX III-C

MEDICAL HISTORY & PHYSICAL EXAMINATION QUESTIONNAIRE

GENERAL STATUS		0	1	2	3	4
010 1	Feeling of well-being		normal	off	poor	ill
2	Alertness		normal	inattentive	depressed	comatose
3	Fatigue	none		slight	moderate	severe
4	Insomnia	none		slight	moderate	severe
5	Irritability	none		slight	moderate	severe
6	Tenseness	none		slight	moderate	severe
7	Boredom	none		slight	moderate	severe
8	Hostility to examiner	none		slight	moderate	severe
9	Delusions	none		slight	moderate	severe
0	Hallucinations	none		slight	moderate	severe
020 1	Sleep		normal	disturbed	inadequate	restless
2	Dreams	none	normal	pleasant	frightening	nightmares
030 1	Water intake		normal	reduced	poor	increased
2	Food intake		normal	reduced	poor	increased
3	Micturition	none	normal	reduced	poor	diuresis
4	Defecation	none	normal		2-5/24 hrs.	5/24 hrs.
5	Libido	none	normal	increased	decreased	
6	Interpers. relations		normal	strained	friction	argumentative
7	Perspiration	none	normal	increased	decreased	

HEAD AND NECK						
100 1	Headache	none		slight	moderate	severe
101 2	Itching	none		slight	moderate	severe
102 3	CVA	none				possible
103						
	Scalp					
111 1	Skin texture		normal	dry	oily	inflamed
112 2	Hair texture		normal	dry	oily	
113						
	Face					
121 1	Skin forehead		normal	dry	oily	
122 2	Facial muscles		normal	weak	hyperactive	paralyzed
123 3	Lip movement		normal	lag	droop	paralyzed
4	Facial color		normal	pale	cyanotic	florid
5	Parotid gland tenderness	none		slight	moderate	severe
6	Submax. gland tenderness	none		slight	moderate	severe
7	Pain	none		slight	moderate	severe

HEAD AND NECK (continued)		0	1	2	3	4
	Neck					
131	1 Skin color		normal	pale	pigmented	red
132	2 Muscle tenderness	none		slight	moderate	severe
133	3 Muscle spasm	none		slight	moderate	severe
	4 Stiffness	none		slight	moderate	severe
	5 Folliculitis	none		slight	moderate	severe
	6 Lymph adenopathy	none		slight	moderate	severe
	7 Throid enlargement	none		slight	moderate	severe
	8 Pain	none		slight	moderate	severe
	9 External swelling	none		slight	moderate	severe

EYES

201	1 Photophobia	none		slight	moderate	severe
202	2 Diplopia	none		slight	moderate	severe
203	3 Blurred vision	none		slight	moderate	severe
	4 Halo around lights	none		slight	moderate	severe
	5 Lacrimation	none		slight	moderate	severe
	6 Itching	none		slight	moderate	severe
	7 Gritty feeling	none		slight	moderate	severe
	8 Blurring	none		slight	moderate	severe
	9 Pain	none		slight	moderate	severe
	Eyelids					
211	1 Ptosis	none		slight	moderate	severe
212	2 Lid lag	none		slight	moderate	severe
213	3 Blepharitis	none		slight	moderate	severe
	4 Sty/chalazion	none		slight	moderate	severe
	5 Laceration	none		slight	moderate	severe
	6 Lachrymal duct swelling	none		slight	moderate	severe
	Conjunctiva					
221	1 Injected	none		slight	moderate	severe
222	2 Conjunctivitis Lateral	none		slight	moderate	severe
223	3 Conjunctivitis Nasal	none		slight	moderate	severe
	4 Conjunctivitis Limbal	none		slight	moderate	severe
	5 Foreign body	none		slight	moderate	severe
	6 Chemosis	none		slight	moderate	severe
	7 Petechiae	none		slight	moderate	severe
	8 Hemorrhage	none		slight	moderate	severe
	Sclera					
231	1 Petechiae	none		slight	moderate	severe
232	2 Hemorrhage	none		slight	moderate	severe
233	3 Icterus	none		slight	moderate	severe
	Ocular Tension					
241	1 Palpation		normal	soft	increased	hard
242	2 Tonometry					
243						

			0	1	2	3	4
EYES (continued)							
		Eye Movements					
251	1	Rectus weakness	none		slight	moderate	severe
252	2	Oblique weakness	none		slight	moderate	severe
253							
		Cornea					
261	1	Keratitis	none		slight	moderate	severe
262	2	Opacity	none		slight	moderate	severe
263	3	Pain	none		slight	moderate	severe
	4	Foreign body	none		slight	moderate	severe
	5	Abrasion/Ulcer	none		slight	moderate	severe
		Anterior Chamber					
271	1	Depth		normal		shallow	obliterated
272	2	Hypopion	none				present
273							
		Iris					
281	1	Pupil size		normal	constricted	dilated	
282	2	Pupil shape		normal	slightly irregular	irregular	grossly distorted
283							
	3	Reaction to light		normal		sluggish	no reaction
	4	Accomodation		normal		sluggish	no reaction
	5	Iritis	none		possible	moderate	severe
		Fundus					
291	1	Color		normal	pale		
292	2	Arteries		normal	narrow	thickened	
293	3	Veins		normal	distended	distended & nicking	
	4	Hemorrhage		none	slight	moderate	severe
	5	Exudates		none	slight	moderate	severe
	6	Detachment	none				present
	7	Discs		normal		cupping	edema

EARS, NOSE AND THROAT

		Ears					
301	1	Itch	none		slight	moderate	severe
302	2	Pain	none		slight	moderate	severe
303	3	Discharge	none		slight	moderate	severe
	4	External otitis	none		slight	moderate	severe
	5	Dizziness	none		slight	moderate	severe
	6	Disorientation	none		slight	moderate	severe
	7	Vertigo	none		slight	moderate	severe
	8	Tinnitis	none		slight	moderate	severe
	9	Deafness	none		slight	moderate	severe

EARS, NOSE AND THROAT (cont'd)

			0	1	2	3	4
		External Ear					
311	1	Auricle		normal			inflamed
312	2	Canal		normal	dry	weeping	suppurative
313	3	Wax	none	normal	slight	moderate	occluded
		Eardrum					
321	1	Color		normal	dull	injected	fiery red
322	2	Reflex	absent	normal	enhanced		
323	3	Fluid	none		slight	moderate	bulging
	4	Perforation	none				present
		Nose-Nostrils					
330	1	Coryza	none		slight	moderate	severe
331	2	Sneezing	none		slight	moderate	severe
332	3	Epistaxis	none		slight	moderate	severe
333	4	Obstruction nares	none		slight	moderate	severe
	5	Frontal sinus pain	none		slight	moderate	severe
	6	Max. sinus pain	none		slight	moderate	severe
	7	"Cold"	none		slight	moderate	severe
	8	Mucosa		normal	pale	injected	red
	9	Discharge	none		slight	moderate	severe
	0	Discharge color	none		clear	white	suppurative
		Lips					
344	1	Color		normal	pale	cyanotic	
345	2	Herpes simplex	none				present
346	3	Cheilitis	none		slight	moderate	severe
		Tongue					
350	1	Color		normal	pale	cyanotic	beefy red
	2	Coating	none		slight	moderate	thick
		Teeth					
360	1	Toothache	none		slight	moderate	severe
	2	Caries	none		slight	moderate	severe
	3	Calculus	none		slight	moderate	severe
		Tooth Designation					
367			01-32	standard numbering system			
		Gingiva					
374	1	Color		normal	pale	cyanotic	
375	2	Bleeding	none		slight	moderate	severe
376	3	Ulceration	none		slight	moderate	extensive

			0	1	2	3	4
EARS, NOSE AND THROAT (cont'd)							
		Pharynx					
381	1	Sore throat	none		slight	moderate	severe
382	2	Color of mucosa		normal	pale	cyanotic	beefy red
383	3	Swelling	none		slight	moderate	severe
		Tonsils					
391	1	Swelling	none		slight	moderate	severe
392	2	Inflammation	none		slight	moderate	severe
LUNGS-THORAX							
		Thorax					
411	1	Cough	none		slight	moderate	severe
412	2	Chest pain	none		slight	moderate	severe
413	3	Rib tenderness	none		slight	moderate	severe
	4	Tenderness over spine	none		slight	moderate	severe
	5	Muscle tenderness (long spinal)	none		slight	moderate	severe
		Respiration					
420	1	Dyspnea	none		slight	moderate	severe
	2	Rest position			inspiratory	mid-position	expiratory
	3	Movement with deep breath		normal		slightly impaired	impaired
	4	Accessory respiratory muscles	not used			used only with deep breath or exercise	used constantly
		Lungs					
450	1	Diaphragm movement		moves		Minimal	Impaired or
451				normally		movement	no movement
452	2	Fremitus		normal		increased	impaired
453	3	Percussion		resonant	hyper-	dull	flat
454					resonant		
455	4	Breath sounds	absent	normal		decreased	increased
456	5	Voice sounds	absent	normal		decreased	increased
	6	Wheezes	none				present
	7	Rales	none		slight	moderate	severe
	8	Friction rub	none				present
	9	Adventitious sounds	none				present
HEART							
500	1	Dizziness	none		slight	moderate	severe
	2	Palpitation	none		slight	moderate	severe
	3	Extrasystoles	none		w.exercise only	infrequent	frequent
	4	Skipped beats	none		w.exercise only	infrequent	frequent
	5	Decreased work capacity	no		slight	moderate	severe
	6	"Choking"	no		single episode	periodic	frequent
	7	Syncope	no		single episode	multiple episodes	frequent or very prolonge

		0	1	2	3	4
HEART (continued)						
500 8	Anginal pain	no				present
9	Persistent arrhythmias	no				present
	Inspection					
510 1	PMI		normal			displaced
511 2	Pulsations		normal	decreased	increased	heaving
512						
	Palpation					
520 1	PMI		normal			displaced
521 2	Thrill	none				present
522						
	Percussion					
530 1	Mediastinal dullness		normal width	increased	decreased	
	Heart Sounds					
540 1	Intensity		normal	faint	loud	
2	PI vs AI			PI greater	AI greater	equal
3	Split 1st sound	none				present
4	Split 2nd sound	none				present
	Systolic Murmurs					
550 1	Apex	none		soft blowing	moderate	loud,harsh
2	Base	none		soft blowing	moderate	loud,harsh
3	Transmission	none	upward	downward	left	right
	Diastolic Murmurs					
560 1	Apex	none		soft blowing	moderate	loud,harsh
2	Base	none		soft blowing	moderate	loud,harsh
3	Transmission	none	upward	downward	left	right
	Friction Rub					
570 1	Apex	none				present
2	Base	none				present
ABDOMEN						
600 1	Nausea	none		slight	moderate	severe
2	Vomiting	none		slight	moderate	severe
3	Cramps	none		slight	moderate	severe
4	Pain	none		slight	moderate	severe
5	Distention	none		slight	moderate	severe
6	Diarrhea	none		slight	moderate	severe

ABDOMEN (continued)		0	1	2	3	4
	Upper Quadrants					
601	1 Peristalsis		normal	slight	moderate	severe
602	2 Tenderness	none		slight	moderate	severe
603	3 Point tenderness	none		slight	moderate	severe
	4 Muscle rigidity	none		slight	moderate	severe
	Lower Quadrants					
611	1 Peristalsis		normal	slight	moderate	severe
612	2 Tenderness	none		slight	moderate	severe
613	3 Point tenderness	none		slight	moderate	severe
	4 Muscle rigidity	none		slight	moderate	severe
	Liver					
620	1 Dullness		normal		diminished	increased
	2 Edge	not palpable		sharp	diffuse	tender
	3 Tenderness	none		slight	moderate	severe
	4 Icterus	none		slight	moderate	severe
	Spleen					
630	1 Dullness		normal		diminished	increased
	2 Size	not palpable		Palpable on deep breath	moderately enlarged	enlarged
	3 Tenderness	none		slight	moderate	severe
	Mass					
641	1 Size			<5 cm.	5-10 cm.	>10 cm.
642	2 Mobility			fixed	slight	free
643	3 Pulsation	none		slight	moderate	strong
644	4 Tenderness	none		slight	moderate	severe
645						
646						
	Hernia					
651	1 Type		umbilical	inguinal	femoral	ventral
652	2 Size			small	moderate size	large
	3 Reducibility				reducible	not reducibl
	4 Pain	none		slight	moderate	severe
	5 Incarcerated bowel	no				yes
	Muscles					
661	1 Muscle weakness	none		slight	moderate	severe
662	2 Reflexes	absent	normal		weak	hyperactive
663						
664						
665						
666						
	Vessels					
670	1 Aortic pulse		normal	increased	decreased	
	2 Femoral pulse		normal	increased	decreased	

			0	1	2	3	4
ABDOMEN (continued)							
		Anus					
680	1	Pruritis	none		slight	moderate	severe
	2	Tenderness	none		slight	moderate	severe
	3	Swelling	none		slight	moderate	severe
	4	Pain	none		slight	moderate	severe
	5	Inflammation perirectal	none		slight	moderate	severe
	6	Ext. hemorrhoid	none	12-3 o'clock	3-6	6-9	9-12
	7	Thrombosed hemorrhoid	none	12-3	3-6	6-9	9-12
	8	Bleeding hemorrhoid	none	12-3	3-6	6-9	9-12
	9	Anal fistula	none	12-3	3-6	6-9	9-12
		Rectum					
690	1	Sphincter tone		normal	relaxed		
691	2	Prostate size		normal	small	enlarged	greatly enlarged
692							
	3	Prostatic mass	none		small	moderate	large
	4	Prostate tenderness	none		slight	moderate	severe
	5	Rectal mass	none		small	moderate	large
	6	Rectal tenderness	none		slight	moderate	severe
	7	Feces color		normal	light	grey	black
	8	Rectal bleeding		none	slight	moderate	severe
GENITOURINARY							
700	1	Dysuria	none		slight	moderate	severe
	2	Hematuria	none		slight	moderate	severe
		Lymph Nodes					
711	1	Enlargement		normal	slight	moderate	severe
712	2	Tenderness	none		slight	moderate	severe
713	3	Character				discrete	matted
	4	Redness Inflammation	none		slight	moderate	severe
		Penis					
720	1	Phimosis	none		slight	moderate	severe
	2	Edema	none		slight	moderate	severe
	3	Lesion-glans	none				present
	4	Lesion-meatus	none				present
	5	Discharge	none		slight	moderate	severe
	6	Pain	none		slight	moderate	severe
		Testis					
731	1	Pain	none		slight	moderate	severe
732	2	Tenderness	none		slight	moderate	severe
733	3	Atrophy	none		slight	moderate	severe
	4	Enlargement	none		slight	moderate	severe
	5	Hydrocele	none		slight	moderate	severe

		0	1	2	3	4
GENITOURINARY (continued)						
	Epididymis					
741	1 Swelling	none		slight	moderate	severe
742	2 Tenderness	none		slight	moderate	severe
743						
	Spermatic Cord					
751	1 Varicocele	none		slight	moderate	severe
752	2 Tenderness	none		slight	moderate	severe
753						
	Kidneys					
761	1 Pain	none		slight	moderate	severe
762	2 Tenderness	none		slight	moderate	severe
763						
	Bladder					
770	1 Frequency of micturition		normal		increased	frequent
	2 Dull pain	none		slight	moderate	severe
	3 Sharp localized pain	none		slight	moderate	severe
	4 Tenderness	none		slight	moderate	severe
	5 Burning on micturition	none		slight	moderate	severe
UPPER EXTREMITIES						
*	Hand					
811	1 Skin temperature		warm	cool	moist hot	dry hot
812	2 Edema	none		slight	moderate	severe
*	Dorsum L Hand					
813	3 Tenderness	none		slight	moderate	severe
*	Dorsum R Hand					
814	4 Pain	none		slight	moderate	severe
*	Palm L Hand					
815	5 Localized Swelling		thenar	hypothenar	ulnar	radial
*	Palm R Hand					
816	6 Localized inflammation		thenar	hypothenar	ulnar	radial
	7 Grip		normal	decreased	weak	very weak
	8 Metacarpal fracture	none			single	multiple
	9 Laceration	none		small	moderate	extensive
	Digits (Odd numbers left hand) (Even numbers right hand)					
*	Thumb					
821	1 Nail color		normal	pale	cyanotic	red
822						
*	Index finger					
823	2 Subungual infection	none				present
824	3 Foreign body	none				present
*	Middle finger					
825	4 Paronychia	none				present
826						

* NOTE: Any one of the fourth unit descriptors can apply to any 3-digit group.

UPPER EXTREMITIES (continued)	0	1	2	3	4
/* Ring finger					
827 5 Pain	none		slight	moderate	severe
828 6 Swelling	none		slight	moderate	severe
* Little finger					
829 7 Inflammation	none		slight	moderate	severe
830 8 Weakness	none		slight	moderate	severe
9 Fracture	none			single	multiple
0 Laceration	none		small	moderate	extensive
Wrist					
841 1 Range of motion		normal		restricted	unable to move
842					
843 2 Weakness	none		slight	moderate	severe
3 Joint pain	none		slight	moderate	severe
4 Fracture	none				present
5 Laceration	none		small	moderate	extensive
Forearm					
851 1 Flexors weakness	none		slight	moderate	severe
852 2 Extensors weakness	none		slight	moderate	severe
853 3 Pronators weakness	none		slight	moderate	severe
4 Supinators weakness	none		slight	moderate	severe
5 Pain	none		slight	moderate	severe
6 Tenderness	none		slight	moderate	severe
7 Swelling	none		slight	moderate	severe
8 Carpopedal spasm	none		slight	moderate	severe
9 Fracture	none		ulna	radius	multiple/ compound
0 Laceration	none		small	moderate	extensive
Elbow					
861 1 Motion		normal		restricted	unable to move
862 2 Tenderness radial head	none		slight	moderate	severe
863 3 Swelling	none		slight	moderate	severe
4 Pain	none		slight	moderate	severe
5 Bursitis	none		slight	moderate	severe
6 Fracture	none				present
7 Laceration	none		small	moderate	extensive
Upper Arm					
871 1 Weakness of flexors	none		slight	moderate	severe
872 2 Weakness of extensors	none		slight	moderate	severe
873 3 Fracture	none			present	compound
4 Laceration	none		small	moderate	extensive
Shoulder					
881 1 Range of abduction		normal		restricted	unable to move
882 2 Range of rotation		normal		restricted	unable to move
883 3 Deltoid weakness	none		slight	moderate	severe
4 Adductors weakness	none		slight	moderate	severe
5 Abductors weakness	none		slight	moderate	severe
6 Bursitis	none		slight	moderate	severe
7 Clavicle fracture	none				present
8 Laceration	none		small	moderate	extensive
9 Dislocation	none			reduced	present

* NOTE: Any one of the fourth unit descriptors can apply to any 3-digit group.

			0	1	2	3	4
		Axilla					
	891 1	Lymph node swelling	none		slight	moderate	severe
	892 2	Lymphangitis	none		slight	moderate	severe
	893 3	Folliculitis	none		slight	moderate	severe
		LOWER EXTREMITY					
		Foot					
*	911 1	Edema	none		slight	moderate	severe
	912 2	Skin Temp.		normal	cool	moist & hot	dry & hot
*		Dorsum L foot					
	913 3	Tenderness	none		slight	moderate	severe
*		Dorsum R foot					
	914 4	Dorsalis pedis pulse		normal	absent	weak	
*		Plantar L foot					
	917 5	Pain		none	slight	moderate	severe
*		Plantar R foot					
	918 6	Localized swelling		none	slight	moderate	severe
	7	Localized inflammation		none	slight	moderate	severe
	8	Nail color		normal	pale	cyanotic	
	9	Tinea pedis	none		slight	moderate	severe
	0	Fracture	none			digit	metatarsal/heel
		Lower Leg					
	921 1	Flexors weakness	none		slight	moderate	severe
	922 2	Extensors weakness	none		slight	moderate	severe
	923 3	Swelling	none		slight	moderate	severe
	4	Tenderness	none		slight	moderate	severe
	5	Pain	none		slight	moderate	severe
	6	Varices	none		slight	moderate	severe
	7	Phlebitis	none		slight	moderate	severe
	8	Fracture	none		fibula	tibia	multiple/ compound
	9	Laceration	none		small	moderate	extensive
		Knee					
	931 1	Range of motion		normal		restricted	unable to move
	932 2	Pain	none		slight	moderate	severe
	933 3	Fluid	none		slight	moderate	severe
	4	Popliteal artery pulsation		normal			absent
	5	Patellar fracture	none				present
		Thigh					
	941 1	Quadriceps weakness	none		slight	moderate	severe
	942 2	Hamstrings weakness	none		slight	moderate	severe
	943 3	Sciatic n. tenderness	none		slight	moderate	severe
	4	Fracture	none			present	compound
	5	Laceration	none		small	moderate	extensive
		Hip-Buttocks					
	951 1	Adductors weakness	none		slight	moderate	severe
	952 2	Abductors weakness	none		slight	moderate	severe
	953 3	Range of flexion		normal		restricted	unable to move
	4	Range of rotation		normal		restricted	unable to move
	5	Pain in hip	none		slight	moderate	severe
	6	Dislocation	none			reduced	present

* NOTE: Any one of the fourth digit descriptors can apply to any 3-digit group.

DYNAMIC PHYSIOLOGICAL SUBSYSTEM III-D

SECTION III-D

IMBLMS FUNCTIONAL BREADBOARD PERFORMANCE/DESIGN REQUIREMENTS

DYNAMIC PHYSIOLOGICAL MONITOR SUBSYSTEM

DYNAMIC PHYSIOLOGICAL MONITOR

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

- 3.1 Performance
  - 3.1.1 Functional
    - 3.1.1.1 Overall System Requirements
    - 3.1.1.2 Measurement Requirements
    - 3.1.1.3 Sensors
    - 3.1.1.4 Signal Conditioners
    - 3.1.1.5 Vests and Wiring Harnesses, and Umbilical Cables
    - 3.1.1.6 Display and Control
  - 3.1.2 Operability
    - 3.1.2.1 Maintainability
    - 3.1.2.2 Transportability
    - 3.1.2.3 Safety
- 3.2 Interface Requirements
  - 3.2.1 Interface Requirements - DPM/PBDM Station
  - 3.2.2 Interface Requirements - DPM, Operator and Subject
  - 3.2.3 Interface Requirements - Measurements/Associated Equipment
- 3.3 Design and Construction
  - 3.3.1 Electrodes, Sensors, Signal Conditioners, Body Vests, and Wiring Harnesses
    - 3.3.1.1 Electrodes
    - 3.3.1.2 Sensors and Transducers
    - 3.3.1.3 Signal Conditioners and DC-DC Converter
    - 3.3.1.4 Vest and Wiring Harnesses
    - 3.3.1.5 Display and Controls
    - 3.3.1.6 Calibration
    - 3.3.1.7 Power Requirements/DPM

4.0 DESCRIPTIVE DEFINITION AND BLOCK DIAGRAMS

APPENDIX - MEASUREMENT REQUIREMENTS DATA SHEET

1.0 INTRODUCTION

This document establishes the requirements for the performance, and design of the Dynamic Physiological Monitor (DPM) subsystem together with the requirements necessary for providing interfaces with other FBB subsystems. The DPM display panel together with body worn measurement sensors, signal conditioners, and vest and wiring harnesses comprises the subsystem.

The DPM is used in an active monitoring mode at either the PBDM station or at a remote site to measure, display, calibrate, and record vital signs, critical pressure suit measurements, and routine physiological and neurological measurements.

2.0 APPLICABLE DOCUMENTS

Section IIIA FBB System Requirements document contains all applicable documents.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional.

3.1.1.1 Overall System Requirements. - The DPM subsystem must be capable of measuring specified physiological parameters using body attached sensors, signal conditioners, and transducers. Registration of these measurements must be accomplished using graphical CRT, and meter presentation. Measurement data will be preserved on peripheral tape recording and pen writer equipment. The DPM subsystem will provide either integral computational support to derive data from the electrical inputs, or will provide interconnection with external processing equipment.

3.1.1.2 Measurement Requirements. - The DPM, used in conjunction with a number of body-worn or peripheral signal conditioners and six individual measurement vests and wiring harnesses will be capable of displaying the following physiological parameters: EEG (Two channels); EOG (horizontal and vertical); EMG (neck muscle); ECG reference (sternal or axillary); Heart rate (cardiotachometer); ECG clinical (Leads I, II, III, AVR, AVL, AVF, V_1-V_6); VCG (Frank leads X, Y, and Z); ZCG (Kubicek method), ZPN (Respiratory rate derived); PCG/VbCG; PWC; Ear canal temperature; Average skin temperature (12 points); Systolic and diastolic blood pressure; and simulated suit pressure, suit flow, and suit pCO_2. Specific measurement data requirements are tabulated in the Section IIID Appendix.

3.1.1.3 Sensors. - Bioelectrical signals will be sensed directly with surface electrodes. A contact type microphone will be used to detect Korotkoff sounds and precordial vibrations. Photoelectric transducers will be used in special applications. Thermistors will be used to monitor body and skin temperature. The sensors will be attached directly to the subject with output connections to signal conditioners. Close coupled attachment leads will be used wherever necessary to minimize signal loss and interference pickup. DC-DC excitation voltages for measurement circuits, as well as output leads will be provided adjacent to the signal conditioners. The sensors will be mounted or attached to the subject in such a way as to minimize response to body movements; be relatively immune to impact and vibration stresses, and operate over the range of the test environment.

3.1.1.4 Signal Conditioners. - Signal modifiers consisting of signal conditioners, amplifiers, integrators, and filters will be used to modify, process, and normalize the bioelectrical signals. Solid-state differential amplifiers designed specifically for amplification of low level signals will be utilized. Single-ended output at high level will be provided. The majority of signal conditioners will be designed to be worn in a pocket of a belt or special vest. Some signal conditioners will be standard circuit boards (EEG, EMG, EOG, Standard 12 Lead ECG).

3.1.1.5 Vest Wiring Harnesses and Umbilical Cables. - The allocation of measurements to various measurement vests and harnesses is tabulated below:

Measurement Vests and Wiring Harnesses

Monitoring	-Axillary or Sternal ECG PCG/VbCG ZPN Temperature Blood pressure (Separate) Pulse wave contour (Separate)
Clinical ECG	-I, II, III AVR, AVL, AVF V_1 - V_6
Vector Cardiogram	-X, Y, and Z (Frank's Lead System) PCG ZPN
Impedance Cardiogram	-ZCG (Excitation and Sensing band electrodes) PCG
Average Skin Temperature	-12 points, individually weighted
Neurological Measurements	-EEG (2 channels) EOG (horizontal and vertical) EMG (Sternocleidomastodeus or Splenius capitis)

Body vests, harnesses and umbilical cables form the electrical interface with the DPM and the PBDM station. The wiring harnesses will interconnect the sensors, signal conditioners and power converters. The harnesses will be flexible, adjustable and comfortable. Provisions will be made on the vests for individual adjustment of sensors by means of take-up straps. The vest design will accommodate the 50th to 95th percentile user. Multi-pin connector(s) will be considered for handling harness umbilicals. Neurological and monitoring measurements can be measured simultaneously. The capability of interchanging certain signal conditioners between harnesses will be provided.

3.1.1.6 Display and Control. - The DPM in its monitoring capacity will display on panel meters the vital signs (Temperature, Heart Rate, Respiration Rate, and Systolic and Diastolic Blood Pressure), and simulated suit parameters (Suit Flow, Suit Pressure, and Suit pCO_2.) Scales will be in medical units and sized to individual accuracy requirements.

Selection of the specified physiological and neurological signals will be affected by multi-position switches. Adjustment of circuit gain will be handled by potentiometers located on the DPM panel. This will permit accommodating the characteristics of the individual subjects.

A single-channel oscilloscope will be required for displaying physiological waveforms to make gross calibration checks.

An audio and visual alarm system will be provided in the DPM for the vital signs. Provisions will be made for separately turning off the audio alarm although another out-of-limits condition will reactivate the alarm. Limits will be established and controlled by means of the computer. Used in the remote mode the alarm system will be inoperative. A summary of the display and control capability is tabulated below:

Analog meters with Upper and Lower Threshold Alarms:	Instrumentation Calibration Scope:
Ear or Average Skin Temperature	Electrocardiogram, reference and 12-lead clinical; VCG
Systolic blood pressure	Phono/Vibrocardiogram; 0.1 - 20, 10 - 30, 30 - 500, 0.1 - 1000 Hz.
Diastolic blood pressure	Pulse wave contour
Heart rate	Impedance cardiogram
Respiration rate	Impedance pneumogram
Suit pressure	Electroencephalogram (2 ch)
Suit flow	Electro-oculogram (Hor. & Vert. ch.)
Suit pCO_2	Electromyogram
	Korotkoff sounds (cuff Microphone)
Controls:	**Calibration:**
Gain adjustment	ECG in DPM
Alarm settings	VCG, ZCG } remote activation of body-worn unit
Oscilloscope adjustments	
Recorder outputs	

3.1.2 Operability. - Section IIIA FBB System Requirements document contains applicable Operability Requirements together with requirements as listed herein.

3.1.2.1 Maintainability. - The DPM will be removed from the PBDM by disengaging the back connectors and sliding it forward from the support structure. A hinged metal cover on the DPM with captive quick-opening fasteners will be required that will swing away from the DPM chassis to permit accessibility for replacing and servicing of all the critical elements.

3.1.2.2 Transportability. - The DPM will be removable from the PBDM and designed for transportation and operation at a remote site. A recessed extendable handle will be provided. In this remote operational mode only meter display capability is required, however, provisions will be made for interconnections with a data recorder, a power supply, and a low pressure air supply.

3.1.2.3 Safety. - Sharp edges, burrs, corners are not permitted. Flush or recessed connections will be provided. Short circuits and other overload

conditions will be controlled with power regulation devices. Fault isolation will be maintained at the module level. If any component is replaced or any preventive or corrective maintenance applied, the DPM must be checked out prior to its reinstallation in the PBDM station.

Harness umbilicals carrying power from the PBDM to vest/wiring harnesses will terminate in a male connector at the PBDM panel. The PBDM interconnection panel will have the female connector installed.

3.2 Interface Requirements

The interface requirements and constraints imposed by the functional, physical, and procedural relationships between the DPM and the PBDM station, and between the DPM, the operators, and subjects will be discussed below.

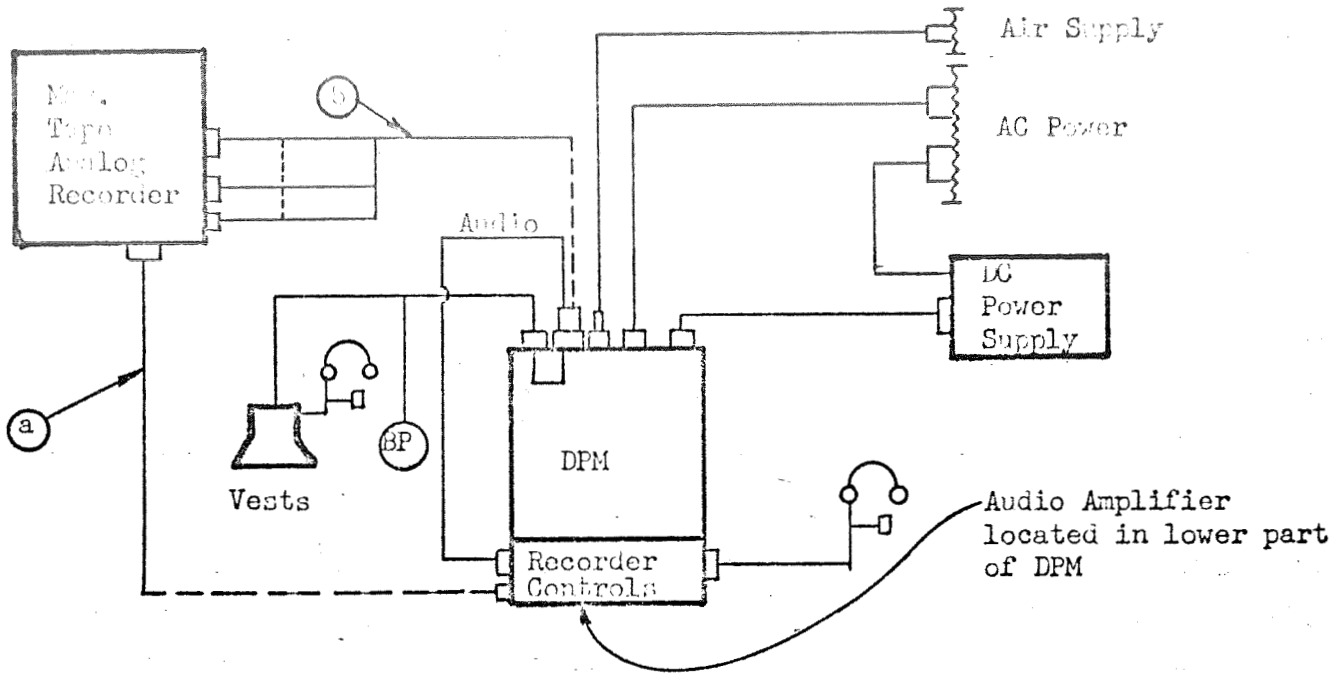
3.2.1 Interface Requirements - DPM/PBDM Station. - The DPM is the basic monitoring unit and is used for the majority of the physiological experiments. For this reason it will be given a central location at the PBDM station. The DPM will be installed at the station in such a way that it can be easily removed and transported.

The flow of physiological signals from the vest/harness combinations will be accomplished with a 15-foot umbilical(s) terminating in a multi-pin connector(s). This connector will be attached to the PBDM station and internal distribution will be made directly to a rear connector on the DPM. If the DPM is being used at a remote location, the 15-foot umbilical cable(s) with its connector will be directly attached to the rear connector(s) on the DPM.

The blood pressures sphygmomanometer cuffplus microphone can be separated from the monitoring vest/harness. An air supply must be provided routed through the DPM programmer input/output ports.

The major interface with the PBDM Data Management Subsystem is through signal output connector(s) at the back of the DPM. All output signals presented at the multi-pin connector(s) at the rear of the DPM module for further switching, must have an output impedance no greater than 220 Ω. This output will be tied into a switching matrix for distribution to display, record, and/or printout (See Figure 1). Physiological and neurological measurements assigned to the DPM will not be normally available to the PBDM Data Management computational capability when the DPM is used in remote operation. "Semi-remote" operation will be possible via interface cabling including the measurement of blood pressure with the pressure programer in close proximity to the subject.

3.2.2 Interface Requirements - DPM, Operator and Subject. - While operating the DPM and its peripheral supporting equipment it is necessary to have the subject physically adjacent to the station and the operator. This permits the operator to set up and visually observe the subject, and to monitor the displays and readouts.



(a) Remote tape recorder controls may require rewiring of recorder if space is limited.

(b) Direct DPM to tape recorder connection requires special cable.

DPM REMOTE OPERATION

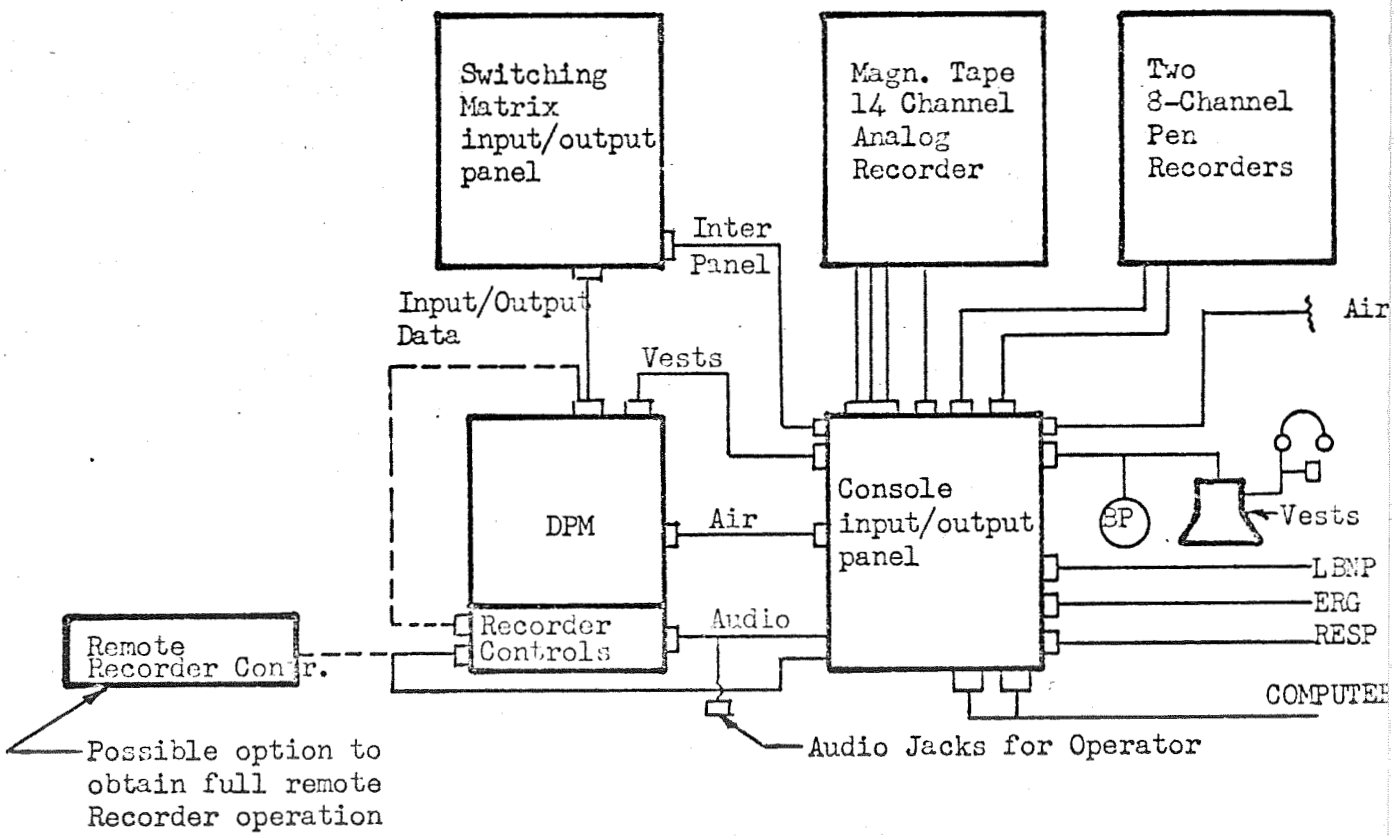


Figure 1 - DPM CONSOLE OPERATION

The operator is required to operate switches to control the tests, to perform calibrations, and to adjust the gain controls. Normal operation of the module will be from a seated position at the station. The operator may leave the station to adjust, calibrate, or check out measurement equipment on the subject, however, this will only occur during experimental set-up or upon completion of the experimental run.

3.2.3 Interface Requirements - Measurements/Associated Equipment. - Measurements will be grouped so that maximum utilization of common equipment will be achieved. Six vest/harness combinations will be used assigned to: (1) Neurological, (2) Monitoring, (3) VCG, (4) ZCG, (5) Clinical ECG, and (6) Average Skin Temperature. Normally these vests are individually worn and never more than one set of signals taken. However, provisions will be made for using the monitoring vest/harness combination with the Neurological measurement system.

Based on these measurement procedures, four 15 feet umbilical cables will be used with pin assignment as follows:

1. Neurological - Separate individual cable assembly and separate connector at PBDM and at DPM

2. Monitoring and Blood Pressure - The blood pressure sphygmomanometer cuff air input and microphone leads will be separate from the monitoring vest/harness. Suitable mechanical interface will be provided to minimize motion artifact or oscillation in blood pressure air supply. A telescoping mechanical arrangement will be utilized for that portion of the air supply line that is external to the PBDM station. Within the PBDM station, hardline plumbing will be provided up to a flexible coupling at the DPM back panel. The pulse contour measurement may be added to the monitoring vest/harness/umbilical assembly.

3. The VCG and ZCG harness cable assembly will utilize a common connector with appropriate pin assignments made.

4. The Clinical ECG, and Average Skin Temperature umbilical cable assembly will utilize a common connector with appropriate pin assignments made. Audio monitoring of subject during measurement is required together with intercommunication between observer and subject. A headset/microphone combination will be employed. The cable assembly will be dressed out in each vest/harness umbilical allowing plug-in attachment of the headset/microphone. The PBDM station will be equipped with plug-in capability for headset/microphone combination.

3.3 Design and Construction

The DPM subsystem will incorporate space-oriented equipment wherever practical. Commercial equipment used will be selected primarily on the basis of compact size, principles of operation, and adaptability to space requirements. The DPM consists of the following elements: Electrodes, Sensors, Signal Conditioners, DC-DC Converters, Body Vests, Wiring Harnesses, Display and Control Units, and Calibration Units. This section will discuss the mechanical, electrical, fluid, test provisions, and materials requirements.

3.3.1 Electrodes, Sensors, Signal Conditioners, Body Vests, and Wiring Harnesses.

3.3.1.1 Electrodes. - All bioelectric signals will be picked up by means of small, reusable, sintered Ag/AgCl pellet electrodes, Gulton Type M-20 or disposable Telectrodes. Provisions shall be made for interchanging these electrodes on the vest and wiring harnesses. The Telectrode disposable electrode is a metalized cloth contact with snap-on connector and an electrode paste reservoir that is sealed to the skin by an adhesive patch. The cloth contact stays wet and completely conductive. Contact jelly is put on the cloth mesh in sufficient quantity to keep the pad moist and sealed in by the adhesive edges. Snap-on connectors are provided with the signal cables that attach to the electrodes. When the measurement is completed, the Telectrode contacts are peeled off and discarded. Impedance signals will be acquired by means of either aluminum foil (3M, #425) or metal-impregnated cloth electrodes. These will have a band configuration for ZCG or rectangular plates for ZPN. Special EEG electrodes developed for NASA by Adey/Kellaway will be evaluated, when made available by the NASA.

3.3.1.2 Sensors and Transducers. - A precordial microphone with an overall frequency response for 0.1 to 1,000 Hz is required for PCG/VbCG measurements. Detection of arterial sound for blood pressure measurement will be accomplished by a contact type microphone for Korotkoff sounds, and a transducer to measure cuff pressure.

For monitoring the pulse contour at a finger site or on the toe, an infrared photocell device such as the Spacelabs Model 404 pulse sensor will be employed. When placed over a peripheral arterial bed, the pulse sensor provides output signals which follow the waveform of the underlying pulsatile flow. Body temperature will be taken by means of custom molded plastic hearing-aid type thermistor sensors. Twelve skin thermistor probes will be used to obtain the average weighted skin temperature. (See weighted formula in Section IIID Appendix.)

3.3.1.3 Signal Conditioners and DC-DC Converter. - Input/output characteristics are covered in the Section IIID Appendix. A brief description of the signal conditioners and DC-DC Converter follows:

Electrocardiogram Signal Conditioner. - The ECG signal conditioner with associated electrodes is designed to provide measurement of ECG activity and develop a signal range of 0.1 to 100 Hz. The units are designed to be worn in pockets of belt or torso vest. The device will be enclosed within a sealed case for the reference and VCG applications and will be configured as a circuit board within the DPM for the clinical ECG application.

Impedance Pneumogram Signal Conditioner. - The ZPN Signal Conditioner and associated electrodes are designed for measurement of a change in transthoracic impedance to a low level current at a frequency of approximately 50 KHz. Measurement is obtained from a pair of appropriately located conductive cloth "plate" electrodes on the astronaut, which develop signals for reliable measurement of respiration rate over a wide dynamic range of respiratory activity.

The unit is designed to be worn in the pocket of a belt or torso vest. A potentiometer on the DPM permits adjustment of circuit gain to accommodate the characteristics of the individual astronaut. The unit will be a hermetically sealed case.

Temperature Signal Conditioner and Probe. - The temperature signal conditioner and probe provide an indication of skin temperature over the range 80°F to 115°F. The ear mold temperature sensors will be provided by LMSC. Yellow Springs thermistors, type 44011X will be used in order to match the Spacelabs furnished signal conditioner. The probe and signal conditioner will be designed for maximum reliability both from the standpoint of continued operational use, and the preservation of accuracy throughout the life of the device. The signal conditioner is enclosed within a hermetically sealed case, and is designed to be worn in the pocket of a belt or torso vest.

EEG Signal Conditioner. - The EEG signal conditioners with associated electrodes are designed specifically for amplification of EEG signals. The amplifiers are designed to provide a single-ended output at high level to match typical PCM telemeter input level requirements and for strip chart recorders. They will be of circuit board construction. The units will be mounted together with other neurological signal conditioners closely adjacent to the subject. Umbilical connection will be provided for interconnecting the assembly to a head device holding the electrodes.

EMG. - The EMG signal conditioner will be made up in a regular circuit board configuration. It will be mounted in the wall-mounted neurological assembly and will be used in conjunction with the EEG and EOG measurements.

EOG. - The EOG Signal Conditioners will be made up in a regular circuit board configuration. They will be placed in the neurological assembly and will be used in conjunction with the EEG and EMG measurements.

Phonocardiogram/Vibrocardiogram. - A specially designed PCG/VbCG signal conditioner with an overall frequency response of 0.1 to 1,000 Hz is required. Four specific frequency bands as listed in the Appendix A Measurement Data Sheet are required. Use of an existing EEG signal conditioner modified for the frequency response required will be investigated.

Blood Pressure. - This unit will utilize a small cuff programmer developed by Technology Incorporated, a Korotkoff sound filter/amplifier, and electronic circuit boards to derive the outputs for the systolic and diastolic pressure meters. An external air supply will be provided. This system will be capable of measuring the systolic and diastolic blood pressures of a subject and of transmitting these signals to recording and display equipment. A display is required for systolic and diastolic blood pressures, and audible alarms will be activated if predetermined upper or lower limits are exceeded. This system is adjustable to take either a single set of readings after manual activation, or for automatic periodic readings. If automatic recycling is employed, the frequency of measurement will be once per 30 seconds.

Pulse Wave Velocity. - The pulse wave velocity "computer", contained in

the DPM, must be capable of using either the R-wave of the reference ECG (preferred, but not always available) or the first heart sound to initiate the computation. A modified Spacelabs Model 800 PWV monitoring system, is required. In view of the existing controversy pertaining to the exact opening moment of the semilunar valves relative to the R-wave, as well as the fact that the exact distance between these semilunar valves and the sensing point of the peripheral pulse wave can only be measured by means of a graduated X-ray-opaque catheter under fluoroscopic control, the PWV computer will only measure the actual transit time between either the R-wave or the first heart sound, and the arrival of the corresponding pulse wave at the peripheral sensing point of the latter. A damped readout of this transit time shall be available on a digital readout at the PBDM. Since the peripheral pulse sensor may be placed as far from the heart as the left foot (for instance, when the subject is in the LBNP device), an estimated distance of up to 1.8 meters, and assuming a minimum pulse wave velocity of 5 m/sec, the expected maximum transit time to be measured may be as long as 400 milliseconds.

Impedance Cardiogram. - One ZCG signal conditioner consisting of a current source, a differential amplifier/detector, a ΔZ and $\Delta \dot{Z}$ amplifier, and a calibration module. The ZCG signal conditioners will be identical to those supplied by Spacelabs for Dr. Kubicek's experiments.

Cardiotachometer. - The DPM will contain a cardiotachometer circuit, which uses the ECG (Lead I or Reference) or VCG (Lead X) signals to drive the heart rate meter on the front panel. The cardiotachometer must provide two different time-constants, 5 seconds and 15 seconds, selectable by means of a switch on the front panel. The longer time-constant is required to obtain a smoother meter readout during exercise.

Pneumotachometer. - A pneumotachometer circuit will be included, which uses the ZPN signal to drive the respiration rate meter on the front panel. A single, fixed time-constant of approximately 10 seconds appears adequate.

DC-DC Power Converter. - The DC-DC power converter is the component of the bioinstrumentation system which delivers +10 and -10 volt power to each signal conditioner. It accepts the single-ended 16.8 volt (nominal) power available from the DPM and converts it to the isolated balanced supply required by the bioinstrumentation system. The unit is hermetically sealed and will be carried with the other components in the crewman's belt or vest. Electronic operational characteristics will incorporate features for reverse polarity protection, load current limiting, and electrical isolation of the input and output.

3.3.1.4 Vest and Wiring Harnesses. - Six vests and wiring harnesses are associated with the DPM for Neurological Measurements, General Monitoring, Clinical ECG, Vectorcardiogram, Average Skin Temperature, and Impedance Cardiogram. The general configuration of the vest and wiring harnesses will provide electrodes and transducers attachment to their appropriate location by means of double-backed adhesive tape, straps, or other holding methods. Adjustable torso vests, several of which are provided with pockets for the various signal conditioners (S/Cs), assist in positioning these electrodes by virtue of the wiring harnesses attached to these vests. The wiring harnesses

provide the connections between the electrodes and transducers, the body-worn signal conditioners (if applicable), and the umbilical cable(s). The umbilical cable(s) connect(s) the signal leads either to the PBDM console, or directly to the DPM module, when the latter is used at a remote location.

Four separate umbilical cable assemblies will be provided for the six vest/wiring harnesses. The umbilical connector at the vest/wiring harnesses will pick up signal leads for the particular specified measurements. Three of the umbilical cable assemblies will terminate in a multi-pin connector at the PBDM station or will be mated to an identical multi-pin connector on the back of the DPM. The neurological umbilical cable will terminate in a separate multi-pin connector at the PBDM station and at the back of the DPM. The multi-pin connector pins will be identified with the signal leads from the individual vest/wiring harnesses.

Each low impedance signal (data) line will consist of twisted pair conductors and each group of such lines will have an overall common shield. Each high impedance signal (data) line will consist of shielded twisted pair conductors. A separate head-set/boom microphone combination for the intercommunication network will be provided to carry the voice signals between the PBDM and the subject.

Separate connectors will be provided on the back of the DPM. The following vests/wiring harnesses have been identified to supply signal inputs to the DPM:

Vest/Harness for Neurological Measurements. - This is actually a holding device, consisting of adjustable straps in a "bathing cap' configuration, which supplies support, positioning, and attachment of four EEG, four EOG, two neck muscle EMG, and one common ground electrode. The following active EEG electrode positions, based on "The Ten-Twenty Electrode System of the International Federation" must be possible: F3, C3 or T3, and O1, or F4, C4 or P4, and O_2. The common ground electrode will be located on the forehead. The two EMG electrodes would allow placement on either the Sternocleidomastodeus or the Splenius capitis.

Since the above neuroelectric signals will be recorded principally for sleep analysis, the five signal conditioners are to be mounted in a small box, to be located near the head of the sleeping subject. A three-foot umbilical will connect the head device to this S/C box, which, in turn will be connected to the PBDM or DPM station with a 15-foot multi-conductor cable. These signal conditioners will be made up in regular circuit board configuration. Parallel inputs from two separate sets of jacks (one for 100 microvolts for EEG and EOG, and one for 1 millivolt for EMG) must be provided on the box containing the S/Cs, to allow calibration by means of the portable Calibration Unit without interrupting the recording of the signals.

Vest/Harness for General Monitoring. - This vest/harness combination contains provisions for the simultaneous monitoring of a reference ECG (either sternal leads or axillary leads, but not both leads simultaneously), PCG/VbCG, ZPN, ear canal temperature, and blood pressure. Also Pulse Wave Contour may be obtained.

The signal conditioners for all but blood pressure shall be worn in small pockets on the vest. The sternal ECG electrodes can be integrated into the basic monitoring vest/harness combinations. Although the measurement of blood pressures is included, the sphygmomanometer cuff plus microphone can be separated from this vest/harness. A mechanical telescoping or hinged arrangement will be used to minimize the effect that an oscillating air supply line has on blood pressure measurements. Flexible couplings will be used at both terminal locations - DPM back panel, and at the sphygmomanometer cuff. Internal distribution of the air supply intake and output will be accomplished with hardline plumbing. An air input supply line will be supplied to connect to an input port of the blood pressure programmer within the DPM. The DPM will provide a suitable quick disconnect fitting on the back of the panel to accommodate this input line. An output quick disconnect fitting will be provided on the back of the DPM panel to link the air output to the subject's cuff. Suitable plumbing will be provided to lead the air output to the subject. A disconnect fitting must be provided at the subject to connect the air output.

When the DPM is used in the remote operation, an air supply will be provided that will connect directly to the programmer within the DPM. The output connector will be tied to the subject through suitable flexible coupling.

In addition to such items as the cuff pressure programmer and the Kòrotkoff sound filter/amplifier, the electronic circuit board(s) will be located in the DPM to derive the outputs for the systolic and diastolic pressure meters.

Provisions must be made to attach the photoelectric Pulse Wave Contour pickup to this vest/harness. The leads to and from this sensor must be long enough to allow placement on a finger of the left hand, or on the left foot. In either case, the leads will be taped onto the subject's arm or leg, respectively.

Vest/Harness for the Clinical ECG. - It is required to switch to seven different basic lead positions when conducting clinical ECG measurements. The switch and signal conditioning circuit board will be installed within the DPM module. The vest will only provide support for the wiring harness and the umbilical connector. A precordial electrode will be provided which will be a standard suction cup electrode with squeeze bulb.

Vest/Harness for the Vectorcardiogram. - The three S/Cs, the Frank resistor network, the calibration unit and other pertinent sub-modules, will be worn on the body in small pockets on the vest. Activation of the calibration unit, which is to provide the calibration signal simultaneously to all three S/Cs, is to be accomplished by means of a remote control button located on the DPM front panel. The Frank network requires 13 precision resistors, two of which have a value R, while the other resistors are decimal multiples thereof. The value of R, which determines the entire impedance level of the network, should be as high as possible, without seriously degrading 60 Hz CMR. A value of R = 50,000 Ohms is recommended. This vest/harness will also have provisions for the PCG/VbCG and the ZPN, which parameters have to be recorded simultaneously with the three VCG signals.

Vest/Harness for Average Skin Temperature. - This vest/harness combination provides attachment of up to 12 skin temperature sensors at various body locations. The temperature at each location will be weighted by a factor specific for that location. The necessary signal conditioners will be body worn on the vest and weighting module, so that a single output, representing the average skin temperature, will be available. Spacelabs, Model 401, Body Temperature Probes will be used as the sensing elements.

Vest/Harness for the Impedance Cardiogram. - Although actually providing a derived display output for the Vascular Dynamics panel, this assembly has one readout, the ΔZ impedance cardiogram signal, on the DPM calibration scope and gets its power from the DPM. The ZCG will be obtained with body-worn band electrodes and S/Cs. The PCG/VbCG and the ZPN will be acquired simultaneously with the ZCG. All output signals from this vest/harness, including ΔZ and ΔZ, will be available at the multi-pin output connector at the back of the DPM module. A separate signal ground, completely isolated from the chassis and the AC ground, must be used throughout the DPM and its associated equipment. This ground shall be available at the DPM signal output connector.

3.3.1.5 Display and Controls. - The front panel layout of the DPM (See Figure 2) contains the following major components:

- An instrumentation calibration scope;
- An ECG Select rotary switch;
- A Sensor Select rotary switch;
- An alarm reset rotary switch;
- A row of individual gain adjustments;
- Four dual analog meters with threshold alarm lights;
- A rotary selection switch for ear or average skin temperature, plus a calibration position;
- A rotary selection switch for manual or automatic blood pressure measurements, plus a calibration position;
- A cardiotachometer time - constant selector switch
- A VCG calibrate button
- Standard Lead button

The ECG Select and Sensor Select switches allow the waveform of the selected lead or transducer to be displayed on the Instrumentation Calibration Scope. By means of the individual gain controls, the amplitude of these signals can be approximately calibrated on this scope to ensure reliable operation of the

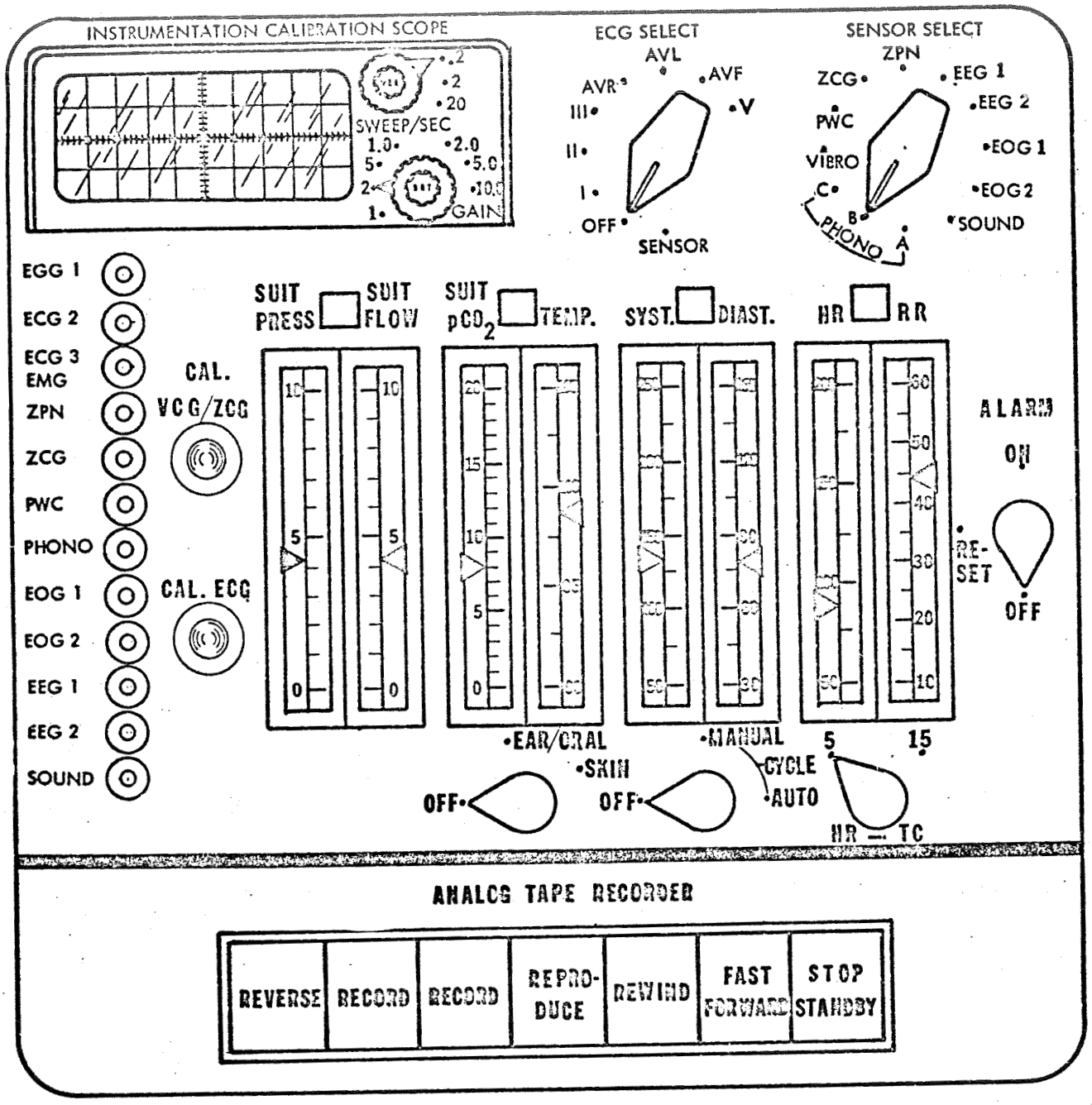


Fig. 2 Dynamic Physiological Monitor

appropriate processing and/or readout electronics within the DPM. This calibration simultaneously provides signal outputs of standardized amplitudes at the back panel of the DPM for further processing by the DMS.

The two parameters displayed on each of the four dual panel meters, share a single visual alarm. The upper and lower thresholds at which these lights are activated, are programmed into the DMS computer. If a threshold is exceeded, the computer sends a 1-5 volt square-wave pulse back to the DPM, which signal activates the appropriate alarm.

The flashing alarm lights will stay on until signal returns to normal, and the error voltage is removed from the line. Activation of any of the visual alarms will simultaneously sound an auditory alarm (Sonalert), located under the top cover of the DPM. The auditory alarm sound level may be regulated and may be turned off separately, if desired. If another out-of-limit condition occurs on the other signals, the auditory alarm will be reactivated. The Data Management Subsystem will provide alarm trigger and reset levels to indicate start and end of alarm situations. A common lead and individual leads for each lamp will be provided at a rear DPM connector with internal interconnection for the audio portion of the circuitry.

The Leads I, II, and III positions of the ECG Select switch will also be used to display the X, Y, or Z leads, respectively, of the vectorcardiogram. The Lead I position will further be used for the display of either the sternal or axillary reference ECG from the monitoring vest/harness. The DPM display and control panel will be limited to a frontal area of $9\frac{1}{2}$ x $9\frac{1}{2}$. An upper portion $9\frac{1}{2}$ in. x $7\frac{1}{4}$ in. will be reserved for display of designated physiological signals. A lower portion $9\frac{1}{2}$ in. x $2\frac{1}{4}$ in. will be reserved for a simulated tape recorder control panel. (See Figure 2) The tape recorder display section will consist of a structural shell attached to the DPM upper structure. Front and rear close-out panels must be provided. The lower structural shell may be used to house DC power regulation modules and will be used to mount an audio amplifier for the microphone, headset combination. Meter displays required for the DPM will be eight single vertical meters, Weston meter, 121.

3.3.1.6 Calibration. - All DPM measurements will be calibrated before and after each test. Certain measurements will be calibrated during the test runs. A calibration oscilloscope with stepwise gain control (.1, .2, .5, 1.0, 2.0, 5.0, or 10.0 V/cm sensitivity) will be installed on the DPM to view various outputs and to provide a qualitative calibration check within $\pm$ 10% of the measured value. The calibration oscilloscope will be used for calibrations such as: ECG, VCG, PCG/VbCG, Arterial Pulse Contour, ZCG and ZPN. Qualitative calibration checks will be accomplished by applying a calibration voltage to the input of each signal conditioner and observing the output on the oscilloscope. This will be done by a portable signal generator that can be transported to the location of the signal conditioners. Exceptions to this are: (1) requirement to provide a separate signal generator in the DPM for the clinical ECG and (2) self-contained calibration unit in the VCG S/C operated remotely by a calibration button on the DPM, (3) self-contained calibration circuitry in the ZCG S/C.

In addition to the qualitative calibration check with the DPM oscilloscope a quantitative calibration procedure will be followed. This will be performed by recording the calibrated signals at the output of the measurement system on a) the penwriters, b) the analog and digital tape recorder. Thus, system accuracy can be assessed quantitatively and the calibrated signals compared directly with the recorded biosignals. Calibration signal requirements are listed in the Section IIID Appendix.

3.3.1.7 Power Requirements/DPM. - The DPM requires 115v, 60 Hz, and 28 VDC regulated power. The DPM will receive its power from an ungrounded 28 volts DC supply. Chassis ground to the AC ground is provided. Further conversion, regulation, reverse polarity protection (if required), load current limiting (if required), and distribution for the operation of all electronics within the DPM module, as well as for the operation of the body-worn signal conditioners and certain transducers, are to be provided within the DPM and/or in the body-worn DC/DC converters. In the PBDM station operational mode, the DPM chassis will be grounded through the AC power connector. The 28 v DC input line will be tied to an isolated signal ground and DPM internal signal lead routing should be connected to this line. In the remote operating mode, provisions will be made to interconnect the AC power line ground with the 28 v DC line.

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

4.1 Conceptual Design

4.1.1 Design Objectives. -

The Dynamic Physiological Monitor Subsystem will be designed to measure and display the majority of the FBB physiological data. The DPM subsystem will incorporate space-oriented equipment wherever practical and commercial equipment used will be selected primarily on the basis of compact size, principles of operation, and adaptability to space requirements.

4.1.2 Design Concept. -

The DPM subsystem consists of a portable processing/display module, six man-worn measurement systems, a blood pressure measurement system, and provisions for connections to a communication system. The measurement harnesses are to be worn one at a time with the exception of the neurological and monitoring harnesses which may be used simultaneously. The communication system is integral with all harnesses except the neurological.

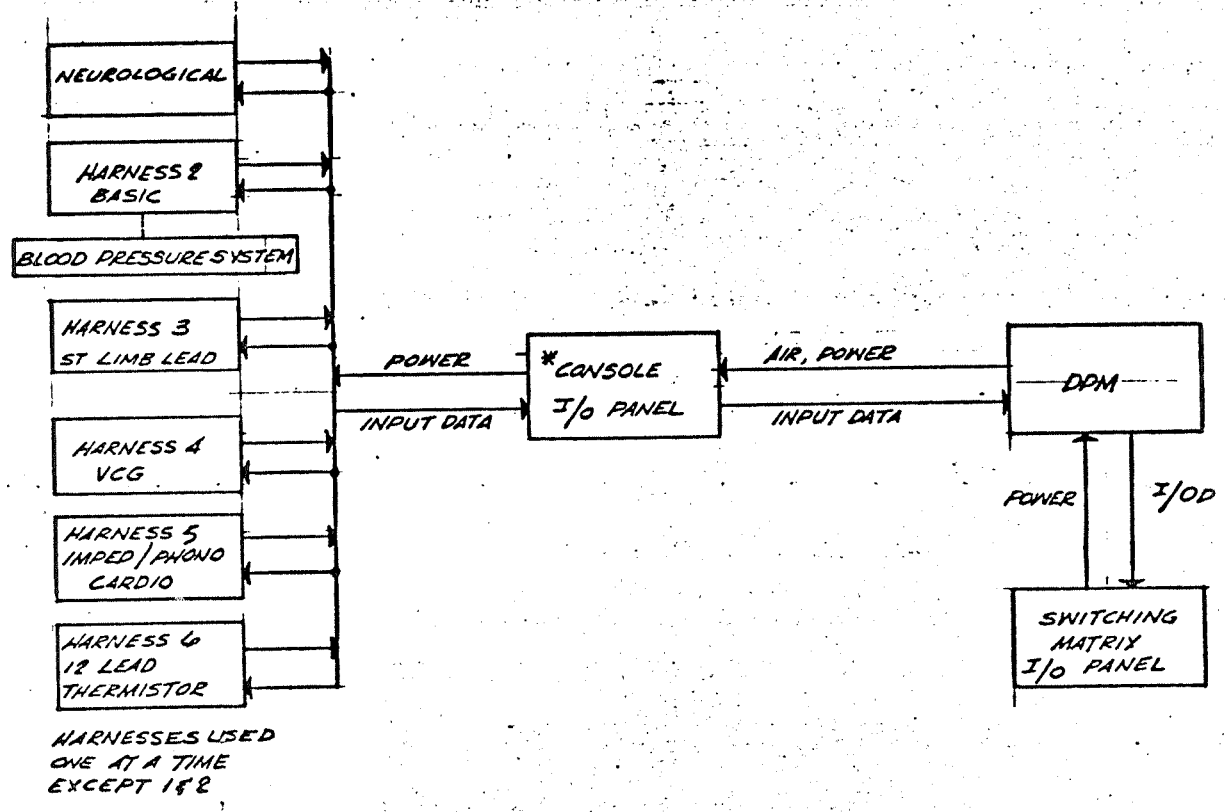
Signals are sent from variously configured body sensors, through conditioning modules (in most cases man-worn), to the DPM. The DPM will provide signal outputs to the DMS for further data handling.

4.2 Block Diagrams

4.2.1 Equipment Elements. -

The DPM Subsystem consists of; Electrodes, Sensors, Signal Conditioners, Body Vests, and Wiring Harnesses, Display and Controls, Calibration Scope, and Alarm System. The six vests and wiring harnesses are associated with the DPM for Neurological Measurements, General Monitoring, Clinical ECG, Vectorcardiogram, Average Skin Temperature, and Impedance Cardiogram. The general configuration of the vest and wiring harnesses will provide electrodes and transducers attachment to their appropriate location on the body. Umbilical cable assemblies will be provided to interface with the PBDM when the DPM is installed at the Station or directly to the DPM when it is used in a remote location.

Figure 3 illustrates the system equipment and the interrelationship between signal input, PBDM Station, DPM Display and Control Monitor, and the DMS. When in place in the PBDM console, the DPM receives all input data from the console I/O panel. Power is supplied to the measurement harnesses via the console I/O panel and DPM from the switching matrix I/O panel. The input data from the harnesses is received by the DPM from the console I/O panel, processed, and sent to Data Management via the switching matrix I/O panel for computation and/or display. In the remote mode the DPM is connected directly to the measurement harnesses via a 15 foot cable. There is no connection between the DPM and Data Management in this mode. All processing and display is handled within the DPM.



* NOT USED IN REMOTE OPERATION

SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 3. DYNAMIC PHYSIOLOGICAL MONITOR	
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-D-19
SUPV		APPD		SIZE B	SH OF
SYS ENGR		SPO/GSETD	CEI/FD NO. CONTR NO.		REV

Form LMSC 26208

4.2.1.1 System Operation. - The DPM has five basic functions, as illustrated in Figure 4; Meter Display, Scope Display, Alarm Transmittal, Signal Processing and Power Conversion. The buffer amplifiers receive the following signals for display on the DPM scope: EEG 1 & 2, EOG v & h, EMG, K Sound, Heart Sound, PWC, ZCG (Δ Z), ZPN, and ECG X, Y and Z.

The buffered PCG signal is fed through the Frequency Select Network and is divided into four frequency bands which are individually fed to the oscilloscope. The ZPN signal is routed to the pneumotachometer which drives the systolic and diastolic meters in the DPM. The pneumotachometer output also goes to the DMS. Suit pressure, flow/and partial CO_2 pressure signals are received from the DMS and sent directly to their respective display meters. The ZCG outputs are sent to the DMS unbuffered. The PWI computer receives the buffered PP and ECG signals. The PWI output goes to the DMS. The blood pressure regulator receives pneumatic input from the PBDM and transforms it into a pressure profile for the man-worn cuff. The ECG signals from the harness is routed via the ECG amplifier in the DPM to the cardiotachometer. The output of the cardiotach is displayed on the DPM scope and is also sent to the DMS.

The Korotkoff (K) sound signal is displayed on the DPM scope. It is also sent to the blood pressure processor. The blood pressure processor receives the amplified K sound signal and the cuff-mounted pressure transducer signal. The blood pressure processor outputs drive the diastolic and systolic meters and are also sent to the DMS. The alarm signals are received from the DMS and are routed through triggering circuits to the audio and visual alarm devices.

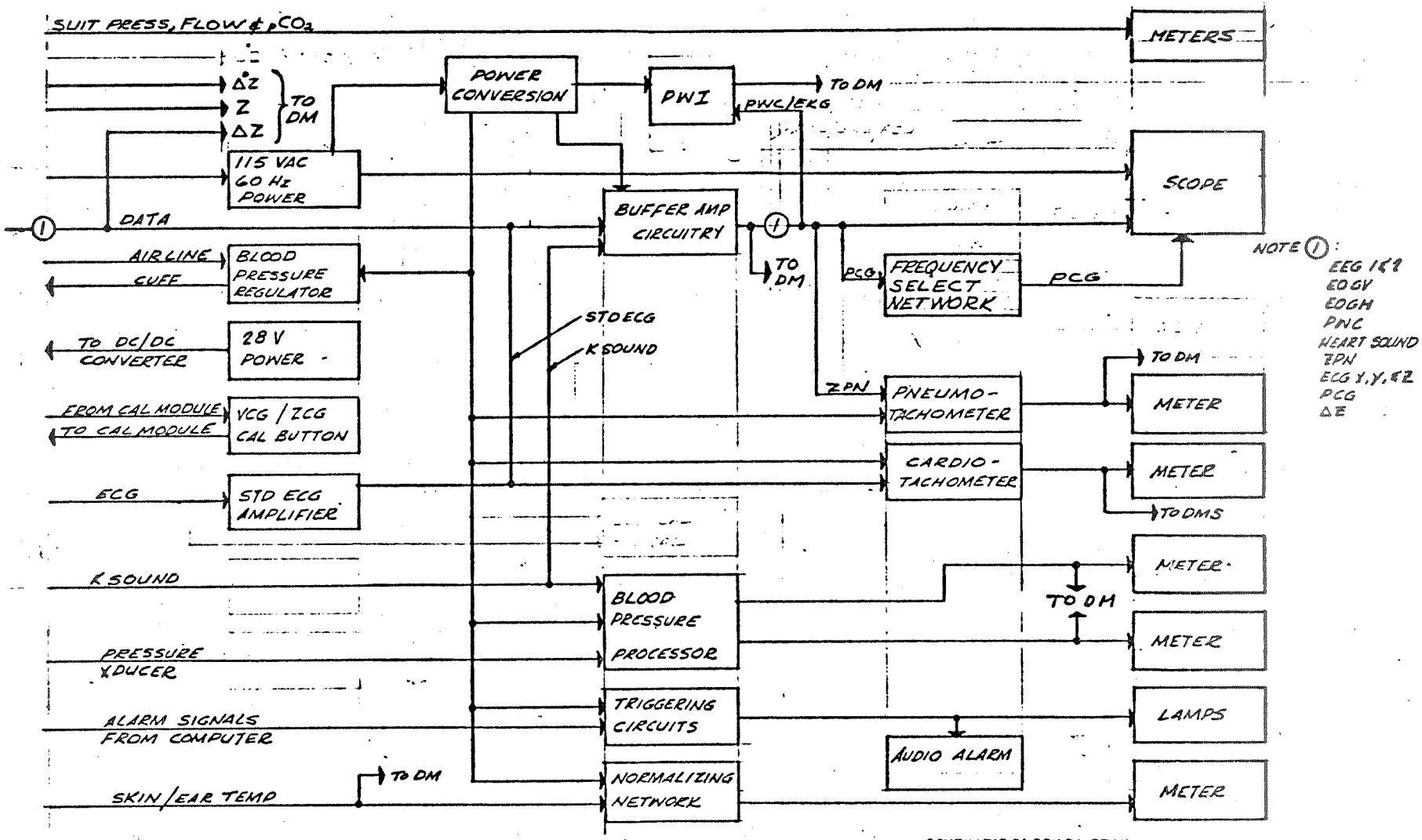
The average skin temperature and the ear canal temperature signals are routed to the normalizing network and then displayed alternately on the temperature meter. Both signals are also sent to the DMS unmodified.

When activated, the VCG/ZCG CAL button on the DPM front panel connects a 10 volt signal from the DC-DC converter in the measurement harness to the man-worn calibration module for activation of the calibration signal.

28 vdc and 115 vac 60 Hz are supplied to the DPM from the PBDM. The power conversion circuitry supplies isolated d.c. voltages as required by the DPM. The DPM scope operates on 115 vac.

28 vdc is supplied to the DC-DC converter No. 104689. 16.8 (nominal) vdc is derived from the 28 vdc and supplied to the DC-DC converter No. 104840.

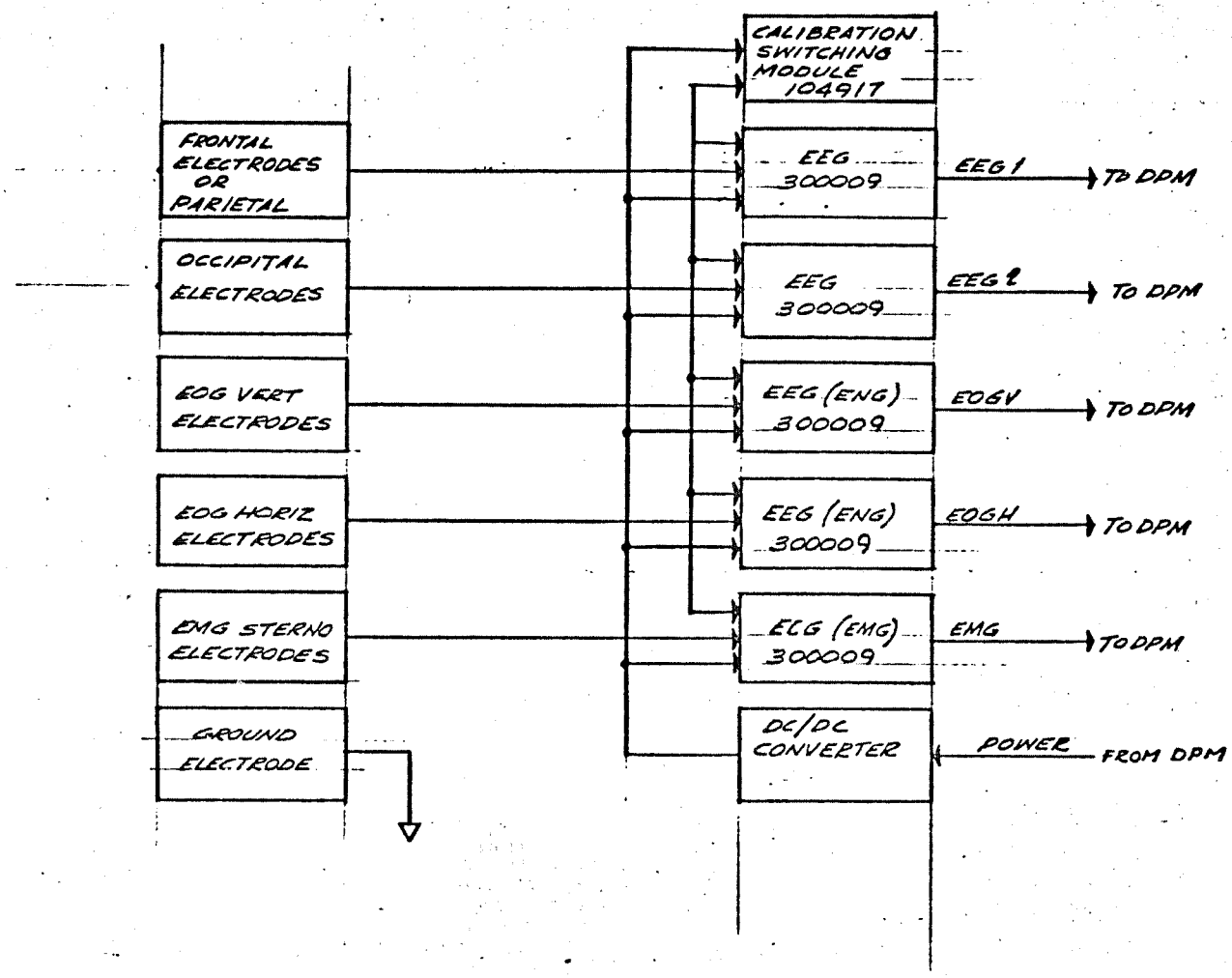
4.2.1.2 Neurological Harness. - The neurological harness shown in Figure 5 will be used for EEG, EOG and EMG. The signal conditioners, d.c. power and calibrate circuits are housed in a wall-mounted box connected to the subject by a three foot cable. The electrodes will be contained in a "cap" worn by the subject. This harness may be worn with the monitoring harness. Positioning of the electrodes is in accordance with the Ten-Twenty Electrode System. The following measurements constitute the neurological harness. Power for these measurements is derived from the DC-DC converter.



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 4. DPM SIGNAL DISTRIBUTION	
CHK		APPD		CODE IDENT NO. 1[illegible]	DOCUMENT NO. [illegible]III-D-21 / REV
SUPV		APPD		SIZE B	SH / OF /
SYS ENGR		SPO/GSETD	CEI/FD NO.	CONTR NO.	

Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 5. NEUROLOGICAL EARPESS #1	
CHK		APPD		CODE IDENT NO.	DOCUMENT NO. / REV
SUPV		APPD			
SYS ENGR		SPO/GSETD	CEI/FD NO. / CONTR NO.	SIZE B / SH / OF	III-D-22

Form LMSC 26208

- Electroencephalogram (EEG)

  The EEG measurement uses four active and one ground electrode located in accordance with the Ten-Twenty Electrode System and two EEG s/c's.

- Electro-Oculogram (EOG)

  The EOG measurement is taken with four active electrodes and one ground electrode located horizontally and vertically about the eyes. The signals are conditioned by two ENG s/c's.

- Electromyogram (EMG)

  An ECG s/c is used in conjunction with two active electrodes, located either on the sternocleidomastoideus or on the splenius, and one ground electrode.

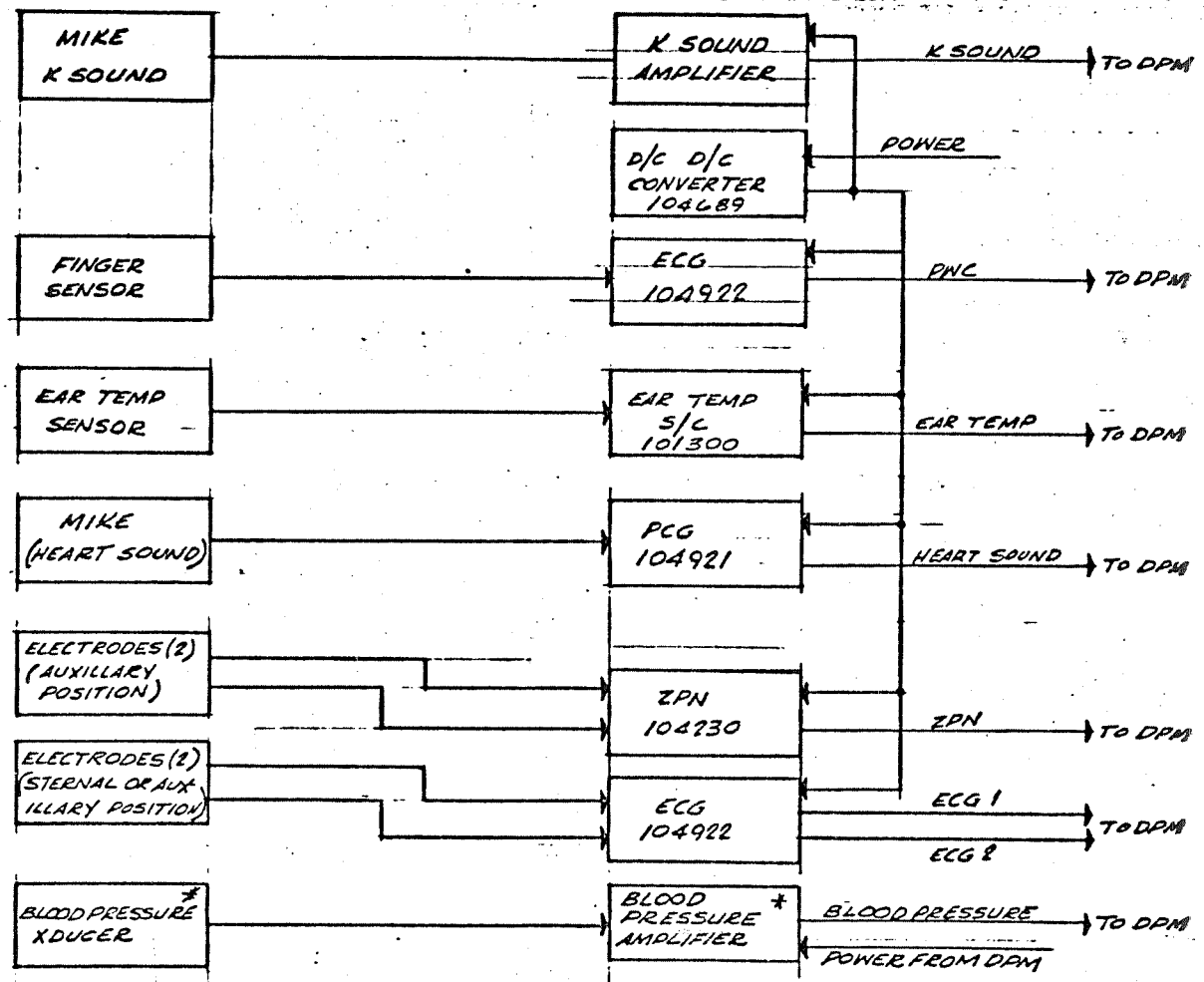
4.2.1.3 Basic Monitoring Harness. - Figure 6 shows the measurement sensors and signal conditioners. The arterial pulse wave shape is displayed on the DPM scope. The PWC sensor can be worn either on the left hand or the left foot. A man-worn amplifier is used in conjunction with the sensor. The PWC signal also is used to derive the PWI measurement. Body temperature is measured by an ear temperature sensor (LMSC) and conditioned by the man-worn ear temperature s/c. This signal is displayed on the temperature meter at the DPM. A three electrode configuration, one ground and two active, with an ECG s/c are used to record a single lead ECG, heart rate, and to compute pulse wave transit time. The Korotkoff microphone and s/c are used in conjunction with the servo-regulated cuff and programmer system to derive diastolic and systolic B.P. The waveforms derived from the Korotkoff sound microphone are displayed on the DPM scope. The DC-DC converter converts the 28 vdc input to a regulated $\pm$ 10 vdc and an unregulated 10 vdc required for actuation of the calibration signals.

4.2.1.4 Clinical ECG Measurement. - The clinical ECG, or standard limb lead harness, consists of four electrodes located on the extremities and one precordial suction cup electrode from which the 12 clinical ECG leads may be obtained. Signal conditioning is done in the DPM. (See Figure 7).

4.2.1.5 Vectorcardiogram. - This measurement, shown on Figure 8, consists of seven active electrodes and one ground electrode located as required by the Frank Lead System. Power is supplied by the DC-DC converter S.I. #104689 to the ECG X, Y, & Z s/c's and FLN s/c. Calibration is accomplished with the calibrate module via a pushbutton on the DPM front panel.

Signals from the electrodes are weighted in the FLN s/c. The weighted signals are amplified in the three ECG s/c's (X, Y, & Z).

The PCG measurement consists of a heart sound microphone, a PCG s/c and a frequency select switch at the DPM. The PCG measurement is part of the VCG, the monitoring and the impedance cardiogram harnesses.

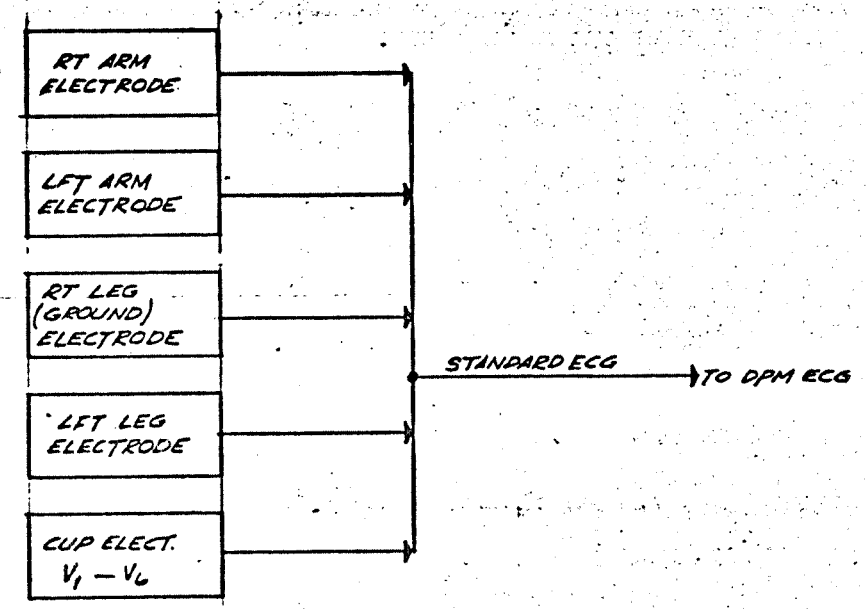


* MAY BE USED WITH ALL HARNESSES

SCHEMATIC BLOCK DIAGRAM

ORIGR DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 6. BASIC MONITORING HARNESS #2		
CHK	APPD		CODE IDENT NO. 1707	DOCUMENT NO. III-D-24	REV
SUPV	APPD				
SYS ENGR	SPO/GSETD	CEI/FD NO. / CONTR NO.	SIZE B	SH OF	

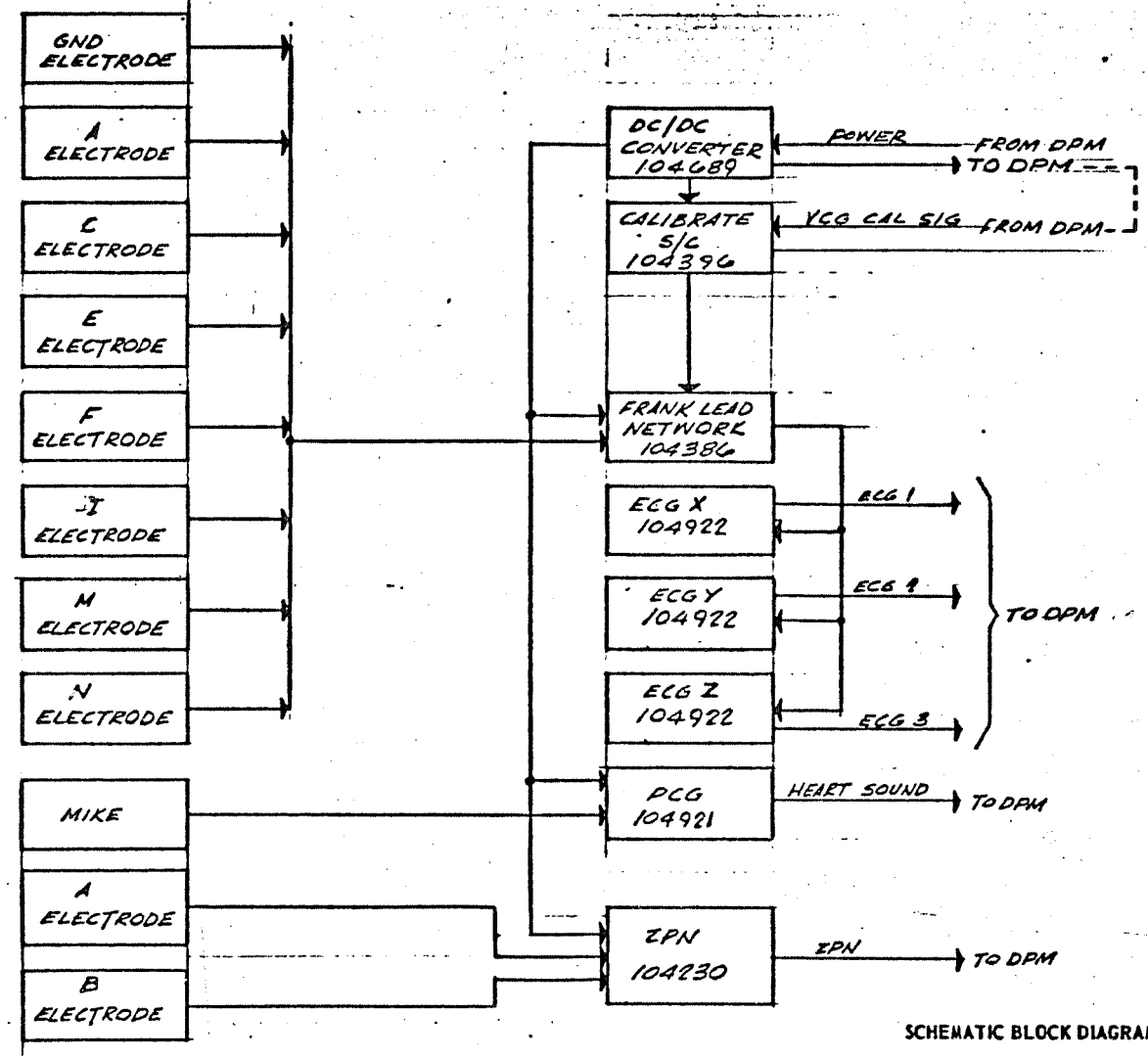
Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 7. STANDARD LIMB LEAD HARNESS #3	
CHK		APPD		CODE IDENT NO. 1'07	DOCUMENT NO. III-D-25
SUPV		APPD			REV
SYS ENGR		SPC/GSETD	CEI/FD NO. / CONTR NO.	SIZE B / SH / OF	

Form LMSC 26200



SCHEMATIC BLOCK DIAGRAM

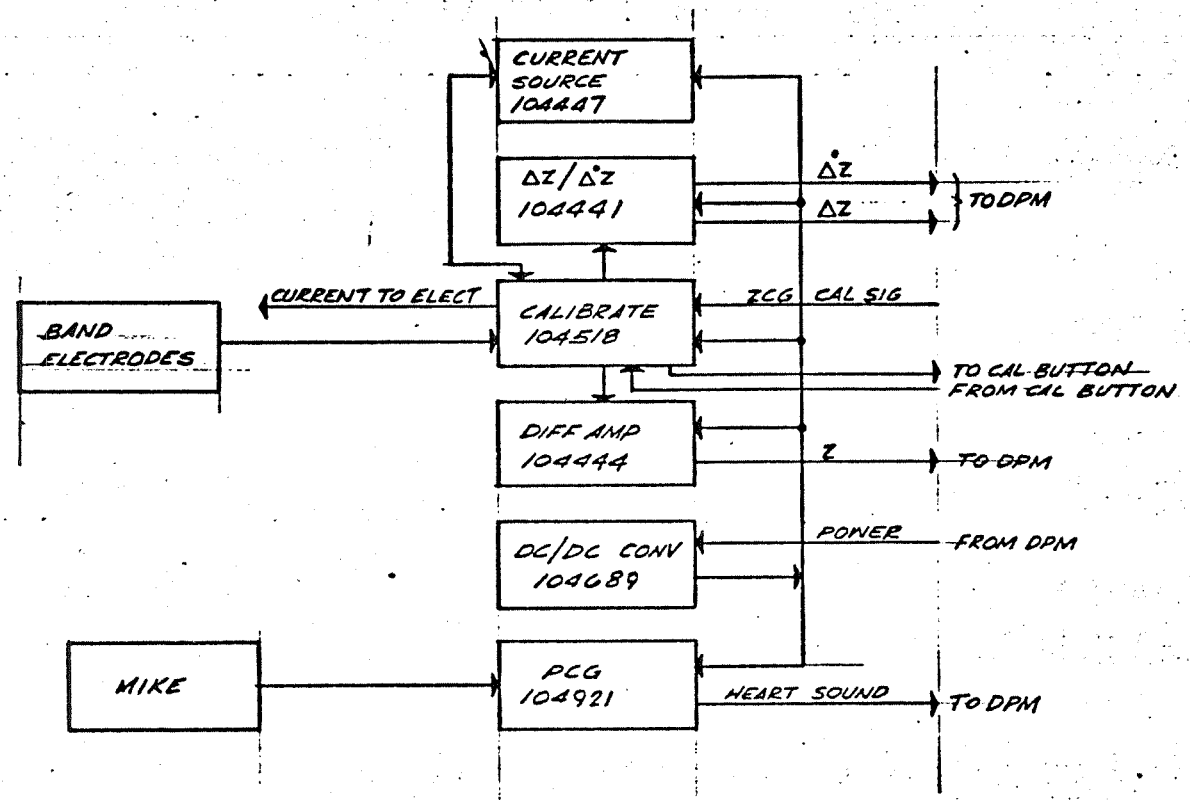
ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 8. VECTORCARDIOGRAM HARNESS #4	
CHK		APPD		CODE IDENT NO. 21707	DOCUMENT NO. III-D-26 / REV
SUPV		APPD			
SYS ENGR		SPO/GSETD	CEI/FD NO. / CONTR NO.	SIZE B / SH / OF	

Form LMSC 36208

A ZPN s/c and two electrodes are used to record respiratory waveform and derived respiration rate. The former will be displayed on the DPM scope and the latter on the DPM respiration rate meter. This measurement is also used with the monitoring system.

4.2.1.6 Impedance Cardiogram (ZCG). - The ZCG is derived from the outputs of two excitation and two sensing band electrodes. The ZCG measurement system shown in Figure 9 consists of the following s/c's: Current Source S.C., ΔZ, $\dot{\Delta} Z$, S.C., Calibrate S.C., Differential Amplifier and Detector, DC-DC Converter, and Phonocardiogram S.C. and Phonotransducer. Measurement of the transthoracic impedance is accomplished by detecting voltage changes which by virtue of the constant current are proportional to thoracic impedance changes.

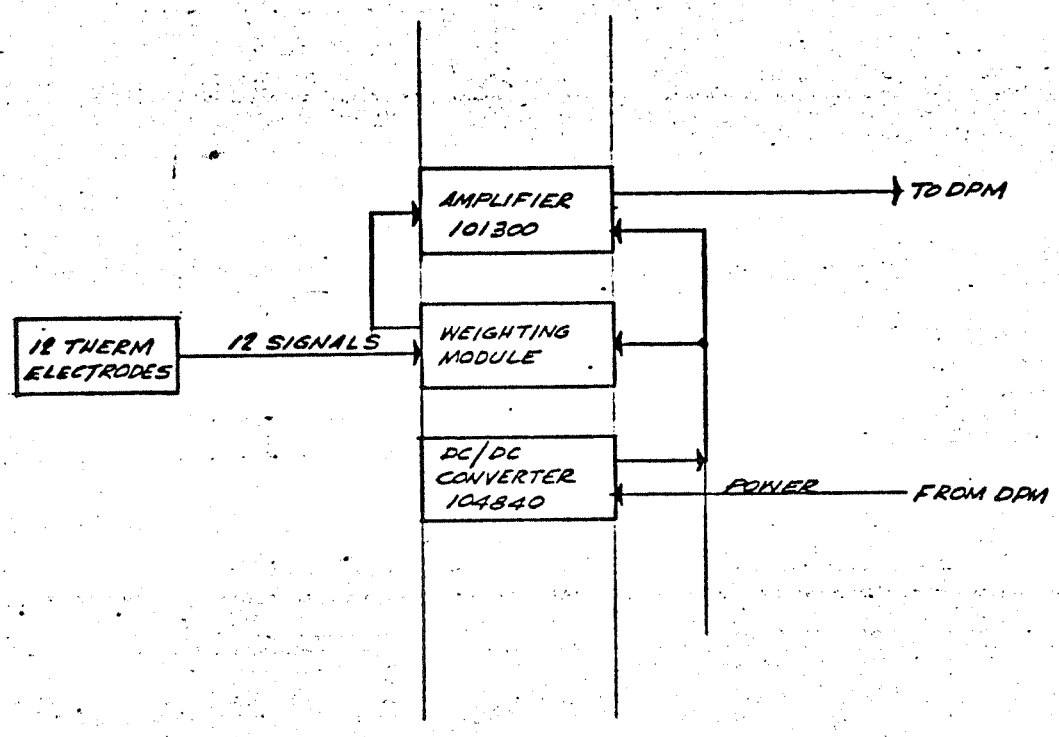
4.2.1.7 Average Skin Temperature. - The average skin temperature is derived from 12 thermistors located at 12 different positions on the body. These twelve signals as shown in Figure 10 are weighted in the weighting module, amplified, and the summation is sent to the DPM. A DC-DC converter Model #104840 is used in conjunction with this measurement system.



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 9. IMPEDANCE CARDIOGRAM : HARNESS #5	
CHK		APPD		CODE IDENT NO. 17071	DOCUMENT NO. III-D-28 / REV
SUPV		APPD		SIZE B / SH / OF	
SYS ENGR		SPO/GSETD	CEI/FD NO. / CONTR NO.		

Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 10. 12 LEAD THERMISTOR HARNESS	
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-D-29 / REV
SUPV		APPD			
SYS ENGR		SPO/GSETD	CEI/FD NO. / CONTR NO.	SIZE B / SH / OF	

Form LMSC 26208

SECTION III-D

APPENDIX

MEASUREMENT REQUIREMENTS DATA SHEETS

Measurement Requirements Data Sheets have been prepared for the 13 measurements included under the Dynamic Physiological Monitor Subsystem. Data includes input/output characteristics, and general data handling requirements.

Measurement	Page No.
EEG	III-D-2A
EOG	III-D-6A
EMG	III-D-9A
Clinical ECG	III-D-13A
VCG	III-D-17A
PCG/VbCG	III-D-21A
ZCG	III-D-24A
ZPN	III-D-29A
Pulse Wave Contour (PWC)	III-D-32A
Body (Ear Canal) Temperature	III-D-35A
Average Skin Temperature	III-D-38A
Reference ECG	III-D-41A
Arterial Blood Pressure	III-D-44A

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Neurological

MEASUREMENT : Electroencephalogram (EEG)

MEASUREMENT DESCRIPTION : Obtain two channels of EEG for sleep, level of consciousnes or clinical monitoring, using any two of the following elec trode combinations: F3 - T3, F3 - C3, P3 - O1, F4 - C4, C4 O2.

1. Input signal characteristics	Bi-phasic, random waveform, 0 - 200 microvolts peak-to-peak.
2. Electrodes, transducers, vest, harness	Four active and one common ground Ag - AgCl re-usea able electrodes with adjustable holding straps, or Adey-Kado electrodes plus bathing cap holding devi See location diagram III-D-5A
3. Signal conditioner(s)	Two EEG S/C; circuit board configuration.
4. Range of measurement	N/A
5. Frequency of measurement	Approx. once per 1 - 2 weeks.
6. Output signal characteristics	
analog/digital	Analog waveform
amplitude	0 - 5 volts
frequency range	0.2 - 100 Hz
accuracy/sensitivity	± 5 % of true waveform
7. Calibration	
type & technique	100 microvolts square wave pulse; manual.
frequency	At beginning and end of each run, and approximatel once per hour during run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, continuous on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, continuous.
manual/programmed A or D switching	Signal routing and lead identification programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	2500 bps.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	10 hours per subject. See # 13.

9. Derived quantities

other measurements required simultaneously for calculations	N/A
digital computation	N/A
display analog/digital; location; updating frequency	N/A
recording analog/digital	N/A
storage time analog/digital	N/A

10. Comparison with previous data N/A

11. Analog/digital display range & resolution/accuracy N/A

12. Printout frequency & other requirements N/A

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject, measurement, and load identification; calibration pulses, digitized waveform, calibration pulses.

For Lab. Verif. record analog on pen recorder.

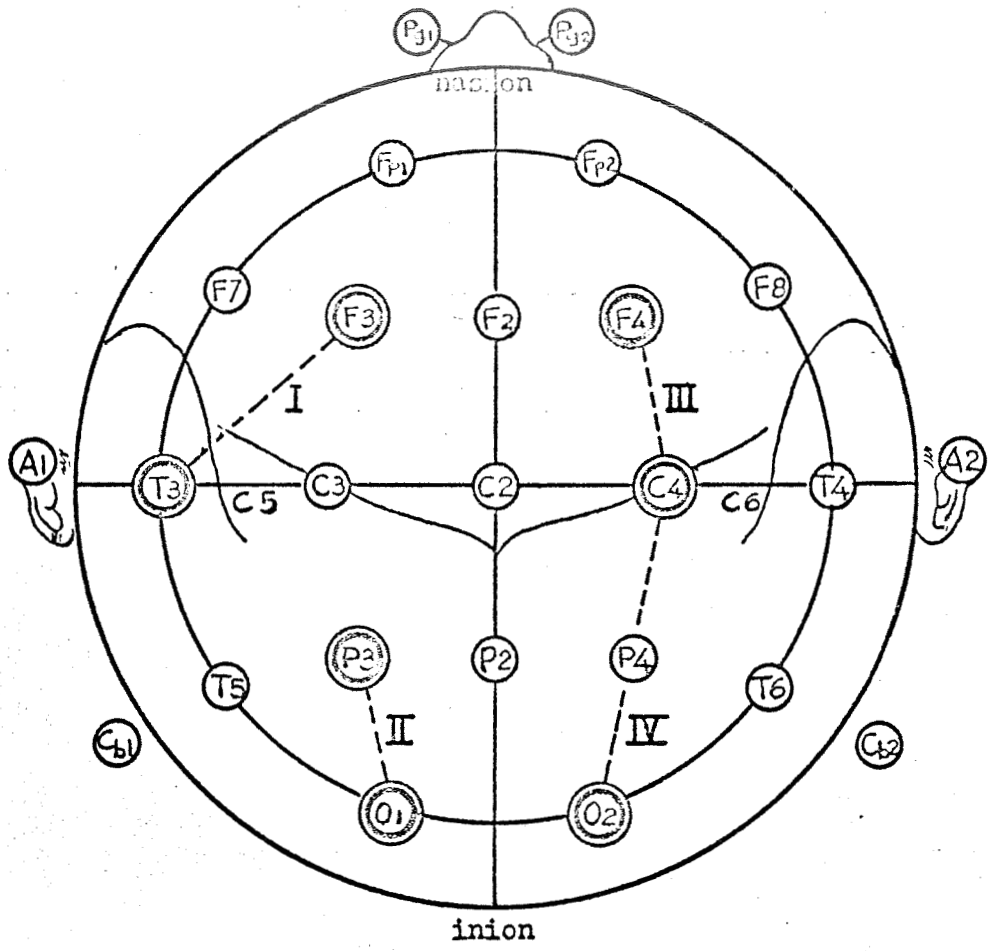
For sleep analysis the S/Cs are to be mounted in separate box, together with those for the ENG and EMG S/Cs, near head-end of bed or couch.

EEG, ENG, and EMG are to be recorded simultaneously when used for sleep analysis.

The designation of the EEG electrode positions is in accordance with the Ten-Twenty-Electrode System of the International Federation (of Electro-Encephalographers).

Parallel S/C input terminals are required on the box for external calibration by mens of the portable Calibration Unit.

THE TEN-TWENTY ELECTRODE SYSTEM OF THE INTERNATIONAL FEDERATION



A single plane projection of the head, showing all standard positions for EEG electrodes and the location of the Rolandic and Sylvian fissures. The outer circle was drawn at the level of the nasion and inion. The inner circle represents the temporal line of electrodes. The doubly circled electrodes are those most likely to be used for EEG sleep analysis. Position C_3 may be used instead of T_3.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Neurological

MEASUREMENT : Electro-Oculogram (EOG)

MEASUREMENT DESCRIPTION : Obtain horizontal and vertical EOG during EEG sleep analysis for rapid eye movement (REM) recording.

1. Input signal characteristics	Bi-phasic, random waveform, 0 - 100 microvolts peak-to-peak.
2. Electrodes, transducers, vest, harness	Four active and one common ground Ag - AgCl reuseable electrodes. A light-weight face mask may be required to prevent dislodging the electrodes. Electrodes are placed at outer canthi of both eyes, and above and below the left eye; ground electrode on forehead.
3. Signal conditioner(s)	Two EOG S/C; circuit board configuration.
4. Range of measurement	N/A
5. Frequency of measurement	Approx. once per 1 - 2 weeks.
6. Output signal characteristics	
analog/digital	Analog waveform. See # 13.
amplitude	0 - 5 volts
frequency range	0.2 - 100 Hz
accuracy/sensitivity	No waveform analysis required. See # 13.
7. Calibration	
type & technique	100 microvolt square wave pulse; manual.
frequency	At beginning and end of each run, and approx. once per hour during run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, continuous on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, continuous.
manual/programmed A or D switching	Signal routing and lead identification programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	2500 bps.
storage time analog/digital	Digitized, till next data dump.
recording/storage quantity per subject	10 hours per subject. See # 13.

9. Derived quantities

other measurements required simultaneously for calculations	N/A
digital computation	N/A
display analog/digital; location; updating frequency	N/A
recording analog/digital	N/A
storage time analog/digital	N/A

10. Comparison with previous data N/A

11. Analog/digital display range & resolution/accuracy N/A

12. Printout frequency & other requirements N/A

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: same as for EEG.

For Lab. Verif. record analog on pen recorder.

For sleep analysis S/Cs are to be mounted in separate box, together with those for the EEG and the nuchal EMG, near head-end of bed or couch.

ENG, EEG, and EMG are to be recorded simultaneously.

Parallel S/C input terminals are required on the box for external calibration by means of the portable Calibration Unit.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Neurological

MEASUREMENT : Electromyogram (Nuchal EMG)

MEASUREMENT DESCRIPTION : Obtain one channel of neck muscle EMG from Sternocleido-mastoideus or Splenius capitis during EEG sleep analysis for recording of gross body movement and restlessness during sleep.

1. Input signal characteristics — Bi-phasic, random waveform, 0 - 1000 microvolts. peak-to-peak.

2. Electrodes, transducers, vest, harness — Two active and one ground AG - AgCl re-useable or disposable electrodes. See location diagram III-D-12

3. Signal conditioner(s) — One EMG S/C; circuit board configuration.

4. Range of measurement — N/A

5. Frequency of measurement — Approx. once per 1 - 2 weeks.

6. Output signal characteristics

analog/digital	Analog waveform. See # 13.
amplitude	0 - 5 volts
frequency range	0.2 - ~~100 Hz~~ 1000
accuracy/sensitivity	No waveform analysis required. See # 13.

7. Calibration

type & technique	1 millivolt square wave pulse, manual.
frequency	At beginning and end of each run, and approx. once per hour during run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, continuous on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, continuous.
manual/programmed A or D switching	Signal routing and lead identification programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	~~2500 bps.~~ Should be 5000 bps Samples/S
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	10 hours per subject. See # 13.

9. Derived quantities

other measurements required simultaneously for calculations	N/A
digital computation	N/A
display analog/digital; location; updating frequency	N/A
recording analog/digital	N/A
storage time analog/digital	N/A

8 bits/sec

Sample/sec

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	N/A
12. Printout frequency & other requirements	N/A

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: same as for EEG.

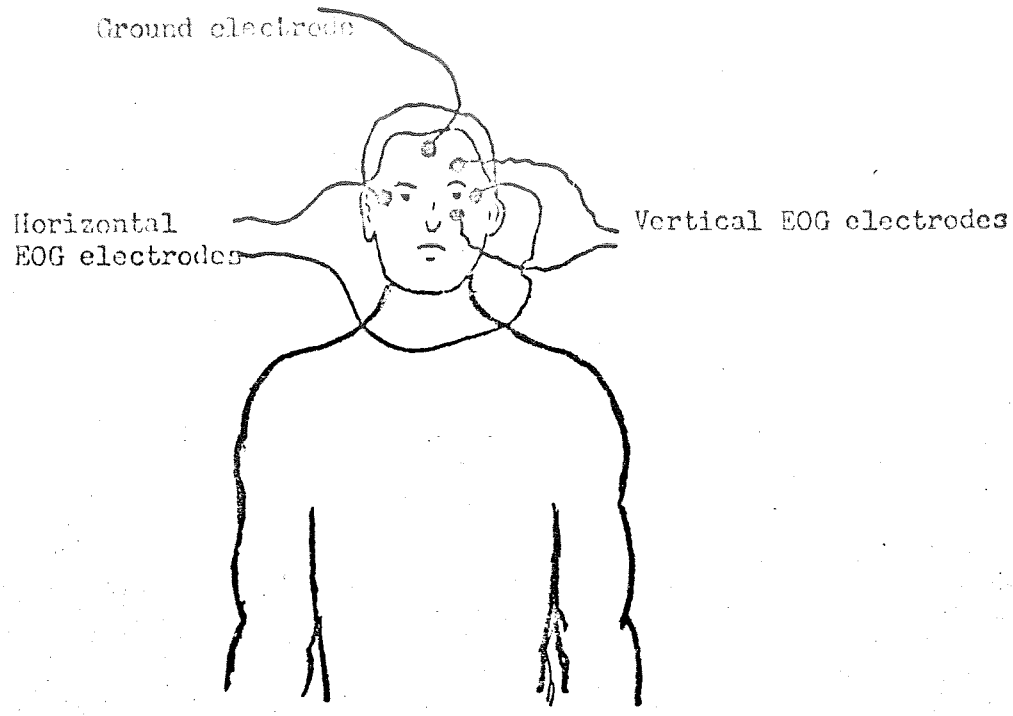
For Lab. Verif. record analog on pen recorder.

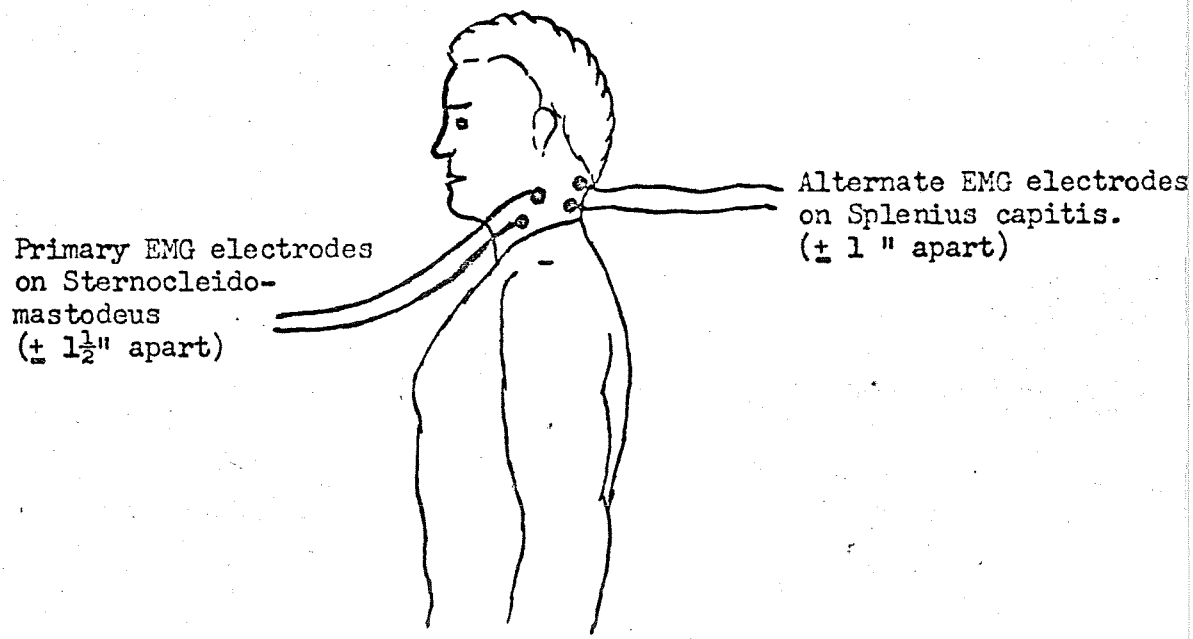
For sleep analysis S/Cs are to be mounted in separate box, together with those for the EEG and the ENG, near head-end of bed or couch.

EMG, EEG, and ENG are to be recorded simultaneously.

Parallel S/C input terminals are required on the box for external calibration by means of the portable Calibration Unit.

EOG AND EMG ELECTRODES LOCATIONS





MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Clinical Electrocardiogram

MEASUREMENT DESCRIPTION : Obtain the twelve clinical ECG leads in sequential order, properly identified as I, II, III AVR, AVL, AVF, V1, V2, V3, V4, V5, and V6.

1. Input signal characteristics — Bi-phasic, repetitive waveform, 0 - 3 millivolts.

2. Electrodes, transducers, vest, harness — Four reuseable or disposable extremity electrodes, one moveable and reuseable precordial suction cup electrode. See location diagram III-D-16A. Requires a separate vest/harness without S/Cs.

3. Signal conditioner(s) — One ECG S/C, circuit board configuration, located within the DPM. Multi-deck, 9-position selector switch required.

4. Range of measurement — N/A.

5. Frequency of measurement — Approx. once per week.

6. Output signal characteristics

analog/digital	Analog waveform.
amplitude	0 - 5 volts.
frequency range	0.1 - 100 Hz.
accuracy/sensitivity	± 5 % of true waveform.

7. Calibration

type & technique	1 millivolt squarewave pulses; manual pushbutton c DPM.
frequency	At beginning and end of each run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, cont. on DPM; Raw, analog, cont. on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, 10 seconds per lead.
manual/programmed A or D switching	Signal routing and lead identification programmed; lead switching manual at DPM.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	400 sps.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	2 - 3 minutes total for all leads.

9. Derived quantities

other measurements required simultaneously for calculations	N/A. Instantaneous heart rate will be derived in DP and will be displayed on analog meter on front pane
digital computation	Average heart rate after each digitized waveform.
display analog/digital; location; updating frequency	Instantaneous heart rate - analog meter on DPM; Average heart rate during recording of each lead on Processor Readout. No updating required.
recording analog/digital	Average heart rate at end of each run.
storage time analog/digital	Digitized till next data dump.

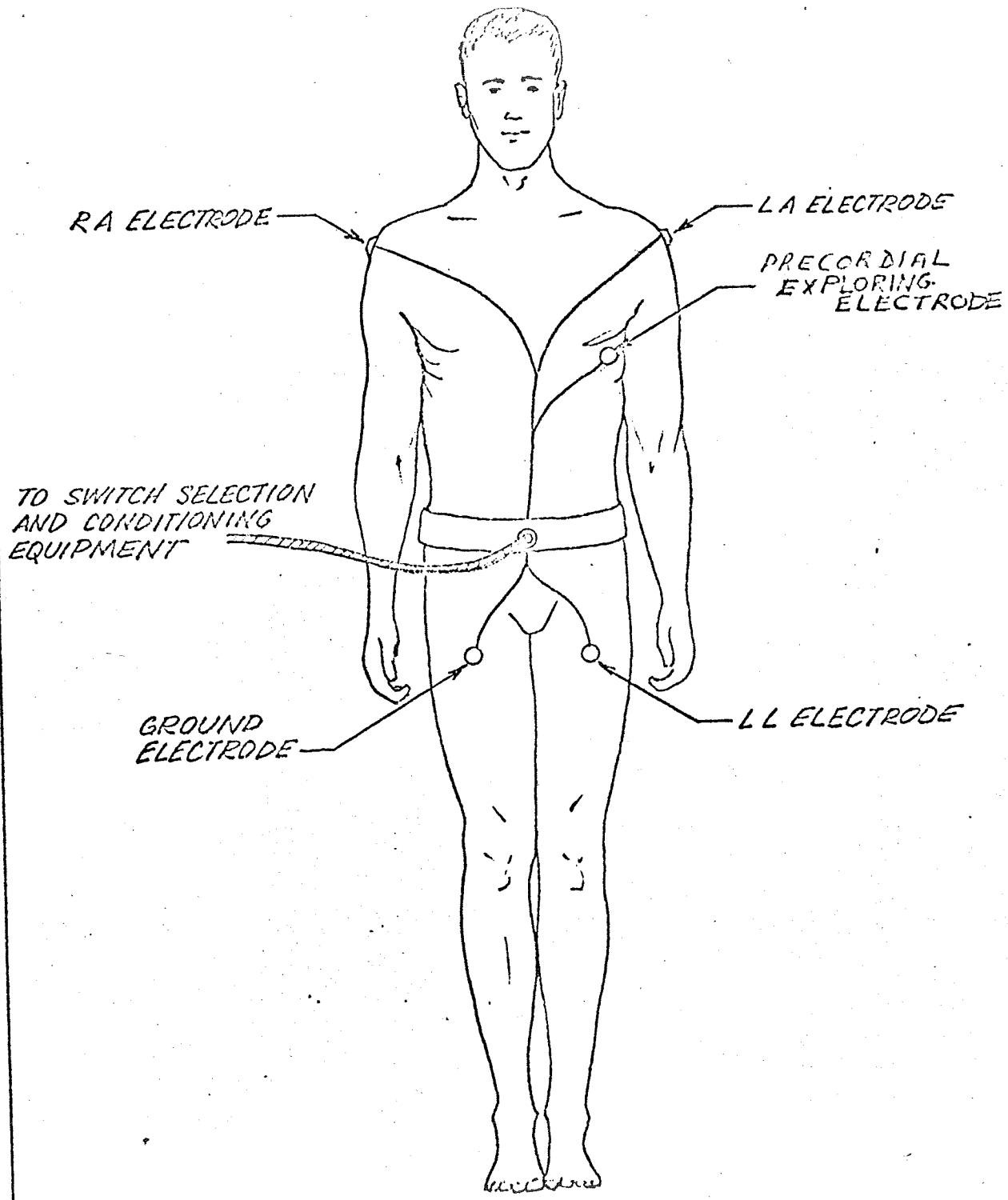
10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Analog: 50 - 200 bpm, 5 bpm resolution. Digital: 50 - 200 bpm, ± 2 bpm.
12. Printout frequency & other requirements	Average heart rate at end of each recorded lead.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject, measurement, and lead ident., digitized waveform, calibration, heart rate.

For Lab. Verif. record analog on pen recorder, and record on FM tape recorder.

Calibration unit inside DPM with pushbutton on front panel.



STANDARD LIMB LEAD HARNESS

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Vectorcardiogram (VCG)

MEASUREMENT DESCRIPTION : Obtain the three-orthogonal components of the human equivalent dipole, using the Frank lead system and resistor network.

1. Input signal characteristics	Bi-phasic, repetitive waveform, 0 - 3 millivolts.
2. Electrodes, transducers, vest, harness	Seven active and one ground electrodes, reuseable or disposable with vest and wiring harness. Eight lead subject cable. See electrode location diagram III-D-20A and Item 13. Requires a separate vest/harness, which also contains provisions for PCG/VbCG and ZPN.
3. Signal conditioner(s)	Three ECG S/Cs, Spacelabs Model 600 or later model; Frank resistor network; Calibration Unit.
4. Range of measurement	N/A
5. Frequency of measurement	Approx. once per 1 - 2 weeks.
6. Output signal characteristics	
analog/digital	Analog waveform.
amplitude	0 - 5 volts.
frequency range	0.1 - 100 Hz. Low frequency response as low as practical.
accuracy/sensitivity	± 1 % of true waveform.
7. Calibration	
type & technique	1 millivolt squarewave pulse; manual pushbutton on DPM remotely activates body-worn cal. unit.
frequency	At beginning and end of each run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, continuous on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, three leads (V_x, V_y, and V_z) simultaneously for approx. 10 seconds per recording.
manual/programmed A or D switching	Signal routing and lead identification programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	400 sps.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Approx. 30 seconds total per recording; may be repeated several times during exercise or LBNP exposure.

9. Derived quantities

other measurements required simultaneously for calculations	N/A. Instantaneous heart rate will be derived in DPM, and will be displayed on front panel meter.
digital computation	Average heart rate during each preceeding recordi
display analog/digital; location; updating frequency	Instantaneous heart rate - analog meter on DPM; Average heart rate during preceeding recording on Processor Readout.
recording analog/digital	Digitized average heart rate at end of each recording.
storage time analog/digital	Digitized till next data dump.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Analog: 50 - 200 bpm, 5 bpm resolution. Digital: 50 - 200 bpm, ± 2 bpm.
12. Printout frequency & other requirements	Average heart rate at end of each recording.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: Subject, measurement, and lead identification; calibration pulses, digitized waveform, calibration pulses, average heart rate.

For Lab. Verif. record the four signals simultaneously on pen and FM recorders.

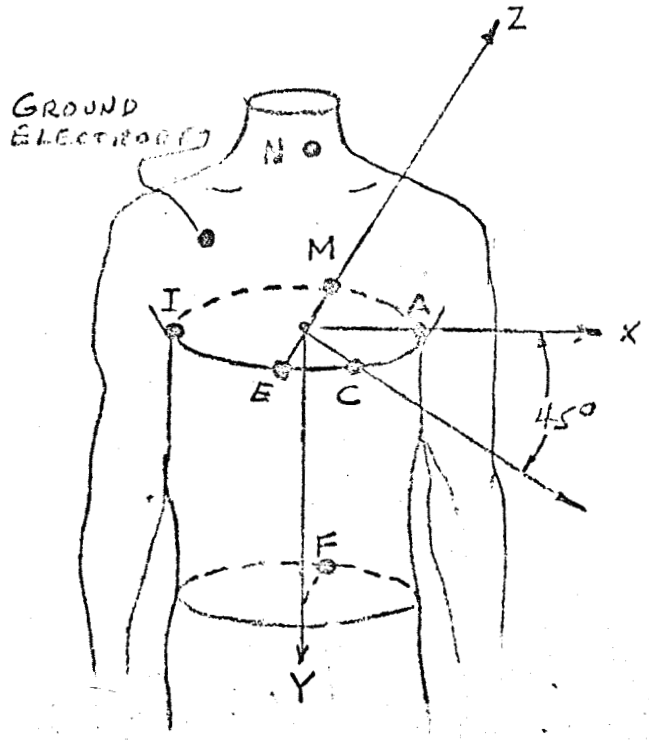
For measurement accuracy, repeatability, and convenience a VCG vest and wiring harness, adjustable to idividual body measurements of the crewmembers is required.

For on-ground analysis of the VCG, the time-base expansion technique of W. R. Peters and R. E. Cole (SAM-TR-65-87) is recommended.

Provisions must be included to activate the body-worn Calibration Unit of this vest/harness combination remotely from the front panel of the DPM.

DPM will contain electronics to derive instantaneous heart rate for display on front panel meter. Variable time constants of 5 and of 15 seconds will be provided to smooth out rapid heart rate fluctuations.

Prepared	NAME	DATE	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION	Page	TEMP	PERM
Checked			TITLE VCG VEST & WIRING HARNESS	Model		
Approved				Report No		



Electrode Placement

N - On the back of the neck.

E - At the fifth interspace transverse level at the front midline.

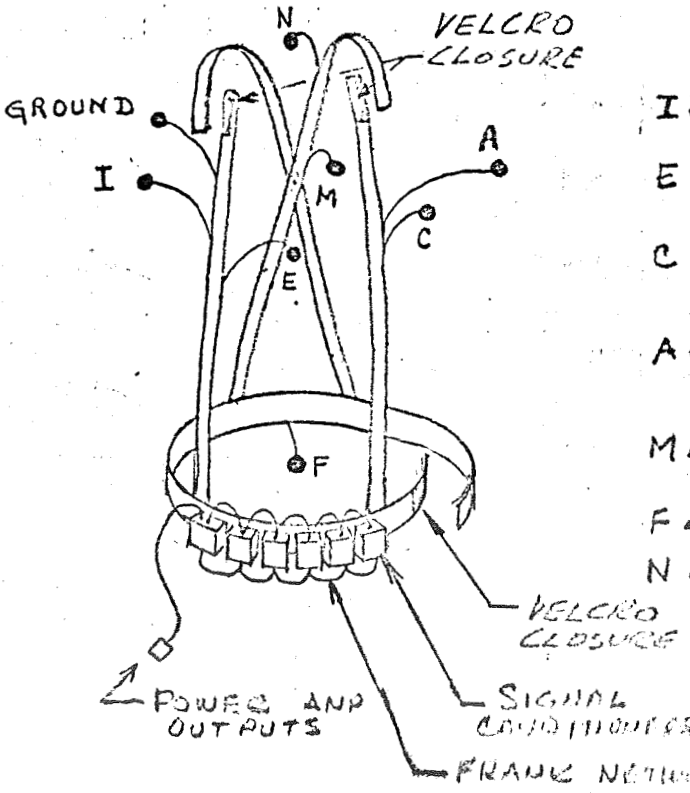
M - At the back midline at the same level as E.

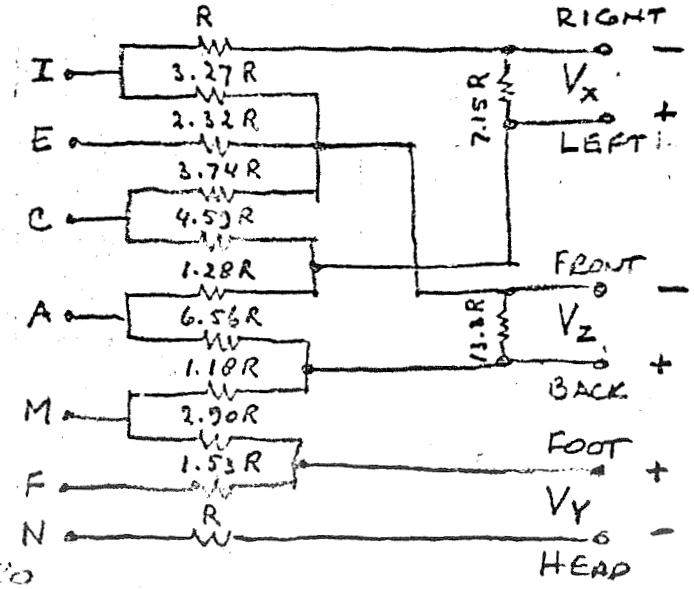
I - At the right midaxillary line at the same level as E and M.

A - At the left midaxillary line at the same level as E, M, and I.

C - Between front midline and left midaxillary line at 45° and at the same level as E, M, I, and A.

F - At the lower back midline





FRANK RESISTOR NETWORK
$R \geq 50{,}000\ \Omega$.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Phono / Vibrocardiogram (PCG/VbCG)

MEASUREMENT DESCRIPTION : Recording of heart sounds and thoracic wall vibrations by means of a precordial microphone with very low frequency response.

1. Input signal characteristics	Sonic and sub-sonic random waveforms; 0 - 5 millivolts.
2. Electrodes, transducers, vest, harness	Industrial Scientific Research Corp. P/N-1039 or Bionix DC to 1000 Hz heart sound microphone. This measurement is included in the Monitoring, the VCG, and the ZCG vest/harness.
3. Signal conditioner(s)	Spacelabs Model 602 or equivalent, with modified frequency response.
4. Range of measurement	N/A.
5. Frequency of measurement	Once to twice a week.
6. Output signal characteristics	
analog/digital	Analog.
amplitude	0 - 5 volts.
frequency range	0.1 - 20 Hz; 10 - 30 Hz; 30 - 500 Hz; 0.1 - 1000 Hz to be provided with frequency selector switch.
accuracy/sensitivity	± 5 % of true waveform.
7. Calibration	
type & technique	1 millivolt; manual.
frequency	At beginning and end of each measurement.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, intermittent on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, continuous; switching to a different frequency passband every ten seconds.
manual/programmed A or D switching	Signal routing and frequency identification programmed; manual frequency band switching on DPM.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	2500 sps. Should be 5000
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	From 1 to 20 minutes.

9. Derived quantities

other measurements required simultaneously for calculations	Reference ECG to be recorded simultaneously. No quantities are to be derived on board.
digital computation	N/A.
display analog/digital; location; updating frequency	N/A.
recording analog/digital	N/A.
storage time analog/digital	N/A.

10. Comparison with previous data — N/A.

11. Analog/digital display range & resolution/accuracy — N/A.

12. Printout frequency & other requirements — N/A.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject, measurement, and frequency band identification; calibration pulse train, digitized waveform, calibration pulse train.

For Lab. Verif. record each of the four frequencies, together with the reference ECG, sequentially on pen recorder.

The PCG/VbCG measurement is to be included in the monitoring vest/harness, the VCG vest/harness, and the ZCG vest/harness.

Frequencies below approximately 1 Hz cannot be accurately recorded with currently available precordial microphones. The Bionix microphone is claimed to have a low frequency responce down to DC.

The frequency selector switch must be located on the front panel of the DPM.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular.

MEASUREMENT : Impedance Cardiogram (ZCG)

MEASUREMENT DESCRIPTION : Recording of pulmonary stroke volume from transthoracic impedance changes , using the Kubicek method.

1. Input signal characteristics	Bi-phasic, repetitive waveform . Amplitude will depend on RF signal amplitude, which has not yet been determined.
2. Electrodes, transducers, vest, harness	Two excitation and two sensing band-electrodes of flexible material. See electrode location diagram III-D-28A. This measurement requires a separate vest/harness, which also contains provisions for the PCG/VbCG.
3. Signal conditioner(s)	One Spacelabs ZCG S/C, consisting of a current source, a differential amplifier/detector, a ΔZ & $\Delta \dot{Z}$ amplifier, and a calibration module.
4. Range of measurement	2 to 25 liters/minute. See further Item 13.
5. Frequency of measurement	Once per 1 - 2 weeks.
6. Output signal characteristics	
analog/digital	Analog (See further Item 13).
amplitude	0 - 5 volts.
frequency range	0.1 - 40 Hz.
accuracy/sensitivity	± 2 % of true waveform. (See further Item 13).
7. Calibration	
type & technique	See item 13.
frequency	At beginning and end of each measurement.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Waveform: raw, analog, continuous on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Waveform: raw, digitized, continuous; approx. 10 seconds.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100 sps. 3
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Approx. 30 seconds, including derived values.

9. Derived quantities

other measurements required simultaneously for calculations	Phonocardiogram to measure duration of systole (time between 1st and 2nd heart sound).
digital computation	$\lvert\bar{Z}\rvert$, $\Delta\lvert Z\rvert$, and $\lvert\dot{Z}\rvert$.
display analog/digital; location; updating frequency	Digital display of derived values on digital readou If used during exercise: every minute.
recording analog/digital	Digital values every minute.
storage time analog/digital	Digitized till next data dump.

10. Comparison with previous data	If used during exercise, previously obtained values should be available in printed form.
11. Analog/digital display range & resolution/accuracy	Digital; $\lvert\bar{Z}\rvert$ - 10 to 40 Ohms; $\Delta\lvert Z\rvert$ - $\pm$ 0.25 Ohms; $\lvert\dot{Z}\rvert$ - +3 to - 7 Ohms/second. Accuracy: $\pm$ 3 %; $\pm$ 3 %; and $\pm$ 4 % respectively.
12. Printout frequency & other requirements	Once every minute.

13. Miscellaneous information, details on referenced items, etc.
Recording sequence: Subject and measurement identification; calibration pulsetrain, digitized waveform, calibration pulsetrain.

For Lab. Verif. the ZCG waveform and the PCG/VbCG waveform have to be recorded simultaneously on pen recorder.

The ZCG vest/harness must include provisions for the PCG/VbCG, which must be recorded simultaneously for computation.

Cardiac Output (CO) must be read out in digital form in liters/minute.

COMPUTATIONS.

<u>1st Method.</u> Estimated Cardiac Output = ΔV x Heart Rate (HR)

$$\Delta V = \rho \frac{L^2}{Z_0^2} \Delta Z$$

ΔV = ventricular stroke volume in ml.
ρ = the electrical resistivity of whole blood at 100 KHz (average value = 150 Ohms/cm).
L = the mean distance between the two sensing electrodes in cm.
Z_0 = the basic impedance between the two sensing electrodes (ohms).
ΔZ = extrapolated maximum impedance change during systole (ohms).
$\dot{Z}$ = maximum negative peak of the 1st derivative of Z.

ΔZ was originally determined graphically by extrapolating the maximum decreasing slope of the impedance change waveform from the base of the curve at the start of the systole to the end of the right ventricular systole, as indicated by the 2nd heart sound. (See figures). To reduce the error in calculating ΔZ, the maximum decreasing slope of the impedance change during systole was determined from the maximum negative peak of the 1st derivative ($\dot{Z}$). The time interval, τ, as shown in Fig. 3 was used to indicate right ventricular ejection time. The time, τ, was measured from the zero-crossing or inflection point of the first derivative, to the maximum negative peak of the 1st derivative in the region of the 2nd heart sound. The product of the maximum negative peak of the 1st derivative and τ was used for the value of ΔZ.

(Kubicek et al.: "Development and Evaluation of an Impedance Cardiac Output System", 37th Meeting Aerospace Medical Assn.)

<u>2nd Method.</u> Estimated Cardiac Output = ΔV x HR

ΔV = ventricular stroke volume in ml.

$$= \frac{\Delta Z}{Z_0} V.$$

ΔZ = extrapolated maximum impedance change during systole.
Z_0 = basic impedance between the two sensing electrodes (Ohms).
V = thoracic volume (liters)

$$= \frac{(\text{thoracic perimeter})^2}{4\pi} \times \text{average sensing electrode separation (cm).}$$

<u>NOTE</u>: The values Z_0, ΔZ, and $\dot{Z}$ should be provided by the signal conditioner.

13. Miscellaneous information, details on referenced items, etc. (Continued)

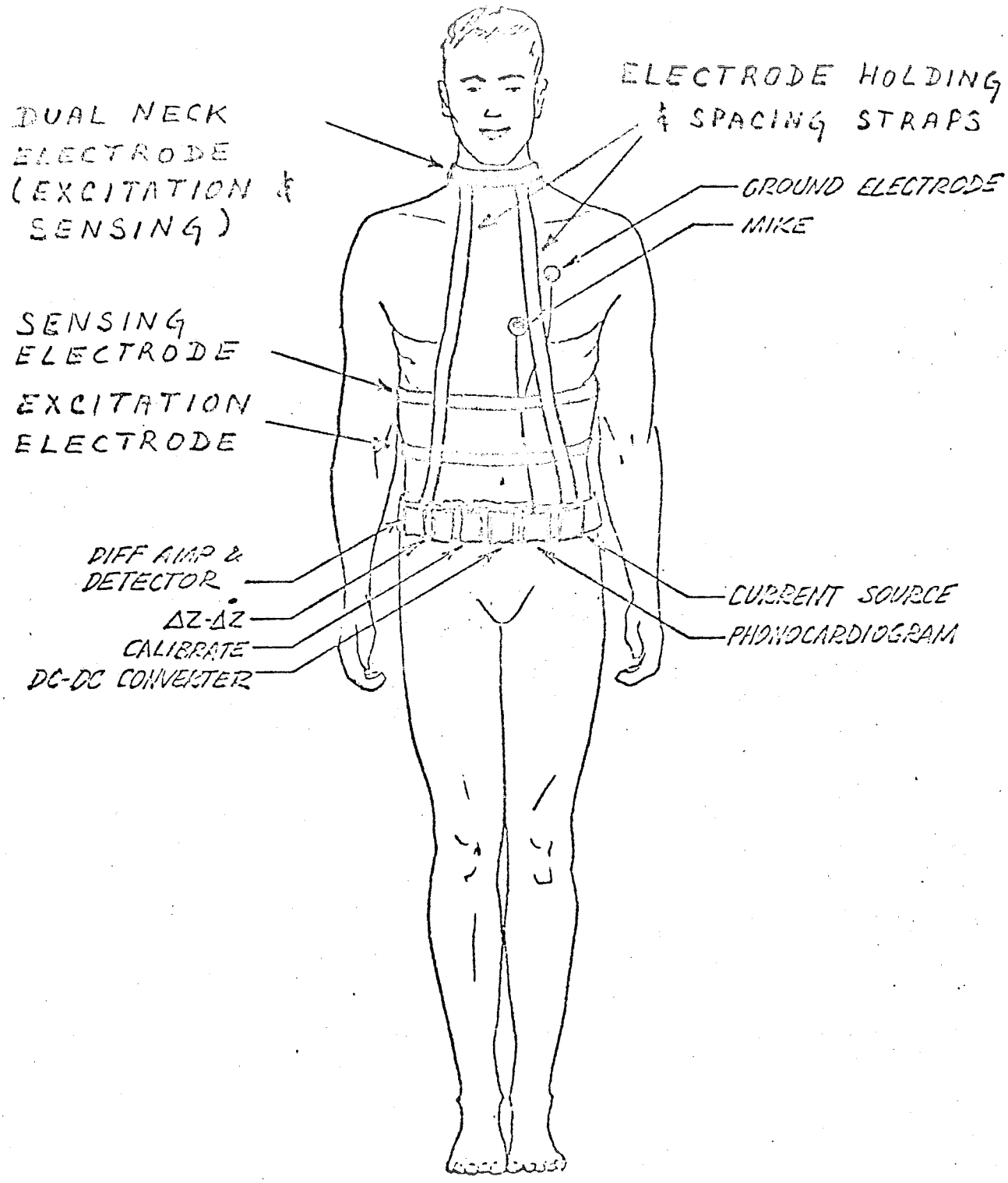
CALIBRATION.

Contacts shall be provided on the output connector, which, when shorted, will initiate a five second (± 20 %), ± 1 % two-point calibration on

$$|Z|, |\Delta Z|, \text{ and } |\Delta \dot{Z}|.$$

$|Z_0|$ shall be calibrated by the automatic alternate switching of two precision calibration resistors in place of the thoracic impedance.

The $|\Delta Z|$ and $|\Delta \dot{Z}|$ amplifiers shall be calibrated at the same time as the $|Z_0|$ calibration, by switching their inputs from the output of the detector (Z output) to the output of a calibration generator. The output of the calibration generator shall contain amplitude information for calibrating the $|\Delta Z|$ amplifier at two points, and slope information for calibrating the $|\Delta \dot{Z}|$ amplifier at two points.



IMPEDANCE CARDIOGRAPH-PHONOCARDIOGRAM

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Impedance Pneumogram (ZPN)

MEASUREMENT DESCRIPTION : Recording of respiratory waveform and derived respiration rate from transthoracic impedance changes.

1. Input signal characteristics	Bi-phasic, repetitive waveform. Amplitude will depend on the RF signal amplitude, which has not ye been determined.
2. Electrodes, transducers, vest, harness	Two combination excitation/sensing "plate" electrodes of conductive cloth, approx. 4" x 6" each, placed transthoracically. (These electrodes are not to be used for simultaneous ECG). This measurement is included in the Monitoring and in the VCG vest/harness.
3. Signal conditioner(s)	Spacelabs Model 603 or equivalent.
4. Range of measurement	10 to 60 respirations per minute.
5. Frequency of measurement	Intermittent or continuous for monitoring purposes.
6. Output signal characteristics	
analog/digital	Analog waveform.
amplitude	0 - 5 volts.
frequency range	0.03 - 10 Hz.
accuracy/sensitivity	As close as possible to true waveform.
7. Calibration	
type & technique	Not provided
frequency	

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Waveform: raw, analog, continuous on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Waveform: raw, digitized, intermittent.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100 sps.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Up to 30 minutes, including derived respiration rate, during exercise program.

9. Derived quantities

other measurements required simultaneously for calculations	N/A; record derived respiration rate from DPM directly.
digital computation	N/A.
display analog/digital; location; updating frequency	Respiration rate in digital form on PBDM. Update every 15 seconds.
recording analog/digital	Respiration rate every 30 seconds during exercise; every 15 minutes during monitoring.
storage time analog/digital	Digitized till next data dump.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Analog: 10 - 60 respirations/minute; 2 rpm resol. Digital: 0 - 60 resp./min.; ± 1 resp./min.
12. Printout frequency & other requirements	Every 30 sec.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject, measurement ident., respiration waveform, resp. rate.

For Lab. Verif. record analog waveform on pen recorder; record on FM tape recorder.

DPM will contain electronics to derive instantaneous respiration rate for display on front panel meter. A fixed time constant of approximately 10 seconds will be provided.

See also: Display, Recording, and Printout Requirements DPM.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Pulse Wave Contour (PWC)

MEASUREMENT DESCRIPTION : Recording of the arterial pulse wave shape changes as the result of experimentally induced stresses.

Computation of pulse wave transit time in conjunction with a reference ECG or PCG.

1. Input signal characteristics	Bi-phasic, repetitive waveform; 200 millivolt level typical - subject and location dependent.
2. Electrodes, transducers, vest, harness	Spacelabs Model 404 Photoelectric Pulse Sensor or equivalent. This measurement is included in the Monitoring and in the VCG vest/harness.
3. Signal conditioner(s)	Amplifier circuit for pulse wave form. Pulse Wave Velocity computer for transit time.
4. Range of measurement	N/A.
5. Frequency of measurement	Once per week.
6. Output signal characteristics	
analog/digital	Analog waveform.
amplitude	0 - 5 volts.
frequency range	0.1 - 30 Hz, approx.
accuracy/sensitivity	± 5 % of true waveform.
7. Calibration	
type & technique	Not provided.
frequency	

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Waveform: raw, analog, continuous on DPM; raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Waveform: raw, digitized, intermittent.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	250 sps.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Up to 30 minutes intermittently during LBNP exposure.

9. Derived quantities	Waveform only:	Pulse Wave Transit Time:
other measurements required simultaneously for calculations	N/A.	Reference ECG, or PCG.
digital computation	N/A.	N/A. Analog computation will be performed by PWV computer in the DPM.
display analog/digital; location; updating frequency	N/A.	Transit time in digitized format on PBDM; update every 5 seconds.
recording analog/digital	N/A.	Transit time in digitized format.
storage time analog/digital	N/A.	Digitized till next data dump.
10. Comparison with previous data	N/A.	N/A.
11. Analog/digital display range & resolution/accuracy	N/A.	Transit time, digital format 0 - 400 milliseconds ± 1 % accuracy
12. Printout frequency & other requirements	N/A.	Every 30 seconds.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject & measurement identification, waveform.

For Lab. Verif. record analog on pen recorder; record on FM tape recorder.

In conjunction with a reference ECG or a PCG signal, the pulse wave contour may be used to measure pulse wave transit time by means of the Pulse Wave Velocity computer, contained in the UPM. This transit time will be presented as an analog voltage, inversely proportional to time, and only requires digitization for presentation at the PBDM digital displays.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Body (ear canal) temperature

MEASUREMENT DESCRIPTION : Measurement of body temperature by means of an ear canal sensor with small time constant.

1. Input signal characteristics	Resistance change of a thermistor in bridge circui resulting in a voltage change.
2. Electrodes, transducers, vest, harness	Yellow Springs type 44011X thermistor in individually molded ear plug. Typical resistance approx. 60 kilohms @ 37° C. This measurement is included in the Monitoring vest/harness.
3. Signal conditioner(s)	Spacelabs Model 607 or equivalent.
4. Range of measurement	85 - 105° F.
5. Frequency of measurement	Intermittent or continuous for monitoring purposes
6. Output signal characteristics	
analog/digital	Analog DC voltage.
amplitude	0 - 5 volts ± 1 %.
frequency range	0 - 1 Hz.
accuracy/sensitivity	± 0.3° F.
7. Calibration	
type & technique	Gain and zero adjustments on S/C, for precise matching to individual thermistors only.
frequency	

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Analog meter readout on DPM, intermittent or continuous; digitized on PBDM.
recording analog/digital (raw, processed; continuous, intermittent)	Digitized, intermittent, every 30 seconds.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	10 sps minimum.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Up to 30 minutes during exercise and LBNP exposur

9. Derived quantities

other measurements required simultaneously for calculations	N/A.
digital computation	N/A.
display analog/digital; location; updating frequency	N/A.
recording analog/digital	N/A.
storage time analog/digital	N/A.

10. Comparison with previous data — N/A.

11. Analog/digital display range & resolution/accuracy — Analog meter on DPM: 85 - 105° F ± 0.5° F.
Digital on PBDM: 85 - 105° F ± 0.3° F.

12. Printout frequency & other requirements — Every 30 seconds.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject & measurement identification, temperature.

For. Lab. Verif. record analog on pen recorder; record on FM tape recorder.

The earmold sensor requires two passages: one for the thermistor leads, the second for sound conduction and pressure equalization.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular & Metabolism

MEASUREMENT : Average Skin Temperature

MEASUREMENT DESCRIPTION : Measurement of average skin temperature by means of summating the weighted temperatures from up to twelve different body locations.

1. Input signal characteristics — Resistance changes of thermistors in bridge circuits resulting in voltage changes.

2. Electrodes, transducers, vest, harness — Spacelabs Model 401 circular body temperature probes with Yellow Springs No. 44011X thermistors. Average Skin Temperature vest/harness. A probe location diagram will be provided as soon as possible.

3. Signal conditioner(s) — Spacelabs Model 606 or equivalent.

4. Range of measurement — 85 - 105° F.

5. Frequency of measurement — Mostly continuous during exercise on biclycle ergometer, and possible during LBNP exposure.

6. Output signal characteristics

analog/digital	Analog DC voltage.
amplitude	0 - 5 volts ± 1 %.
frequency range	0 - 1 Hz.
accuracy/sensitivity	± 0.5° F.

7. Calibration

type & technique	Factory calibrated.
frequency	

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Analog meter readout on DPM, mostly continuous; digitized on PBDM.
recording analog/digital (raw, processed; continuous, intermittent)	Digitized, intermittent, every 30 seconds.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	10 sps minimum.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Up to 30 minutes during exercise and LBNP exposure

9. Derived quantities

other measurements required simultaneously for calculations	N/A.
digital computation	N/A.
display analog/digital; location; updating frequency	N/A.
recording analog/digital	N/A.
storage time analog/digital	N/A.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Analog meter on DPM: 85 - 105° F ± 0.5° F. Digital on PBDM: 85 - 105° F ± 0.5° F.
12. Printout frequency & other requirements	Every 30 seconds.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject and measurement identification, temperature.

For Lab. Verif. record on analog pen recorder; record on FM tape recorder.

A special sub-modules on the vest/harness will contain the weighing potentiometers for the individual temperature channels.

The following weight averaging formula will be used:

T average = (T forehead x 0.07) + (T right arm x 0.07) +
(T left arm x 0.07) + (T right hand x 0.025) +
(T left hand x 0.025) + (T right foot x 0.035) +
(T left foot x 0.035) + (T right lower leg x 0.065) +
(T left lower leg x 0.065)+ (T right thigh x 0.095) +
(T left thigh x 0.095) + (T trunk x 0.35).

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Reference Electrocardiogram (ECG)

MEASUREMENT DESCRIPTION : Recording of a single lead ECG for monitoring purposes, to obtain heart rate, to compute pulse wave transit time, and for various correlation studies.

1. Input signal characteristics — Bi-phasic, repetitive waveform, 0 - 3 millivolts.

2. Electrodes, transducers, vest, harness — Three reuseable or disposable electrodes, one of which is the ground electrode. The two active electrodes will be placed in either transthoracic or in sternal configuration. Monitoring vest/harness.

3. Signal conditioner(s) — One Spacelabs Model 600 or equivalent.

4. Range of measurement — N/A.

5. Frequency of measurement — Mostly continuous during monitoring.

6. Output signal characteristics

analog/digital	Analog waveform.
amplitude	0 - 5 volts.
frequency range	0.1 - 100 Hz. See # 13.
accuracy/sensitivity	± 5 % of true waveform.

7. Calibration

type & technique	1 millivolt squarewave pulses; manual pushbutton on DPM.
frequency	At beginning and end of each run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, continuous on DPM; Raw, analog, continuous on Display Monitor.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, 5 seconds out of every minute.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	400 sps.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Up to two hours per 24-hour period total.

9. Derived quantities

other measurements required simultaneously for calculations	N/A. Instantaneous heart rate will be derived in DPM, and will be displayed on analog meter on front panel.
digital computation	Average heart rate during each preceeding 30 second period.
display analog/digital; location; updating frequency	Instantaneous heart rate - analog meter on DPM; Average heart rate during preceeding 30 seconds on Processor Readout.
recording analog/digital	Average heart rate at end of each 30 seconds, digitized.
storage time analog/digital	Digitized till next data dump.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Analog: 50 - 200 bpm, 5 bpm resolution. Digital: 50 - 200 bpm, ± 2 bpm.
12. Printout frequency & other requirements	Average heart rate at end of each 30 second period

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject and measurement identification, calibration, digitized waveform, average heart rate, calibration.

For Lab. Verif. record waveform and heart rate on pen recorder, and record on FM tape recorder.

Calibration unit inside DPM with pushbutton on front panel.

DPM will contain electronics to derive instantaneous heart rate for display on front panel meter. Variable time constants of 5 and of 15 seconds will be provided to smooth out rapid heart rate fluctuations.

See also: Display, Recording, and Printout Requirements DPM.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Dynamic Physiological Monitor

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Arterial Blood Pressure (Indirect; Systolic and Diastolic)

MEASUREMENT DESCRIPTION : Measure systolic and diastolic blood pressure by means of sphygmomanometry, using the Riva-Rocci principle of cuff inflation and deflation while monitoring the Korotkoff sounds at the brachial artery.

1. Input signal characteristics	Cuff pressure waveform - rapid inflation to 200 mm Hg, followed by slow deflation. Complex sound waveforms from Korotkoff sound microphone recorded simultaneously with, or superimposed on, pressure tracing.
2. Electrodes, transducers, vest, harness	Sphygmomanometer cuff with Korotkoff microphone. Can be used in conjunction with any of the available vest/harness combinations, as it constitutes a separate sub-assembly.
3. Signal conditioner(s)	Servo-regulated cuff programmer (Technology Inc.), Korotkoff sound amplifier with filter network, processing electronics to derive systolic and diastolic blood pressure readouts on analog meters.
4. Range of measurement	50 - 250 mm Hg systolic. 30 - 150 mm Hg diastolic.
5. Frequency of measurement	For monitoring once every 15 mins. During experiments every 30 seconds or less frequently.
6. Output signal characteristics	
analog/digital	Analog pressure curve and sound waveform.
amplitude	0 - 5 volts
frequency range	0 - 5 Hz for pressure (Approx.) K-sound filter peaked at 40 Hz, possibly also 90 and 120 Hz.
accuracy/sensitivity	± 5 mm Hg design goal.
7. Calibration	
type & technique	Manual inflation bulb and aneroid manometer used with stethoscope.
frequency	Before each experiment or monitoring run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Analog, raw K-sound on DPM scope. Derived SP and DP on DPM analog meters; digitized on PBDM. Intermittent, whenever taken.
recording analog/digital (raw, processed; continuous, intermittent)	Derived SP and DP, digitized; intermittent.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	N/A.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Variable.

9. Derived quantities

other measurements required simultaneously for calculations	N/A. SP and DP derived by electronics within DPM.
digital computation	N/A. SP and DP derived by DPM electronics.
display analog/digital; location; updating frequency	N/A.
recording analog/digital	N/A.
storage time analog/digital	N/A.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Analog meters: SP 50 - 250 mm Hg, DP 30 - 150 mm Hg; 5 mm Hg resolution. Digital: SP 0 - 250 mm Hg, DP 0 - 150 mm Hg; ± 2 mm Hg.
12. Printout frequency & other requirements	For monitoring once every 15 mins. During experiments every 30 secs.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject and measurement identification, systolic and diastolic pressures.

For Lab. Verif. the cuff pressure trace and the Korotkoff sounds must be recorded simultaneously and superimposed on pen recorder and on FM tape recorder.

The DPM will contain all electronics necessary to convert the two input signals into systolic and diastolic pressure readings. A "hold" circuit is required to retain the previous readings until the next reading has been taken.

VASCULAR DYNAMICS SUBSYSTEM III-E

Section III-E

IMBLMS FUNCTIONAL BREADBOARD

PERFORMANCE/DESIGN

REQUIREMENTS

VASCULAR DYNAMICS

SUBSYSTEM

VASCULAR DYNAMICS

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

- 3.1 Performance
  - 3.1.1 Functional
    - 3.1.1.1 Overall System Requirements
    - 3.1.1.2 Measurement Requirements
    - 3.1.1.3 Cardiac Output
    - 3.1.1.4 Peripheral Venous Pressure
    - 3.1.1.5 Limb Plethysmograph
    - 3.1.1.6 Capillary Fragility
  - 3.1.2 Safety
- 3.2 Interface Requirements
- 3.3 Design and Construction
  - 3.3.1 Sensors, Signal Conditioners, and Supporting Test Equipment
    - 3.3.1.1 Sensors
    - 3.3.1.2 Signal Conditioners
    - 3.3.1.3 Supporting Test Equipment
  - 3.3.2 Displays and Controls
  - 3.3.3 Calibration Requirements
  - 3.3.4 Power Requirements

4.0 DESCRIPTIVE DEFINITION AND BLOCK DIAGRAMS

APPENDIX MEASUREMENT REQUIREMENTS DATA SHEETS

1.0 INTRODUCTION

This document establishes the requirements for the performance, and design of the Vascular Dynamics Subsystem, together with requirements necessary to provide interface compatibility with other FBB subsystems. The Vascular Dynamics subsystem consists of measurement sensors, signal conditioners, a body-worn vest and wiring harness, limb cuffs and limb enclosures and a display panel. The Vascular Dynamics subsystem is used in conjunction with the PBDM station to measure, display, and provide recording interface for measurements concerned with cardiovascular activity during exercise or stress conditions.

The measurement of Capillary Fragility (Rumple Leede) has been included under the Vascular Dynamics Subsystem as this hematological measurement is related to cardiovascular investigations and equipment.

2.0 APPLICABLE DOCUMENTS

All applicable documents are referenced in FBB System Requirements.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional. -

3.1.1.1 Overall System Requirements. - The Vascular Dynamics Subsystem must be capable of detecting specific measurement changes using non-invasive techniques with body attached electrodes and signal transducers, which feed the basic information to either body-worn or remotely located signal conditioners. The subsystem requires interface with a computer for computational support. Control provisions will be incorporated on the panel for the supporting test equipment (Ergometer and LBNP). Display of data will be on meters with analog signals made available for recording.

3.1.1.2 Measurement Requirements. - The Vascular Dynamics Subsystem must be capable of measuring and/or displaying the following parameters:

1. Cardiac output
2. Peripheral venous pressure
3. Limb plethysmography
4. Capillary Fragility (Rumple Leede)

Specific measurement data requirements are tabulated in Section III-G Appendix. In addition, it must be capable of displaying and controlling the pressure settings for the LBNP, and the loads and RPM for the bicycle ergometer.

3.1.1.3 Cardiac Output. - This measurement employs the impedance cardiogram technique of Kubicek, the requirements and characteristics of which were presented in Section III-D, Dynamic Physiological Monitor. The DPM does not include a readout facility for derived cardiac output. A separate meter is therefore required on the Vascular Dynamics panel to allow a direct display of cardiac output (thoracic blood flow). This meter has a range from 2 to 25 l/min. The digital display of this parameter will have a 2 decimal accuracy. Cardiac output determinations using the CO_2 rebreathing technique are described in Section III-F, Respiratory Subsystem.

3.1.1.4 Peripheral Venous Pressure. - The direct method requires a venapuncture and pressure transducer. It will provide an accurate baseline to evaluate the plethysmograph technique. The indirect method of measuring the peripheral venous pressure involves comparison of the two pressure transducer traces during deflation of the sphygmomanometer cuff. It requires the use of a rigid forearm plethysmograph, a sphygmomanometer cuff, and two pressure transducers. The value of the venous blood pressure is entered manually for recording via the numerical Data Entry Keyboard.

3.1.1.5 Limb Plethysmography. - Two methods of limb plethysmography will be used to measure the volume increase of the lower legs while the subject is exposed to negative pressure in the LBNP device. The standard method will employ silastic rubber strain gages, either filled with mercury or another electrolyte; the second method utilizes ultrasound in conjunction with a phase-shift detector to measure the increase in limb diameter. This last technique is experimental and is presently under development at LMSC.

Through appropriate calibration and computation, both methods allow for an expression of either pulsatile flow or volume increase per 1000 or percent of the resting value, or of blood flow in $cm^3/100\ cm^3$ of tissue/minute. The volume increase and the blood flow measurements require the use of an occlusion cuff proximal to the transducers to prevent venous return.

3.1.1.6 Capillary Fragility (Rumple Leede). - This measures the resistance to rupture of superficial capillaries as the result of a five (5) minute application of a blood pressure cuff inflated to a pressure of 100 mm Hg. Visual observation is made and recorded.

3.1.2 Operability. - Section III-A FBB System Requirements document contains applicable operability requirements.

3.1.2.1 Safety. - The Vascular Dynamic subsystem employs major peripheral equipment such as the ergometer and the LBNP. These two devices expose the subject to a stressful environment so it is necessary when conducting measurements using this equipment that qualified personnel are available and that the test operator has a clear view of the subject at all times. Remote control and adjustment of the LBNP pressure at the Vascular Dynamic panel is required if a single experimentor is stationed at the PBDM so that he can immediately equalize the LBNP to ambient pressure at the first sign of impending subject syncope.

3.2 Interface Requirements

The Vascular Dynamics Subsystem must meet the display and control requirements associated with measurements taken while using the LBNP or Ergometer. The basic interface requirements between the Vascular Dynamics Subsystem and the PBDM

Station are similar to those associated with the DPM. The signal outputs are made available to the computer through switching. The physical location of the Display panel for Vascular measurements is not critical except that it should be located relatively close to the DPM to permit monitoring of the vital signs during stressful activities.

3.3 Design and Construction

The Vascular Dynamics Subsystem consists of the following elements: Sensors, Signal Conditioners, and Display and Control Units. This section will discuss the mechanical, electrical, test provisions and material requirements. The design requirements for cardiac output (except for the display meter) are dilineated in Section III-D, Dynamic Physiologic Monitoring. Measurements of Zo, Z, and Z together with PCG and ZPN will be made available to the computer for computation of Thoracic Blood Flow which will be displayed on the Vascular Dynamics Panel.

3.3.1 Sensors, Signal Conditioners, and Supporting Test Equipment.

3.3.1.1 Sensors. - Peripheral Venous Pressure - Direct Method. - Venipuncture requiring a Statham SP-37 miniature blood pressure transducer, a needle, and a driver/amplifier will be utilized to measure venous pressure directly, and to furnish accurate baseline data to evaluate the plethysmographic technique.

Peripheral Venous Pressure - Indirect Method. - A modification of the plethysmographic technique of Uspenskii and Vasil'ev for the measurement of indirect venous pressure employs a rigid, cylindrical, forearm plethysmograph, closed at the distal end. The arm is inserted in the cylinder and opening between the arm and cylinder is closed off with a thin rubber collar. A tube at the distal end is connected to a suitable pressure transducer, while a squeeze bulb will be attached temporarily to a side tube to check the patency of the seal. After this check, the pressure inside the plethysmograph is equilibrated with ambient, and the outlet valve is closed. A suitable air source is required which will be connected via a plenum and a needle valve to a regular sphygmomanometer cuff placed on the upper arm, and to a second pressure transducer. The pressure transducers to be used in determining venous pressure will furnish pressure readings from 0 to 20 cm H_2O. High accuracy in low pressure ranges, fast response, and low static and temperature errors are necessary performance characteristics. A Statham P-15 cuff pressure transducer, or equivalent, has the desirable characteristics.

The output of the two pressure transducers are displayed on two channels of a long-persistence display CRT. Outputs correspond to cuff pressure versus the plethysmographic pulse trace, from which the venous pressure can be read off. (See Fig. 1).

Limb Plethysmography. - Two methods of detecting limb volume changes will be used. A strain gage (Whitney Gage) consisting of a length of silastic tubing filled with mercury or other electrolyte will be attached around the limb segment to be measured. Contact is made to the ends of the electrolyte column by means of wires inserted into the ends of the tubing. As the tubing is stretched, the column is lengthened and narrowed, thereby increasing its electrical resistance. When the tension is removed, the gage returns to its original length. The resistance increases linearly with length when the length changes are small

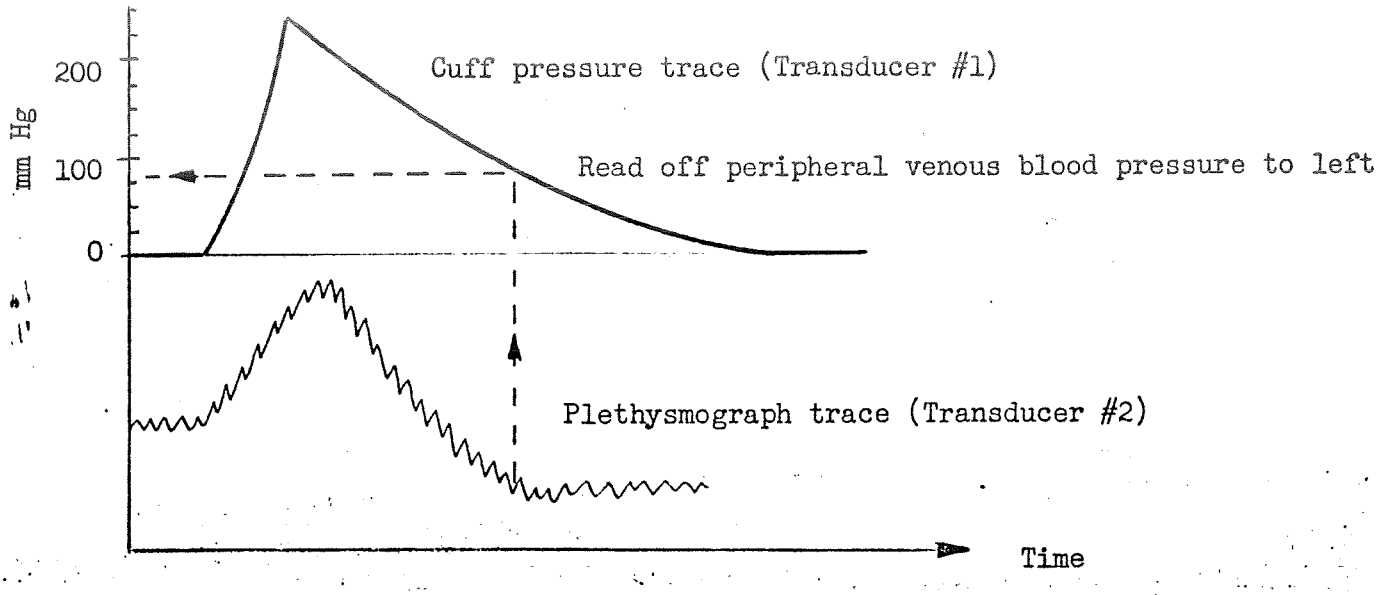


Fig. 1 Rigid Arm Plethysmograph and Occlusion Cuff Traces to Pressure

compared to the total unstretched length of the gage. A substitution for mercury will be investigated due to its hazard under spaceflight conditions.

An ultrasonic method will also be used, for which two piezoelectric transducers are coupled to opposite sides of the limb. One transducer is driven by a carrier at about 100 K Hz, amplitude modulated by a signal at about 50 K Hz. The phase shift of the modulation signal from the initial value is picked up by the second transducer, and will be detected and used to indicate changes in limb diameter. These diameter changes can then be converted to volume changes.

3.3.1.2 Signal Conditioners. - Signal conditioners will be required for the forearm plethysmograph pressure, the occlusion cuff pressure, the strain gage plethysmograph, and the ultrasonic plethysmograph. Each signal conditioner will provide an output of 0-5 volts, with an output impedance of 200 ohms or less. These signal conditioners will be solid state, mounted on circuit boards.

3.3.1.3 Supporting Test Equipment. - A non-deliverable LMSC space-oriented bicycle ergometer will be utilized to provide stressful exercise test conditions. The ergometer has the capability of providing exercise load profiles from 100 to 400 watts, at 25 watt increments. Tachometer and load outputs are available for display.

A non-deliverable LMSC laboratory model of an LBNP will be utilized to provide negative pressure to the lower torso and extremities. Quick dumping provisions are available. Accurate pressures can be maintained, since an open system is employed with high flow and low leak rates.

Remote control and adjustment of the LMSC pressure and ergometer work load, are required so that a single experimentor can safely conduct the LBNP procedure and vary the work load during an exercise profile without interference with the subject's performance. Provision will be provided for this control on the

vascular panel if NASA provides detailed information and schematic diagrams of the NASA control units for the LBNP and ergometer. The 0 to 5 volt signals of LBNP pressure, and of ergometer load and pedalling speed, will be displayed on the PBDM panel.

3.3.2 Displays and Controls. - The Vascular Dynamics panel (See Fig. 2) provides switches and controls to activate and adjust the various measurement equipment. The use of the mercury stain gage or ultrasonic method will be under switch control. A single analog meter and display left or right limb percent volume changes cardiac output (thoracic blood flow) ranging from 2-25 liters/min. will be displayed on a single scale analog meter. The LBNP pressure will be displayed with a range of zero to minus 80 mm Hg. A dual analog meter is used to display the ergometer load (50-300 watts) and RPM (40-90 RPM).

3.3.3 Calibration Requirements. - Calibration circuitry is provided as an integral part of the ZCG signal conditioners with contacts provided on the output connector.

The transducers used in the direct and indirect technique for measuring peripheral venous pressure will be calibrated manually with an aneroid manometer. The strain gage method of limb plethysmography includes electrical calibration signals in the adjustable Wheatstone bridge which is part of the signal conditioner. The Ultrasonic method of measuring limb plethysmography will be precalibrated by comparing against strain gage technique, in conjunction with phase shift null setting.

The NASA ergometer requires special calibration equipment as part of the ground support equipment. The LBNP pressure transducer may be calibrated manually with an aneroid manometer.

3.3.4 Power Requirements. - The Vascular Dynamic Subsystem requires 115 v, 60 Hz, and dc regulated power. Commercial units having their own power supply may also be utilized. A 28 vdc power supply is available through the PBDM console. Table 1 summarizes the electrical characteristics and data requirements.

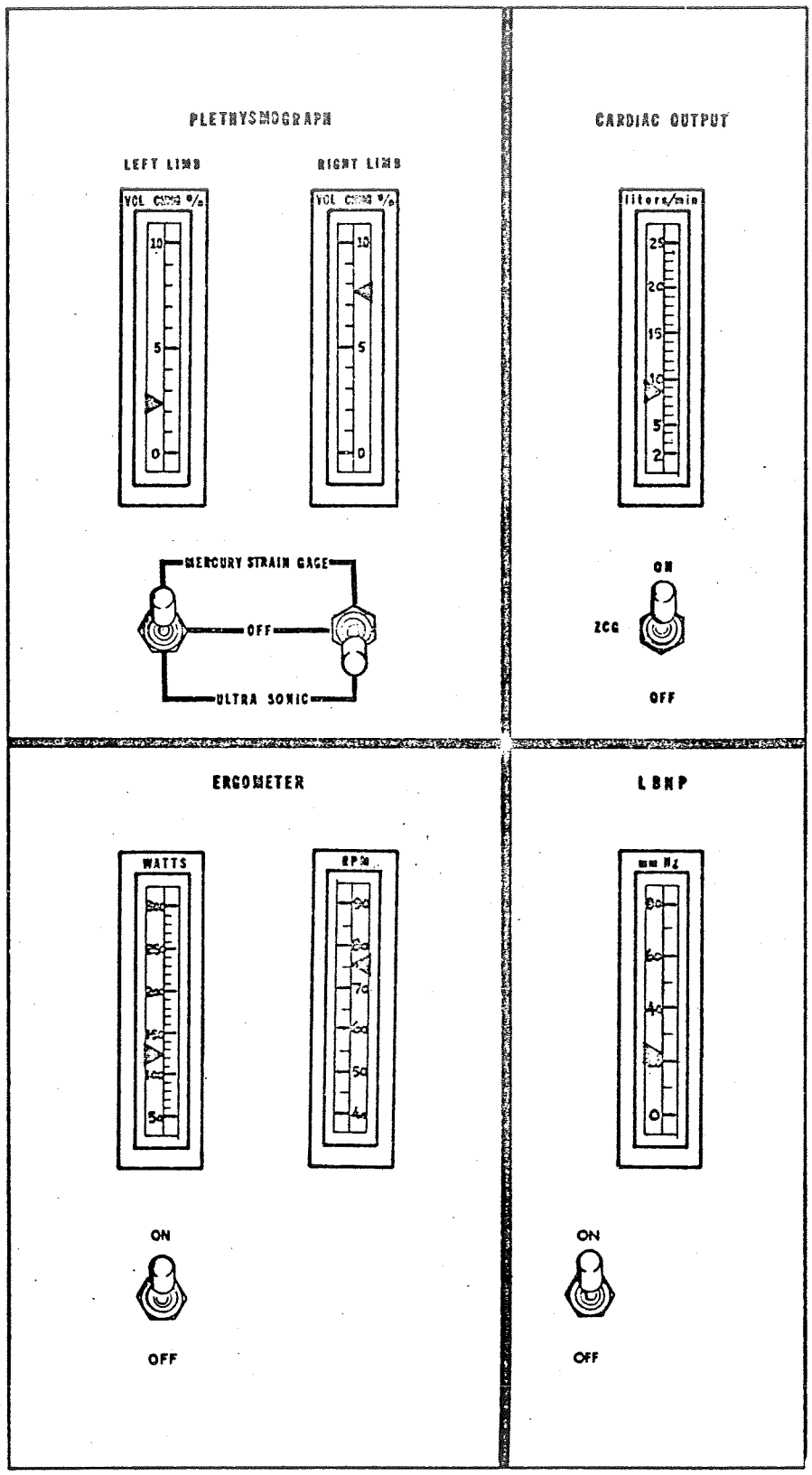


Fig. 2 Vascular Dynamics Panel

TABLE 1

EQUIPMENT ELECTRICAL CHARACTERISTICS

	OUTPUT VOLTAGE OF SIGNAL CONDITIONER	OUTPUT IMPEDANCE OF SIGNAL CONDITIONER	FREQUENCY RESPONSE REQUIRED	ANALOG SWITCHING MATRIX	NO CONVERSION MANIMUM SAMPLE RATE REQUIRED
	VOLTS	OHMS	Hz		SAMPLES/SEC
ERGOMETER					
Rotation Rate	0-5	200	0 to 1	X	4
Power	0-5	200	0 to 1	X	4
LBNP					
Pressure	0-5	200	0 to 1	X	4
CARDIOVASCULAR					
Rigid Shell Pressure	0-5	200	0 to 50	X	200
Cuff Pressure	0-5	200	0 to 10	X	40
Invasive Pressure	0-5	200	0 to 10	X	40
PLETHYSMOGRAPH					
Strain Gage	0-5	200	0 to 100	X	400
Ultrasonic	0-5	200	0 to 100	X	400

DISPLAYS	SOURCE
Cardiac Output	Computer
Pleth Left Leg	Computer
Pleth Right Leg	Computer
Pleth Arm	Computer
LBNP Pressure	LBNP
Ergom Rotat. Rate	Ergometer

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

4.1 Conceptual Design

4.1.1 Design Objective. - A major objective of the Vascular Dynamics Subsystem is to provide a centralized display and control panel designed to accept cardiovascular measurements made during exercise or stress conditions. Interconnection with the Data Management Subsystem will be provided for complete data handling.

4.1.2 Design Concept. - The Display and Control Panel will be centrally located at the PBDM Station. Analog meters will be used to display the required data. Switching capability will be provided in the design to select either the Mercury Strain Gage or Ultrasonic method during limb plethysmography. Either right or left limb volume changes may be presented.

The NASA ergometer and LBNP have integral control systems, however, LMSC recommends that control units are desirable under direct observer control and will provide space provisions at the Panel.

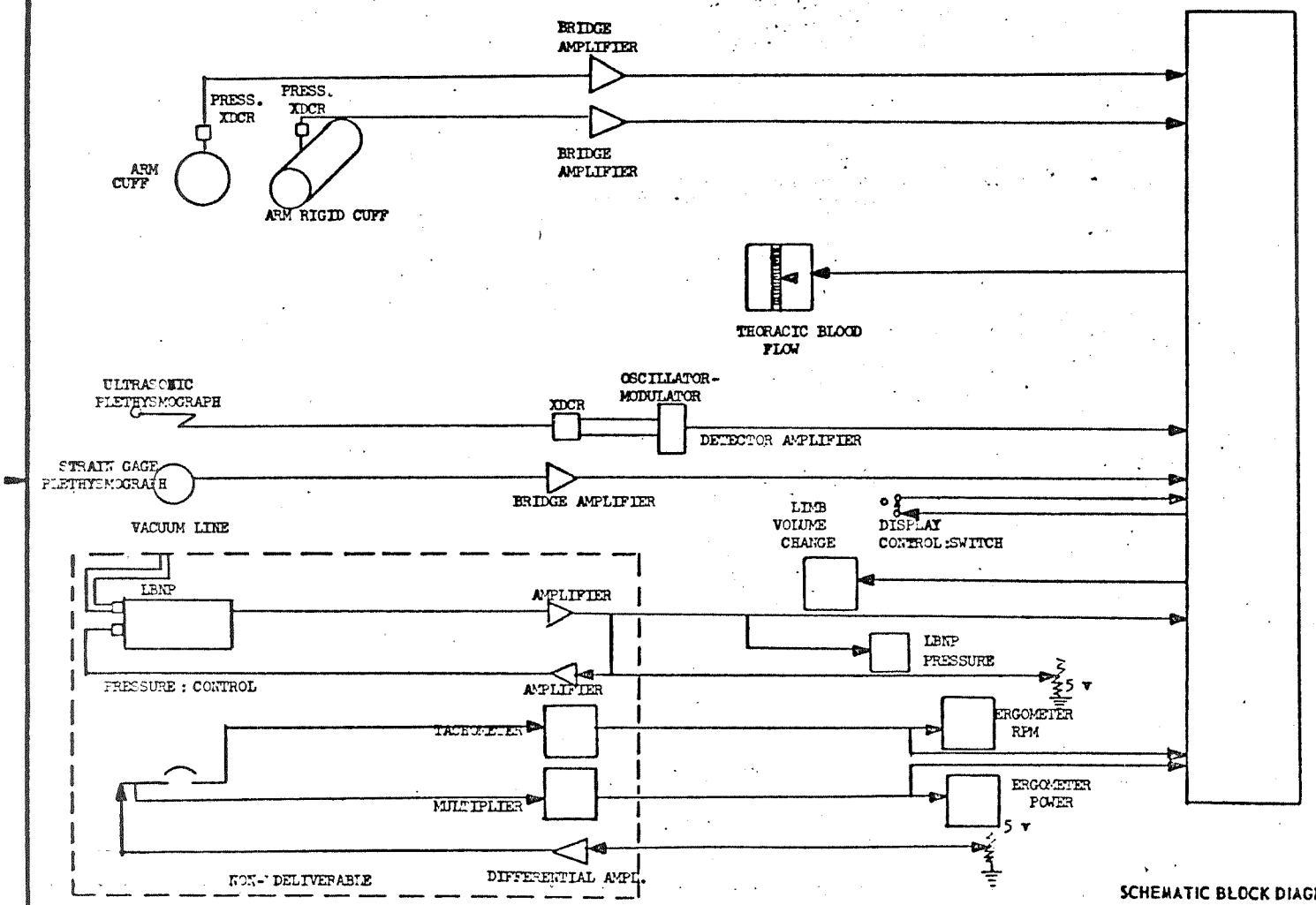
4.2 Block Diagrams

4.2.1 Equipment Elements. - The Vascular Dynamics Subsystem is made up of a display and control panel measuring $9\frac{1}{2}$ in. x 19 in. Six Weston Model 131 meters will be used and will be designed to accept 0-5v output signals. Two position toggle switches will be used. Measurement equipment are illustrated in Fig. 3 and consist of Arm Rigid Cuff Device for Venous Pressure determination, a standard arm cuff, pressure transducers, and bridge amplifiers. Limb plethysmography equipment consists of an Ultrasonic Unit, and a Mercury Strain Gage Unit. Transducers, amplifiers are used in conjunction with these units. Provisions for connecting and displaying Ergometer and LBNP data are shown.

4.2.1.1 Venous Pressure Measurement. - Venous pressure is measured by an occluding cuff with its pressure transducer, a rigid shell with its pressure transducer, two rubber bulbs used as small air pumps, and data management provisions for displaying the two pressures. (See Fig. 4). The occluding cuff is inflated by its rubber bulb until the venous flow is reduced, which causes the arm to swell. This swelling causes an increase in pressure in the rigid shell. The occluding cuff pressure is then reduced with a resulting decrease in rigid shell pressure. Curves of the two pressures versus time are presented on the monitoring oscilloscope and the venous pressure is determined by visual analysis of the curves. The rigid shell rubber bulb is used in checking for leaks in the seal with the arm.

4.2.2.2 Ultrasonic Plethysmograph. - The ultrasonic plethysmograph measures changes in acoustical distance through a limb segment. It operates by feeding an amplitude modulated acoustical signal through the limb and measuring the phase shift of the modulation as the limb varies in size.

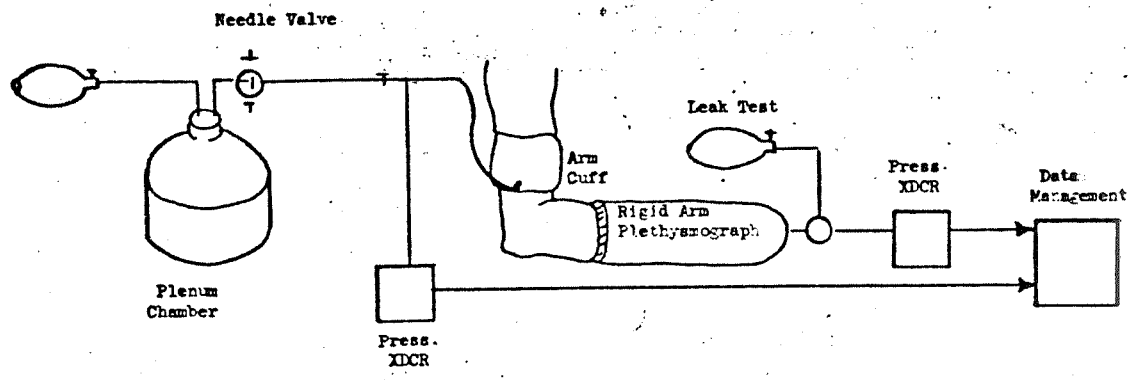
As illustrated in Fig. 5, a sine wave electrical signal (100KHz) is generated



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 3 - VASCULAR DYNAMICS SUBSYSTEM
CHK		APPD		
SUPV		APPD		CODE IDENT NO. 1[illegible]077 — DOCUMENT NO. III-[illegible]-10 — REV
SYS ENGR		SPO/GSETD	CEI/FD NO — CONTR NO.	SIZE B — SH — OF

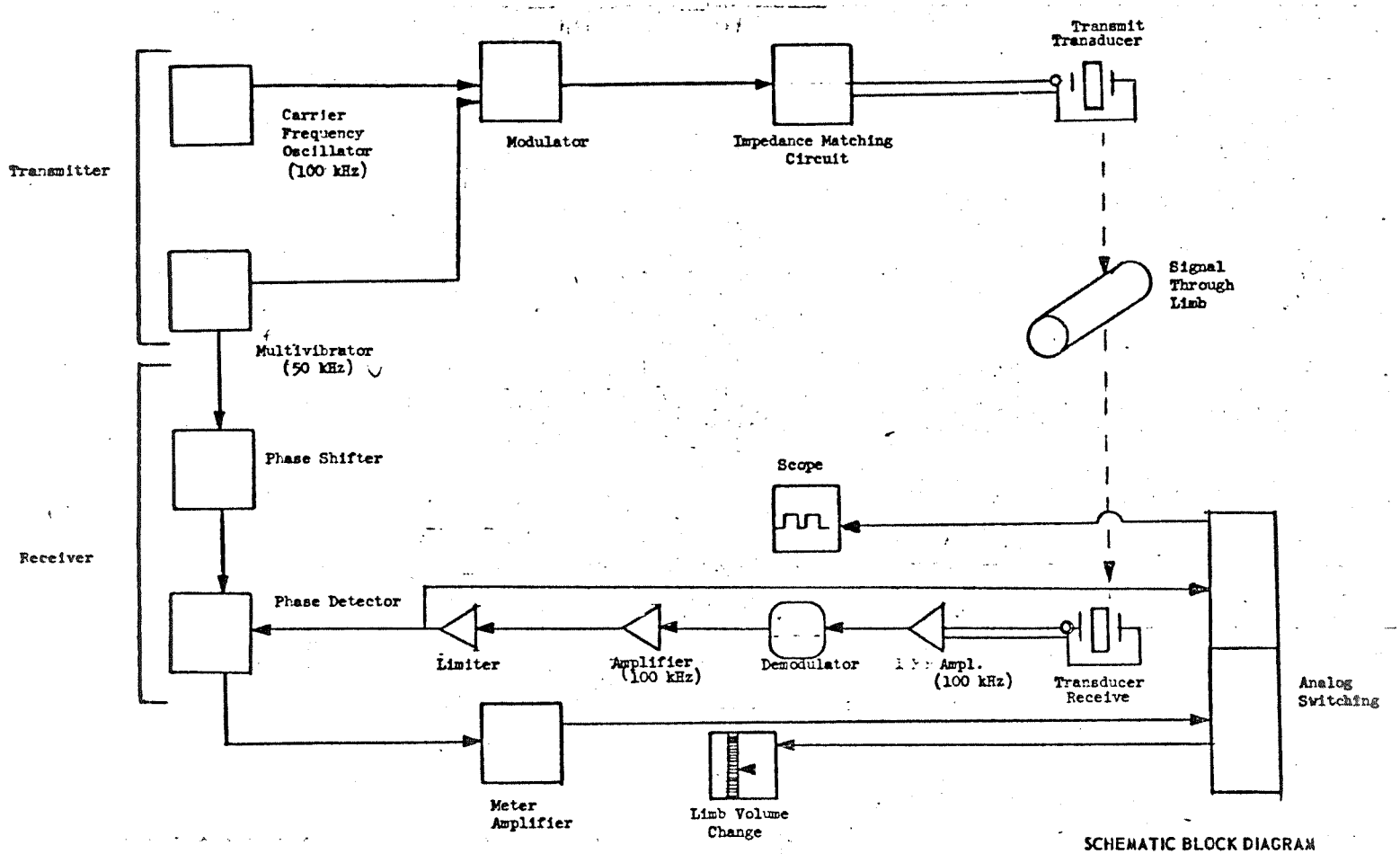
Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 4. - RIGID ARM PLETHYSMOGRAPH		
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-2-11	REV
SUPV		APPD				
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B / SH / OF		

Form LMSC 26708



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIG. 5 ULTRASONIC PLETHYSMOGRAPH	
CHK		APPD		CODE IDENT NO 17077	DOCUMENT NO.
SUPV		APPD		SIZE B SH OF	III-E-12
SYS ENGR		SPO/GSETD	CEI/FD NO. CONTR NO.		

Form LMSC 26700

by the carrier frequency oscillator, and a square wave signal (100k Hz) is generated by the modulation frequency multivibrator. The carrier signal is 100 percent square wave modulated in the modulator and the modulated signal drives a piezoelectric transducer which is acoustically coupled to the limb. Another piezoelectric transducer converts the modulated acoustic signal back to electrical form to be carrier frequency amplified, demodulated, modulation frequency amplified, limited, and fed into the phase detector. The output of the phase detector is a voltage proportional to the difference in phase between the signal from the limiter and the signal from the modulation frequency multivibrator as initially adjusted by the phase shifter. This phase shift voltage, proportional to the acoustical distance between the transducers is amplified and fed into the analog switching matrix for further processing and display. Characteristic of the modulation signal will be observed on the monitoring oscilloscope.

Section III-E

APPENDIX

MEASUREMENT REQUIREMENTS DATA SHEETS

Measurement Requirements Data Sheets have been prepared for the following Vascular Dynamics Measurements:

Measurement	Page No.
– Peripheral Venous Pressure (Direct Technique)	III-E-2A
– Peripheral Venous Pressure (Indirect Technique)	III-E-5A
– Limb Plethysmography (Strain Gage Method)	III-E-8A
– Limb Plethysmography (Ultrasonic Method)	III-E-12A
Capillary Fragility (Rumple Leede)	III-E-15A

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM	:	Vascular Dynamics
MEASUREMENT GROUP	:	Cardiovascular
MEASUREMENT	:	Peripheral Venous Pressure (Direct technique)
MEASUREMENT DESCRIPTION	:	Obtain the peripheral venous blood pressure by means of an indwelling hypodermic needle in a superficial vein and recording the pressure tracing output.

1. Input signal characteristics	Straight line pressure trace.
2. Electrodes, transducers	Statham SP-37 miniature blood pressure transducer and hypodermic needle.
3. Signal conditioner(s)	Strain gage driver and amplifier for Statham transducer.
4. Range of measurement	0 - 300 mm H_2O pressure.
5. Frequency of measurement	Once every 1 - 2 weeks.
6. Output signal characteristics	
analog/digital	Analog trace.
amplitude	0 - 5 volts (after amplification).
frequency range	0 - 10 Hz or higher.
accuracy/sensitivity	± 2 % of pressure-equivalent amplitude.
7. Calibration	
type & technique	Manual with aneroid manometer
frequency	Before each measurement.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Analog meter readout of pressure only at vascular dynamics panel. Continuous.
recording analog/digital (raw, processed; continuous, intermittent)	Digitized meter readout. Continuous.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	N/A.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	5 seconds per reading. Several readings may be taken if used during LBNP exposure.

9. Derived quantities

other measurements required simultaneously for calculations	N/A.
digital computation	N/A.
display analog/digital; location; updating frequency	N/A.
recording analog/digital	N/A.
storage time analog/digital	N/A.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Digital readout 0 - 300 mm H_2O, ± 3 mm.
12. Printout frequency & other requirements	Once per reading.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject and measurement identification, pressure.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Vascular Dynamics

MEASUREMENT GROUP : Cardiovascular

MEASUREMENT : Peripheral Venous Pressure (Indirect technique)

MEASUREMENT DESCRIPTION : Obtain the peripheral venous blood pressure by means of simultaneous recording of the pressure tracings of a low pressure occlusive arm cuff and a rigid forearm plethysmograph during inflation and deflation of the arm cuff.

1. Input signal characteristics	Arm cuff: bi-phasic signal, rapid upslope followed by slow downslope. Plethysmograph: rising and falling bi-phasic pressure waveform.
2. Electrodes, transducers	Occlusive arm cuff, plenum, pressure squeeze bulb, pressure transducer. Rigid arm plethysmograph, pressure transducer. Two Statham PM-97 TC (± 0.05 psi) pressure transducers or equivalent.
3. Signal conditioner(s)	Two strain gage driver/amplifiers for Statham transducers.
4. Range of measurement	0 - 300 mm H_2O pressure.
5. Frequency of measurement	Once every 1 - 2 weeks.
6. Output signal characteristics	
analog/digital	Analog waveforms.
amplitude	0 - 5 volts (after amplification).
frequency range	0 - 50 Hz or higher.
accuracy/sensitivity	± 5 % of actual waveform.
7. Calibration	
type & technique	Manual with aneroid manometer.
frequency	Before each measurement.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog waveform on Display Monitor; intermittent.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized waveform; intermittent.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identifcation and measurement number.
A/D conversion frequency	250 sps.
storage time analog/digital	Digitized till next data dump.
recording/storage quantity per subject	Approx. three minutes per subject for three complete cycles.

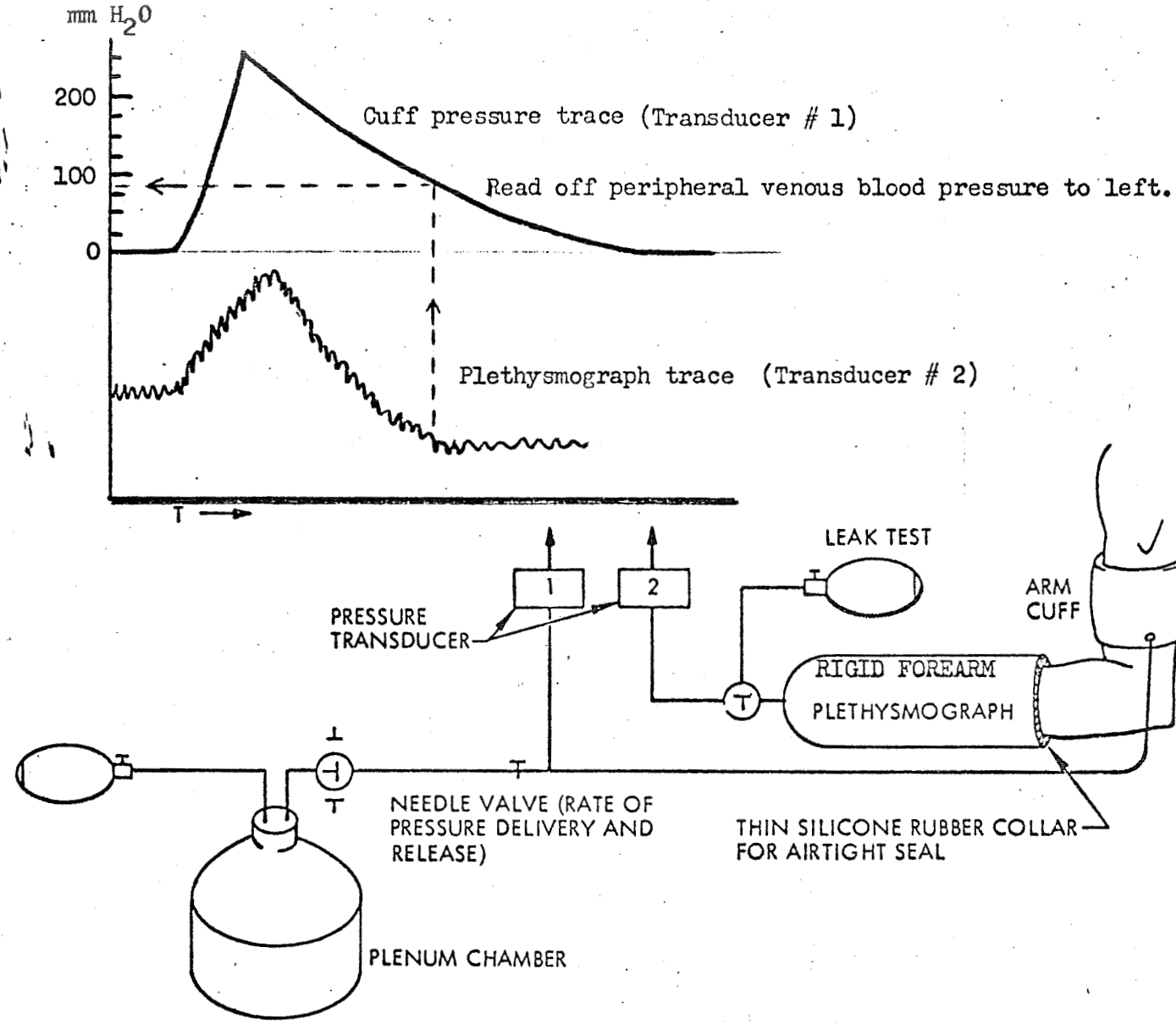
9. Derived quantities

other measurements required simultaneously for calculations	N/A.
digital computation	N/A.
display analog/digital; location; updating frequency	N/A.
recording analog/digital	N/A.
storage time analog/digital	N/A.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	Analog waveform, $\pm$ 3 mm H_2O.
12. Printout frequency & other requirements	N/A.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject and measurement idenfication, digitized waveforms, manually derived peripheral venous blood pressure value.



Arm Plethysmograph for Measuring Peripheral Venous Pressure

Section III-E Appendix

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Vascular Dynamics

MEASUREMENT GROUP : Cardiovascular (Vascular Dynamics)

MEASUREMENT : Limb Plethysmography (Straingage method)

MEASUREMENT DESCRIPTION : Measurement of increase in lower leg volume as the result of LBNP exposure, with and without restriction of venous return by means of an occlusive thigh cuff, by means of measuring resistive changes in electrolyte-filled strain gages.

1. Input signal characteristics	The basic signal consists of a bi-phasic, repetitive waveform, representing the arterial pulse contour.
2. Electrodes, transducers	Silastic rubber strain gages, filled with mercury or other electrolyte.
3. Signal conditioner(s)	Adjustable Wheatstone bridge and variable gain bridge output amplifier.
4. Range of measurement	0 - 10 % volume change.
5. Frequency of measurement	Once per 1 - 2 weeks.
6. Output signal characteristics	
analog/digital	Analog voltage.
amplitude	0 - 5 volts.
frequency range	DC - 100 Hz.
accuracy/sensitivity	0.2 °/oo
7. Calibration	
type & technique	Electrical calibration signals included in Wheatstone bridge for 2 °/oo and 5 °/oo, manually operated.
frequency	Several times during measurement run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog plethysmogram on Display Monitor and on pen recorder. Continuous.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, analog, digitized, continuous.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	200 sps.
storage time analog/digital	Digitized until next data dump.
recording/storage quantity per subject	Approx. 10 minutes.

9. Derived quantities	% increase in limb volume
other measurements required simultaneously for calculations	10-second time base.
digital computation	See # 13.
display analog/digital; location; updating frequency	Digital display of % increase in limb volume every 10 seconds on PBDM. Analog on Vascular Dynamics panel to show cumulative volume increase.
recording analog/digital	Digitized value every 10 seconds.
storage time analog/digital	Digitized until next data dump.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	% increase in limb volume, 0 - 10 % ± 0.1 % accuracy, digital. Analog ± 0.5 % accuracy.
12. Printout frequency & other requirements	Every 10 seconds.

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject and measurement identification, plethysmographic mode identification (strain gage), digital values of limb volume increase in % every 10 seconds during venous occlusion.

PRINCIPLE OF COMPUTATION

The normal plethysmographic waveform, together with a 5 % calibration pulse recorded after gain reduction to 1/30, are shown in Fig. 1.

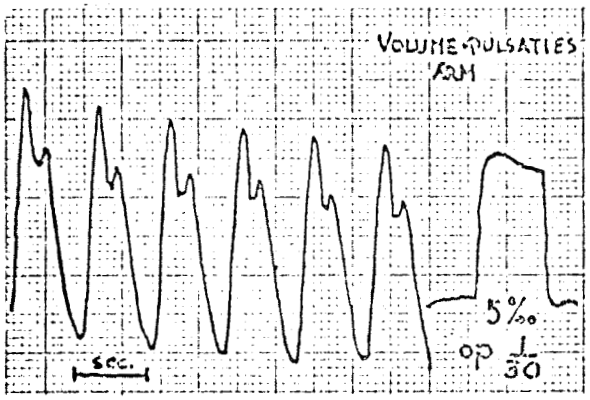
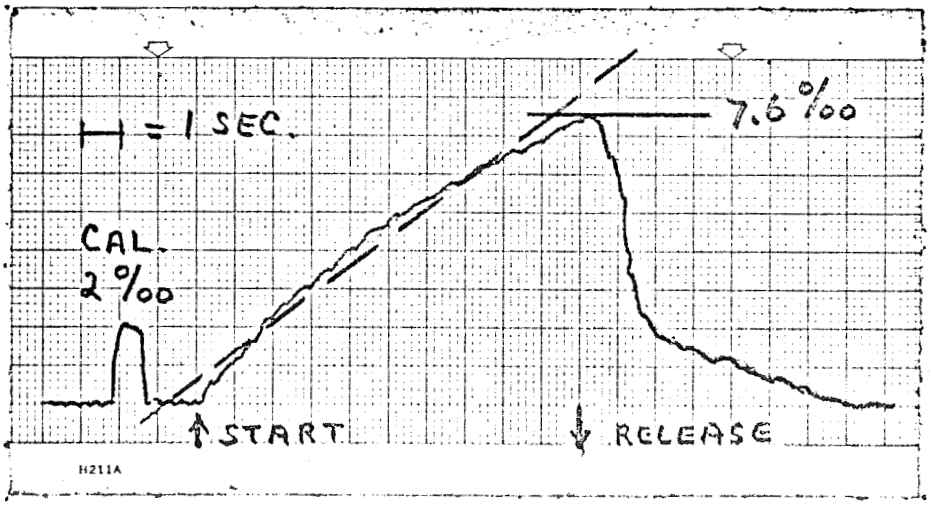


Fig. 1. Synchronised volume variations with cardiac pulse. Pulse height ± 0.3 ‰

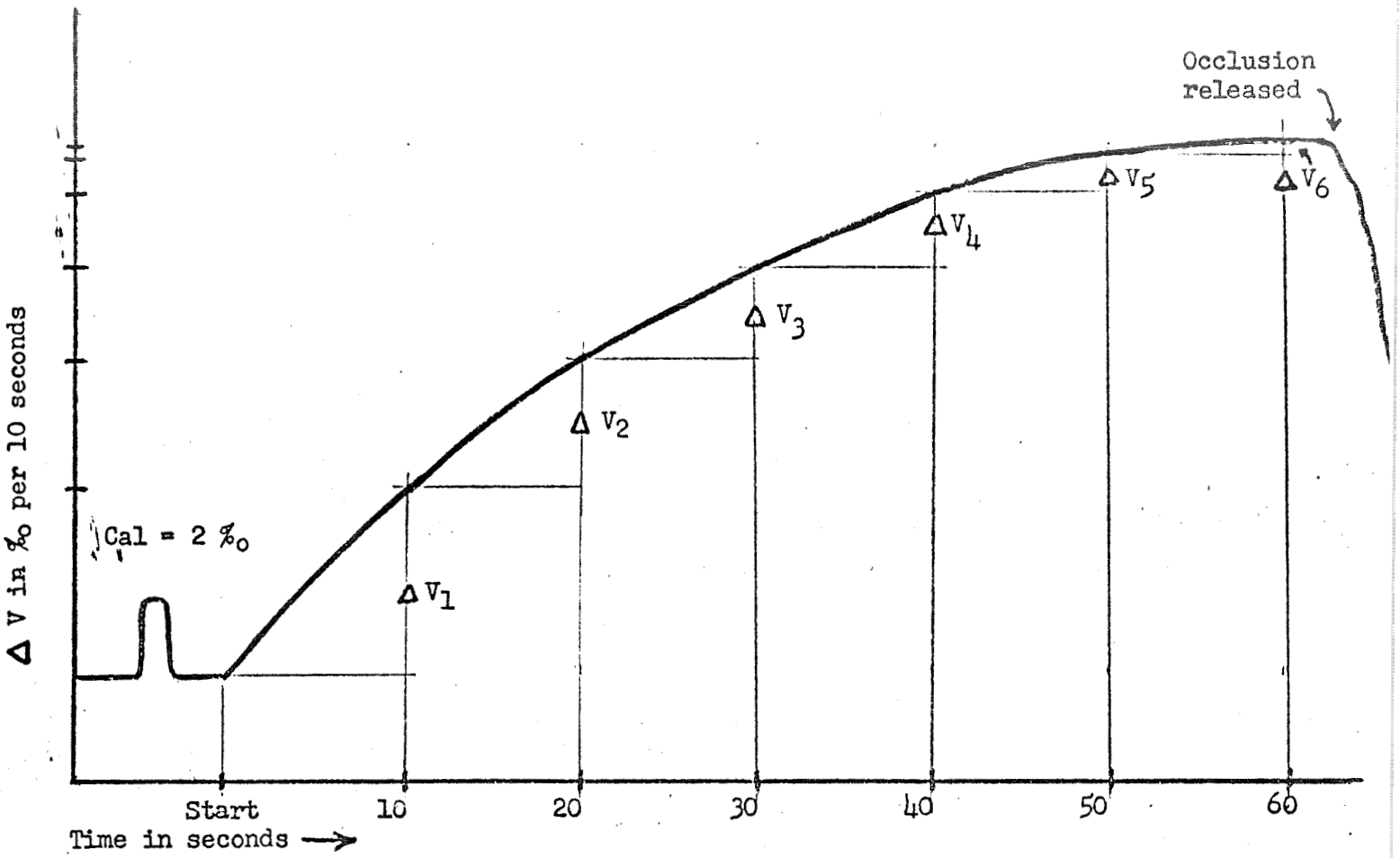
A normal, single stage, venous occlusion plethysmogram is performed as follows: The plethysmograph amplifier gain is reduced to approx. 1/70. The pulsations of the cardiac pulse are now barely visible in the baseline signal.
At "Start" the venous occlusion cuff is rapidly inflated to a pressure somewhat above the diastolic blood pressure. Arterial blood continues to flow into the limb segment, causing a gradual volume increase. After 10 seconds the occlusion pressure is released.
The volume variation per minute can be calculated:

$$\% \ V_{minute} = 6 \times \% \ V_{10 \ seconds}.$$



A more complete evaluation, to be included in the FBB, is shown on Page No. II-14- A 4.

13. Miscellaneous information, details on referenced items, etc.



When the occlusion of the limb segment is continued, the volume increase per unit time (here taken as 10 seconds) will gradually decrease, until the back pressure in the limb segment is equal to the systolic blood pressure. At this point no further volume increase will take place.

Say that it takes a total of sixty seconds to reach this point of maximum filling.

The DMS must measure the volume increase for each 10-second period, multiply this value by six, and record and print out this value. The next measurement begins where the previous measurement ended.

The printed record of the experiment shown in the above graph would be approximately:

4.86, 3.42, 2.34, 1.80, 0.90, 0.36 (% volume increase per minute).

The figures correspond to bloodflow in $cm^3/100\ cm^3$ of tissue/ minute.

It is felt that this procedure provides an excellent representation of venous distensibility, since it is only dependent upon the systolic blood pressure at the time the last ΔV measurement is taken, and not upon the instantaneous blood flow (= filling rate) during the measurement of V_1, V_2, etc.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Vascular Dynamics

MEASUREMENT GROUP : Cardiovascular (Vascular Dynamics)

MEASUREMENT : Limb Plethysmography (Ultrasonic Method)

MEASUREMENT DESCRIPTION : Meausrement of increase in lower leg volume as the result of LBNP exposure, with and without restriction of venous return by means of an occlusive thigh cuff, by measuring the phase angle between transmitted and received ultrasonic signals.

1. Input signal characteristics — Pulses of ultrasonic square waves.

2. Electrodes, transducers — Ultrasonic transmit and receive X-tals (Barium titanate or equivalent); crystal holder; Score paste for signal coupling.

3. Signal conditioner(s) — Signal generator (100 K Hz), multivibrator (50 K Hz), amplifiers, demodulator, phase shifter, phase detector.

4. Range of measurement — 0 - 90° phase shift.

5. Frequency of measurement — Once per 1 - 2 weeks.

6. Output signal characteristics

analog/digital	analog voltage.
amplitude	0 - 5 volts.
frequency range	DC to 100 Hz.
accuracy/sensitivity	0.5%

7. Calibration

type & technique	Precalibrated by comparing against strain gage technique, in conjunction with phase shift null setting.
frequency	

8. Data handling

display analog/digital (raw, processed; local, remoto; continuous, intermittent)	Raw, analog, detector square wave output on Display Monitor; Intermittent. Raw, analog phase angle plethysmogram on Display Monitor and pen recorder; Continuous.
recording analog/digital (raw, processed; continuous, intermittent)	Phase angle plethysmogram: raw, analog, digitized, continuous.
manual/programmed A or D switching	Signal routing programmed.
manual/verbal data entry	Subject identification and Measurement number.
A/D conversion frequency	200 sps. (phase angle plethysmogram).
storage time analog/digital	Digitized until next data dump.
recording/storage quantity per subject	Approx. 10 minutes.

9. Derived quantities — % increase in limb volume.

other measurements required simultaneously for calculations	10-second time base.
digital computation	See # 13.
display analog/digital; location; updating frequency	Digital display of % increase in limb volume every 10 seconds on PBDM. Analog on Vascular Dynamics panel to show cumulative volume increase.
recording analog/digital	Digitized value every 10 seconds.
storage time analog/digital	Digitized until next data dump.

10. Comparison with previous data — N/A.

11. Analog/digital display range & resolution/accuracy — % increase in limb volume, 0 - 10 % ± 0.1 % accuracy, digital. Analog ± 0.5 % accuracy.

12. Printout frequency & other requirements — Every 10 seconds.

13. Miscellaneous information, details on referenced items, etc.
Recording sequence: subject and measurement identification, plethysmographic mode identification (ultrasonic), digital values of limb volume increase in % every 10 seconds.

PRINCIPLE OF COMPUTATION.

The average velocity of ultrasonic waves through a limb consisting largely of muscles and fat, is assumed to be 1600 meter/second = 1,600,000 millimeter/second.

For a carries frequency of 100 K Hz, the wavelength

$$= \frac{1,600,000}{100,000} = 16 \text{ millimeters.}$$

1° of phase shift corresponds to a limb diameter increase

$$\Delta D = \frac{16}{360} = 0.0445 \text{ millimeter.}$$

The percentage increase in circumference

$$\%\Delta C = \frac{\Delta D}{D} (100)$$

It has been shown that

$$1 \%\Delta C = 2 \%\Delta \text{Volume.}$$

With the initial diameter of the limb, D, measured, and D provided by the equipment as degrees of phase shift, the percentage volume increase can be calculated.

$$\%\Delta V = \frac{1}{2} \frac{\Delta D}{D} \cdot 100$$

The value of D must be entered into the DMS manually before each measurement run.

Recording details have been presented on Measurement Requirements Data Sheets II-14- A 3 and A 4. The same applies for this measurement.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Vascular Dynamics

MEASUREMENT GROUP : Hematology

MEASUREMENT : Capillary Fragility (Rumple Leede)

MEASUREMENT DESCRIPTION : Measurement of resistance to rupture of superficial capillaries as the result of a 5-minute application of a blood pressure cuff inflated to a pressure of 100 mm Hg.

1. Input signal characteristics	Visual observation only
2. Electrodes, transducers	Standard spygmomanometer cuff with squeeze bulb and aneroid manometer
3. Signal conditioner(s)	N/A
4. Range of measurement	Subjective evaluation
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	N/A
amplitude	N/A
frequency range	N/A
accuracy/sensitivity	N/A
7. Calibration	
type & technique	N/A
frequency	N/A

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	N/A
recording analog/digital (raw, processed; continuous, intermittent)	Record subjective evaluation, graded (0 to 4) on data entry keyboard
manual/programmed A or D switching	N/A
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	N/A
storage time analog/digital	Digitized evaluation till next data dump.
recording/storage quantity per subject	Minimal

9. Derived quantities

other measurements required simultaneously for calculations	N/A
digital computation	N/A
display analog/digital; location; updating frequency	N/A
recording analog/digital	N/A
storage time analog/digital	N/A

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	N/A
12. Printout frequency & other requirements	Once per 1 - 2 weeks

13. Miscellaneous information, details on referenced items, etc.

Recording sequence: subject and measurement identification; numerical value of subjective observation of superficial petechial (pinpoint hemorrhages) distal to blood pressure cuff.

SECTION III-F

IMBLMS FUNCTIONAL BREADBOARD PERFORMANCE/DESIGN REQUIREMENTS

RESPIRATORY SUBSYSTEM

RESPIRATORY

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

3.1 Performance
3.1.1 Functional
3.1.1.1 Overall System Requirements
3.1.1.2 Invididual Test Requirements
3.2 Interface Requirements
3.2.1 Interface Requirements-Subject/Respiratory Equipment
3.2.2 Interface Requirements-Respiratory Equipment/PBDM Station
3.2.3 Interface Requirements-Respiratory Equipment and Operator
3.3 Design and Construction
3.3.1 General Features
3.3.2 Equipment Requirements
3.3.2.1 Flowmeters, Valves and Plumbing
3.3.2.2 Transducers and Signal Conditioners
3.3.2.3 Gas Analyzers
3.3.3 Display and Controls
3.3.4 Calibration and Power Requirements

4.0 DESCRIPTIVE DEFINITION AND BLOCK DIAGRAMS

APPENDIX - MEASUREMENT REQUIREMENTS DATA SHEETS

1.0 INTRODUCTION

This document establishes the requirements for the performance and design of the Respiratory Measurement Subsystem together with the requirements necessary to provide interface with other FBB subsystems. The Respiratory Measurement Subsystem is comprised of two open-loop flow circuits, rapid-response gas analyzers, integrating flowmeters, and a simple arrangement of control valves. The Respiratory Measurement System will be used to obtain twenty-five pulmonary measurements and in addition, provide calibration, instrument switching and control, and connection to the PBDM for numerous computational operations.

2.0 APPLICABLE DOCUMENTS

Section III-A FBB System Requirements document contains all applicable documents.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional Requirements. -

3.1.1.1 Overall System Requirements. - The Respiratory Subsystem will be capable of obtaining respiratory measurements in the following areas: (a) lung volumes, (b) ventilation, (c) breathing mechanics, and (d) gas distribution. Measurement data will be displayed on CRT monitors and digital readouts, and preserved on peripheral tape recording equipment and oscillographic recorders.

The respiratory measurement categories, measurement identification, and associated equipment items are given in Table 1.

All respiratory measurements will be obtained with the subject stationed at the integrated respiratory equipment section. The subject/equipment interface height must be adjustable to accommodate anthropometric variance and allow for performance of individual subjects on a bicycle ergometer.

Gas analyzers and flowmeters will be precalibrated; however, pre- and post-measurement calibrations (electrical only) are to be integrated into the preliminary measurement routines of the data management system. Appropriate routing of signals from the flowmeters and gas analyzers is also to be handled by the data management system. Computations for certain respiratory measurements are complex, however, the required computations can generally be categorized as follows:

(a) those which require the introduction of one or more scaling factors

(b) signal delay routines (looping)

(c) "multiplier" routines where two or more processed outputs are involved

(d) simple integrations over preselected time periods.

RESPIRATORY MEASUREMENT CATEGORY	MEASUREMENT DESCRIPTION	Flowmeter - I	Flowmeter - II	Volume Integration	Added Volume Determination	Derived Value	O_2 Analyzer	CO_2 Analyzer	N_2 Analyzer	He + CO Analyzer	Special Equipment	Remarks
Lung Volume	Inspiratory Capacity					X						IC=VC - ERV
	Expiratory Reserve Volume	X		X								
	Vital Capacity	X		X								
	Residual Volume		X	X	X				X			
	Total Lung Capacity					X						TLC = VC + VR
Ventilation	Respiration Rate	X										
	Tidal Volume	X		X								
	Minute Tidal Volume	X		X	X							
	Respiratory Dead Space		X	X					X			
	Alveolar Distribution		X	X					X			
Breathing Mechanics	Maximum Breathing Capacity	X		X	X							
	Timed Vital Capacity	X		X								1 and 3 seconds
	Max. Inspiratory Flow	X										Peak Flow Value
	Max. Expiratory Flow	X										Peak Flow Value
	Airway Resistance	X									X	Interrupter Technique
	Lung Compliance	X		X							X	Requires Esophageal Balloon
	Minute Alveolar Ventilation		X	X				X				
Gas Distribution	Alveolar PO_2						X					
	Alveolar PCO_2							X				
	O_2 Consumption		X	X			X	X				
	CO_2 Production		X		X			X				
	Respiratory Quotient					X						R.Q. = $\frac{CO_2 \text{ Produced}}{O_2 \text{ Consumption}}$
	Diffusing Capacity	X		X						X	X	Box Balloon Assembly
Cardiac Output	CO_2 Rebreathing Technique			X				X			X	

Table 1 - Measurement Categories, Identification, and Associated Equipment

In addition to the Respiratory Measurements, the Respiratory Subsystem will be responsible for monitoring temperature, pressure, humidity, and atmospheric composition. The range and accuracy of the measurements will be:

	Range	Accuracy
Ambient temperature	32 to 122°F	± 1/2°F
Ambient humidity	10 to 99% RH	± 3% RH
Ambient pressure	710 to 790 mm Hg	± 1 mm Hg
Nitrogen content	0 to 85%	± 1%
Oxygen content	1 to 100%	± 1/2% (in the 11 to 21% range)
Carbon dioxide content	0 to 10%	0.125%

The effects of non-standard cabin atmosphere on pulmonary measurements for the Flight IMBLMS could possibly be quite profound. Variations in total pressure are less of a problem than variations in the oxygen/nitrogen ratio. Standard correction factors for respiratory gas equations would be invalid in the latter case. A voluminous amount of computer storage space for pulmonary table data would be required to perform the necessary computations. A solution to this Flight IMBLMS problem would be to provide the necessary quantity of standard-composition gases or perform the computations on the ground. Pulmonary calculations for the FBB will be based on a normal gas composition and usual variations in atmospheric pressure.

3.1.1.2 Individual Test Requirements. - The functional requirements for each of the pulmonary measurements is given in this section. A description of the output signal characteristics and computations associated with each measurement may be found in the Section III-F Appendix.

Mode A - (Spirometry Measurements). - Standard spirometric measurements are performed with a system that incorporates the following equipment: mouthpiece, pneumotachometer head, flow transducer, and volume integrator.

The flow transducer converts the Δ pressure across the pneumotachometer head into a signal which is proportional to flow. This signal is fed into the volume integrator to obtain a volumetric measurement of the inspired and/or the expired air. The outputs from the flow transducer and volume integrator are processed by the data management system to obtain a digital representation of flow and volume. In order to obtain the desired accuracy of these measurements, it is necessary to measure the temperature of the expired air and the barometric pressure.

Mode B - (Energy Metabolism and Expired N_2 Determinations). - The measurement of oxygen consumption, carbon dioxide production, and expired nitrogen determinations require the same equipment as used in Mode A augmented by a one-way valve (which separates the inspired from the expired air) and gas analyzers to determine the partial pressure of oxygen, carbon dioxide and nitrogen. The outputs from the gas analyzers are fed into the data management

system in order to perform the necessary computations.

Mode C (Special Measurements). - Special equipment items are required for the measurement of the following parameters: lung compliance, airway resistance, diffusive capacity and cardiac output.

This equipment includes a box-balloon assembly, a rebreathing bag, a flow interrupter , a pressure transducer, an esophageal balloon, and He and CO gas analyzers. Since it is necessary to measure the volume of the gas mixture inspired from the box-balloon assembly, a pneumotachometer is required for determination of the inspired volume.

Routine pulmonary measurements will include:

Vital Capacity (VC)

Timed Vital Capacity ($VC_{1''}$, $VC_{3''}$)

Tidal Volume (V_T)

Minute Tidal Volume (MTV)

Expiratory Reserve Volume (ERV)

Inspiratory Capacity (IC)

Maximum Breathing Capacity (MBC)

Maximum Inspiratory Flow (MIF)

Maximum Expiratory Flow (MEF)

Vital Capacity (VC). - This test provides a measure of the subject's functional lung volume; that is, the maximum volume of gas that can be expelled following a maximum inspiration. Vital capacity is the most widely used measurement for assessing overall pulmonary function.

Timed Vital Capacity ($VC_{1''}$, $VC_{3''}$). - This is a simple test which measures the volume that is expired by maximal effort at 1 and 3 seconds. This measurement provides an indication of the force or strength of expiration.

Tidal Volume (V_T). - Tidal volume is the depth of normal breathing, i.e., the volume of gas inspired or expired during each respiratory cycle. This measurement provides an indication of the adequacy of pulmonary ventilation. Other factors must be considered along with the tidal volume in order to make a proper assessment of the adequacy of alveolar ventilation.

Minute Tidal Volume (MTV). - This is a measurement of the volume of air inspired or expired during the course of one minute. This is performed with a integrating flowmeter which totalizes the expired portions of normal breathing.

Expiratory Reserve Volume (ERV). - This is the maximal volume of gas that can be expired from the normal end-expiratory level. This measurement is subject to considerable variability even within the same subject. Normally the respiratory

reserve volume is 25% of the vital capacity.

Inspiratory Capacity (IC). - This is the maximal volume of gas that can be inspired from a resting expiratory level. This is to be derived from the measurements of vital capacity and expiratory reserve volume, i.e.,

$$IC = VC - ERV$$

The inspiratory capacity is normally 75% of the vital capacity.

Maximum Breathing Capacity (MBC). - This is the maximal volume of gas that can be breathed per minute. In this measurement procedures, the subject moves as much air as possible during a 15 second period. The ability of the subject to breath at sustained high velocity is dependent upon several factors: the muscular force available, the compliance of the lungs and thoracic cage, and the resistance of the airway and pulmonary tissues. This measurement is performed with a flowmeter, and an integrator which totalizes the expired volume measurement.

Maximum Inspiratory Flow (MIF). - This test provides a measure of the rapidity with which a subject fills his lungs. It does not provide information as to the specific mechanical factors involved but it separates inspiratory and expiratory efforts. The measured value is expressed in liters per second and may be obtained directly from the flowmeter output signal.

Maximum Expiratory Flow (MEF). - This is the maximum flow rate attainable during expiration. The discussion under Maximum Inspiratory Flow is applicable.

The remaining pulmonary measurements are as follows:

Residual Volume (V_R). - This is the measure of the volume of air remaining in the lungs after a maximum expiration. The measurement procedure requires the subject to breath 100% oxygen until the nitrogen, which formerly made up 80% of the residual volume, is removed. The output signals from the flowmeter and nitrogen analyzer provide an exponential decay function from which the computation of residual volume may be obtained.

Total Lung Capacity (TLC). - This is the volume of gas contained in the lung at the end of a maximal inspiration. Total lung capacity is derived from measurement of vital capacity and residual volume (V_R).

$$TLC = V_R + VC$$

Alveolar Distribution (V_A). - This test provides a semi-qualitative measure of the evenness of gas distribution in the alveoli of the lung. The subject inspires a single breath of 100% oxygen and expires slowly. The change in the fractional concentration of nitrogen between 750 and 1250 ml of expired air is the measurement of interest.

Respiratory Deadspace (V_D). - This is defined as the volume of gas contained in the conducting passages of the pulmonary system between the subject's mouth and the alveloi. To obtain a measure of dead space the subject must inspire a single breath of 100% oxygen and the expired air must be monitored for its

nitrogen concentration and total volume.

Partial Pressures of Oxygen and Carbon Dioxide in the Alveoli ($F_{A_{O_2},CO_2}$).- The fractional concentration of oxygen and carbon dioxide at the end-expiratory level closely approximates that of alveolar air. Measurement of these values may be accomplished by peak-detection of the signal outputs from the CO_2 and O_2 gas analyzers. The minimal reading of oxygen concentration and the maximal reading of carbon dioxide are considered to be representative of alveolar air.

Carbon Dioxide Production (V_{CO_2}). - This measurement provides an indication of the activity level of the subject; it tends to increase in exercise and in states of anxiety. Actual measurement requires monitoring the volume and fractional concentration of carbon dioxide in the expired air. This measurement is to be provided on a continuous, as well as, a breath-by-breath basis.

Oxygen Consumption (V_{O_2}). - Oxygen consumption is defined as the volume of oxygen consumed by the subject per minute. This measurement requires analysis of several parameters: inspired oxygen concentration, expired oxygen concentration, expired volume, ambient pressure, and expired nitrogen concentration. (See Section III-F-Appendix for details of the computations). Oxygen consumption is to be computed on a continuous, as well as, a breath-by-breath basis.

Respiratory Quotient (R.Q.). - Knowledge of the Respiratory Quotient value provides information about the oxidation of foodstuffs. This measurement is defined as the ratio of carbon dioxide produced to oxygen consumed. Therefore, it is obtained directly from these two measurements.

Diffusing Capacity (D_{CO}). - This is a measure of ability of the lung to move the inspired gases from the alveoli to the pulmonary blood vessels. This measurement is to be obtained using the Single-Breath, Carbon Monoxide Method. The subject is required to inspire maximally from a mixture of known concentrations of carbon dioxide and helium. The subject then breath-holds for approximately ten seconds. The alveolar gas is collected and analyzed with the CO and He analyzers, and from this, the Diffusing Capacity calculated.

Cardiac Output. - The Carbon Dioxide Rebreathing Method is to be used for the determination of cardiac output. This involves the rebreathing of a known mixture of carbon dioxide from a bag and the simultaneous monitoring of the fractional concentration of carbon dioxide. The value of interest is the equilibration point of carbon dioxide in the subject's expired volume and in the contents of the rebreathing bag. Prior determination of the subject's carbon dioxide production permits the computation of the cardiac output.

Pulmonary Airway Resistance. - The measurement of pulmonary resistance is to be performed with the "interrupter" technique. This procedures involves a special piece of equipment which interrupts the air flow in the breathing circuit. A pressure-sensing element is incorporated in to the design of the tracheal side of the appartus. The measured pressure and the (pre-interrupted) flow value are used to compute the airway resistance.

Lung Compliance. - This measurement requires the determination of (a) intrapleural pressure, and (b) inspired volume. An esophageal balloon is swallowed by the subject for the purpose of measuring intrapleural pressure. A flowmeter is used to measure the inspired volume. The subject breaths at progressively

increased volumes, for at least 3 breaths. The pressure in the esophageal balloon is recorded at the peak of each inspiration. The resultant data is plotted on a pressure-volume curve. The slope of the line connecting the points represents the lung compliance.

3.2 Interface Requirements

The interface requirements and constraints imposed by the functional, physical and procedural relationships between the Respiratory Subsystem and the PBDM station, and between the respiratory Subsystem, the operator, and the subject will be discussed below.

3.2.1 Interface Requirements - Subject/Respiratory Equipment. - Respiratory measurements require close and direct contact between the subject and initial measurement equipment. This is due to the sensitivity of the equipment, the need for minimizing pressure drop through the ducting in order to avoid unnaturally great breathing effort and the necessity of avoiding the transit time delay and the dilution which occur if the duct or sampling lines are too long.

The subject's degree of participation in the respiratory measurement, in both passive and active modes is restricted to performing specified breathing maneuvers. This imposes the requirement to provide critical measurement equipment at the subject's location and display and control equipment at a nearby operator's position.

3.2.2 Interface Requirements - Respiratory Equipment/PBDM Station. - Determination of the subject's respiratory functions require data which are either direct measurements (e.g., flow rate or gas composition) or indirect requiring computation support for derived results. Gas analyses provide electrical output normally directed to display meters for quantitative presentation of gas composition. CO_2, and N_2 Gas Analyzers are typical examples. Many of the displayed outputs are not significant by themselves but are utilized in computing derived quantities.

The major interface between the respiratory equipment and the PBDM station performs the function of routing electrical data to the PBDM station for analog switching, digital computation, and ultimately digital readout/recording.

3.2.3 Interface Requirements - Respiratory Equipment and Operator. - While operating the Respiratory Subsystem, it is necessary to have the subject physically adjacent to the station and the operator. This permits the operator to establish initial calibration and have the subject coordinate his breathing with duct valve operation during the tests. The operator's prime duties during respiratory measurements are to establish correct procedural steps, monitor the measurement range, ensure the validity of the test, and monitor the well-being of the subject.

3.3 Design and Construction

3.3.1 General Features. - Consistent with the design philosophy of employing equipment orientated toward spaceflight hardware, breathing flowrates and accumulated volumes of expired breath should be measured not by the conventional bulky

spirometers, but by pneumotachographs for rate of flow, and electronic integration of this flow to obtain volume. Dead air space in the breathing ducts should be minimized, and the sampling lines to the gas analyzers should be short. Special equipment items, such as a box balloon, which are required for certain pulmonary measurements, should be integrated into the total design of the Respiratory Measurement System.

Accurate analysis of respiratory gases is essential for many of the measurements planned for the FBB. Breath-to-breath determinations require the use of gas analyzers with response times of less than 0.1 seconds.

The primary measurments should be displayed on analog meters. A capability for visible chart recording should be available for FBB test evaluation. Those quantities needed to perform computations should be routed to the data management system.

The physical configuration of the respiratory measurement equipment should provide for three main groupings: (1) a plumbing arrangement of ducts, valves, flowmeters, etc.; (a) an array of gas analyzers plus box-balloon, environmental monitors and micromanometer; and (3) a group of electronic equipment associated with the flowmeters.

This equipment will be arranged for optimum performance in several modes.

3.3.2 Equipment Requirements. -

3.3.2.1 Flowmeters, Valves and Plumbing. - The plumbing ducts should have minimum bends and be short and not less than one inch inside diameter to minimize resistance to flow. The flowpath to and from the mouthpiece must be directed by a valve to one of four ducts to provide routing to different equipment to perform various measurements. Several other two position valves will be needed to direct branch flow.

Pulmonary airway resistance measurements requires a rapidly closing and opening electrically actuated flow interrupter.

A "J" valve is required to provide separate paths for inspiration and expiration during Mode B operation. This J valve should have a pressure drop of less than 5 cm of water at a flow rate of 500 liters per minute.

The flow meters should have a linear relationship of pressure drop to flow and be able to measure flows up to 500 liters per minute with a pressure drop of less than 1.1 cm of water.

3.3.2.2 Transducers and Signal Conditioners. - Basic output characteristics which all of the signal conditioners should have is a DC voltage range of 0 to 5 and an output inpedance of less than 200 ohms. A majority of the equipment does not meet these limits and will therefore require buffer amplifiers before interfacing with the data management system.

The pressure differences generated by the flowmeters need to be converted to an electrical signal. This flow signal also must be integrated electrically to produce a signal analogous to volume.

A third pressure transducer will be needed to measure the pressure pulse which occurs when the flow interrupter closes; this transducer should be capable of handling pressures up to 0.2 psid with a rapid response.

In order to enable a computer to correct for the effect of temperature variations on flowmeters, rapid response thermistors will be required at both of the flowmeters. The signal conditioner for these thermistors must not dissipate more than 0.1 milliwatt in each thermistor lest it become heated and gives a false reading.

3.3.2.3 Gas Analyzers. - A total of five gas analyzers will be needed to perform the required pulmonary measurements. Three of these, oxygen, nitrogen and carbon dioxide, will be used for breath-by-breath analyses, and must therefore have response times of less than 0.1 second. Oxygen content must be measured with an accuracy of $\pm$ 1/2%, nitrogen $\pm$ 1% and carbon dioxide $\pm$ 0.125%. To avoid dilution and time lag, the sampling lines to these three analyzers must tap the breathing duct immediately adjacent to the subject's mouthpiece.

The measurement of Lung Diffusion Capacity will require two additional gas analyzers for helium and carbon monoxide. The sample which is supplied to the helium analyzer will need to be previously dried by an in-line desiccant container to avoid errors due to water vapor content. Accuracy of helium and carbon monoxide gas analyzers should be within 3% of the meter reading.

3.3.3 Display and Controls. - The signal conditioners, integrators, amplifiers, chart recorder and analog meters for flow, volume and breathing temperature complete with their respective controls should be located on an end panel of the PBDM (See Figure 1).

The gas analyzers, box balloon, environmental monitors and micromanometer should be housed in an auxiliary cabinet located at the right end of the PBDM, and the plumbing arrangement of ducts, valves, flowmeters, etc. should be installed on the right hand side of this cabinet. (See Figure 2). The height of the mouthpiece must be adjustable to conform with the height of the subject when seated on the ergometer.

3.3.4 Calibration and Power Requirements. - The CO_2 gas analyzer has an integral device for automatic calibration without using sample gas. The O_2 gas analyzer does not require calibration as long as the ambient air contains 20.9% O_2. The N_2 analyzer does not routinely require calibration gases. At periodic intervals a gas calibration procedure can be employed for verification. The CO analyzer does require calibration using a cylinder of calibration gas, which is supplied. The He gas analyzer does not require any sample gas since calibration is electrical. Total power required by all respiratory equipment including the 2 channel strip recorder is approximately 1400 watts at 115 v, 60 Hz.

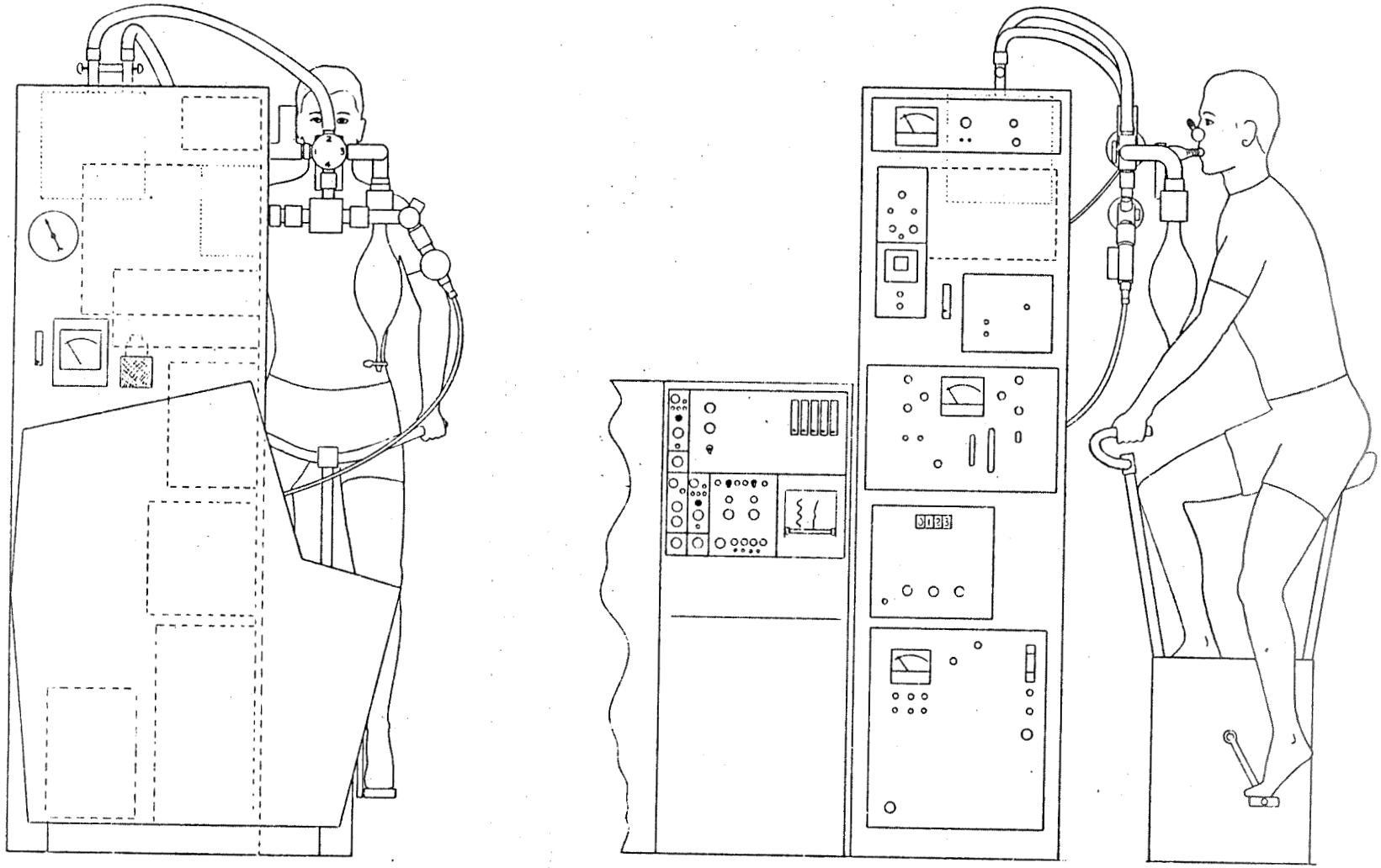


Fig. 1 Respiratory Subsystem

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

4.1 Conceptual Design

4.1.1 Design objectives. - The respiratory measurement equipment must be versatile enough to measure 25 different pulmonary quantitites (some directly, and some by computation). At the same time it should be simple to operate and as compact as possible. The equipment must be compatible with other (peripheral) equipment such as the ergometer and capable of accommodating various individual subjects as well as conditions varying from exertion to sedentary.

4.1.2 Design Concept. - The equipment must interface efficiently with the subject and the operator. The accessibility is illustrated in Fig. 1 of Section 3.3. The subject's mouthpiece leads to a plumbing arrangement of ducts, valves and flowmeters. Small tubes carry gas samples to the gas analyzers which are housed in a vertical cabinet together with a box-balloon, micromanometer and the environmental monitors. The PBDM console equipment consists of electronic instruments associated with the flowmeters.

4.2 Block Diagrams

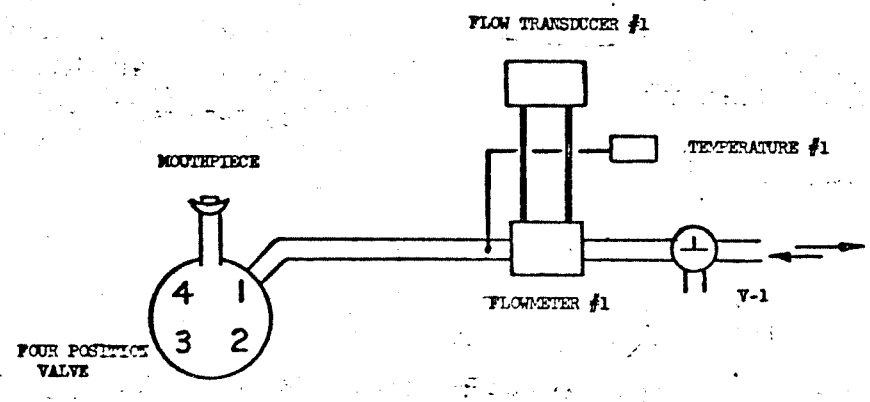
4.2.1 Operational Modes. - The respiratory measurement subsystem operates in three modes.

4.2.1.1 Mode A, (Fig. 2) - The subject's mouthpiece is connected to a four position valve which is turned to position #1. This position opens a tube leading through a pneumotachograph type of flowmeter and valve V1 to room ambient. Flow transducer #1 converts the pressure difference across the flowmeter to an electrical signal proportional to rate of flow. Temperature #1 at the flowmeter is measured electrically by a thermistor.

4.2.1.2 Mode B, (Fig. 3) - The four position valve is turned to position #4. This connects the subject's mouthpiece with the J valve. During inspiration, either ambient air or pure oxygen are inhaled depending upon the position of T valve V-2. The oxygen tank pressure is reduced through two successive regulators. When the subject exhales, the expired breath is directed by the J valve through Flowmeter #2 and exhausted to ambient. Flow Transducer #2 converts the pressure drop to an electrical signal analogous to rate of flow.

The gas sampling tube is connected immediately adjacent to the mouthpiece. Suction pumps draw a continuous sampling of both inspired and expired gas into the oxygen, carbon dioxide and nitrogen analyzers. The gas sample is then returned to the duct just below position #4 of the four position valve.

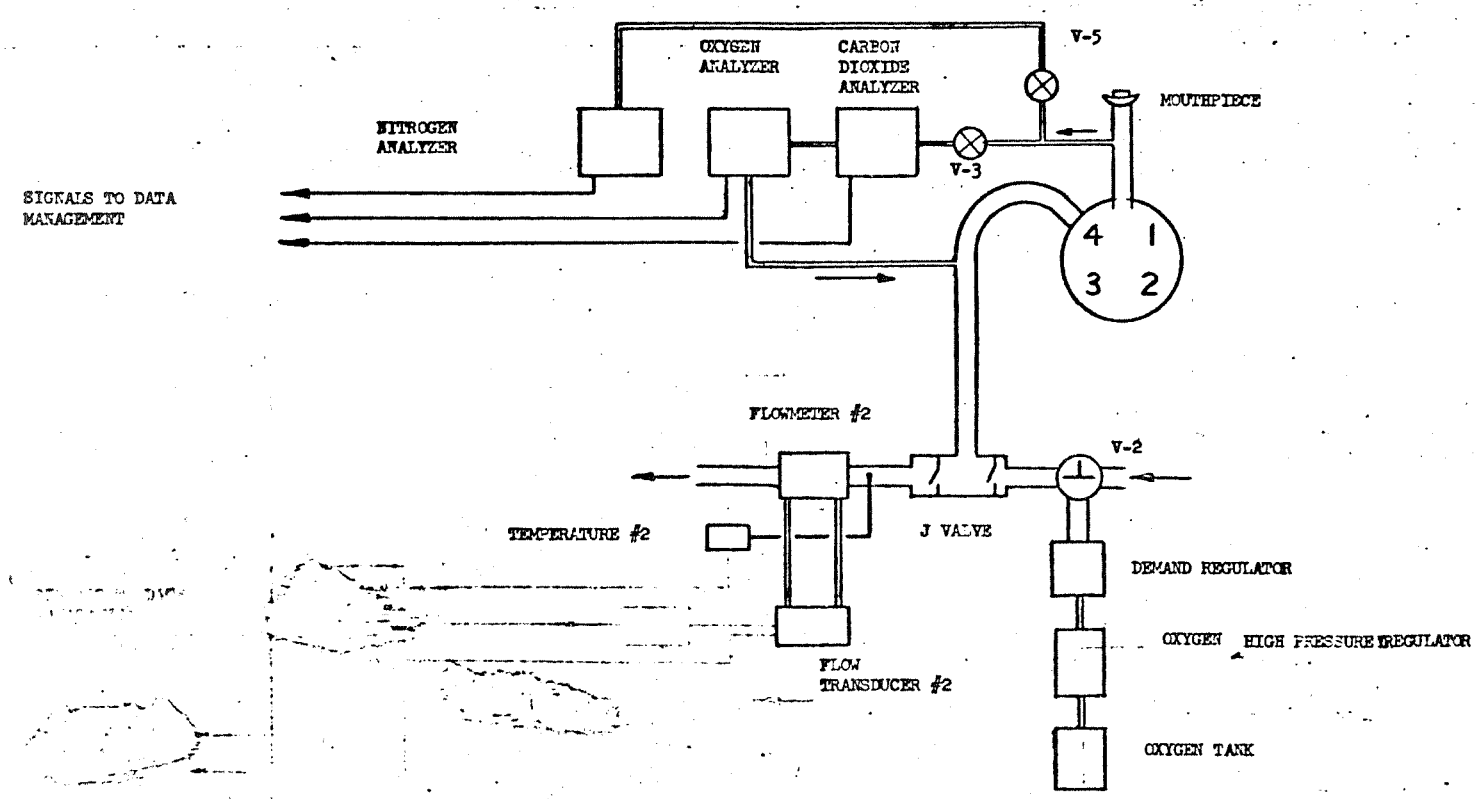
4.2.1.3 Mode C, (Special Measurements, Fig. 4). - Pulmonary Airway Resistance is measured by use of the flow interruptor shown in Fig. 4 . This is a solenoid operated shutter which is used to momentarily block the duct leading from position #1 during expiration. When this happens, it generates a pressure pulse which is sensed by the differential pressure transducer, and is displayed quantitatively on the long-persistence oscilloscope at the PBDM Station.



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 2. RESPIRATORY - MODE A CONFIGURATION		
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO.	REV
SUPV		APPD				
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B / SH / OF	III-F-13	

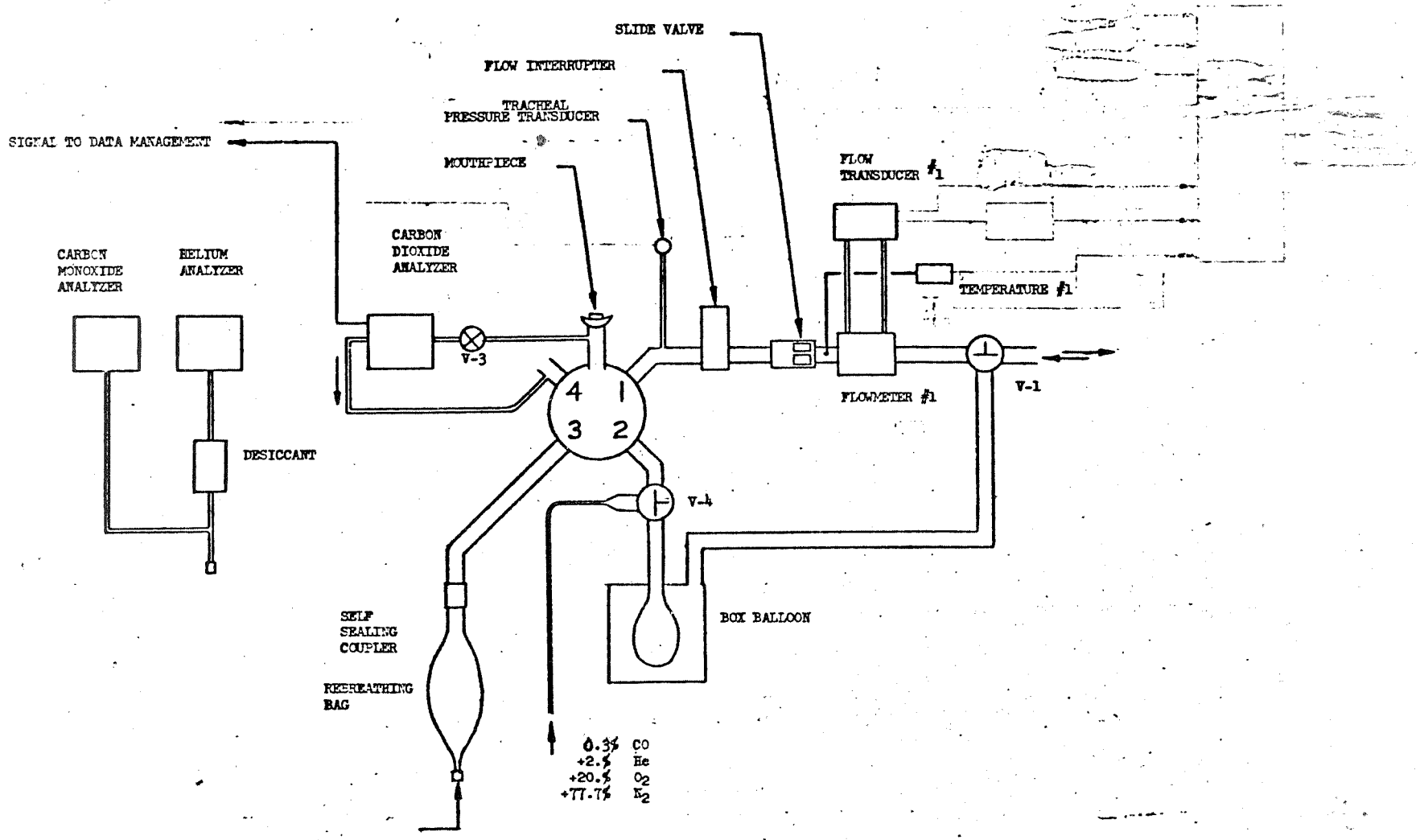
Form LMSC 2620B



SCHEMATIC BLOCK DIAGRAM

ORIGR DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA		TITLE FIGURE 3. RESPIRATORY - MODE B CONFIGURATION	
CHK	APPD			CODE IDENT NO. 1091	DOCUMENT NO. III-F-14 / REV
SUPV	APPD			SIZE B / SH / OF	
SYS ENGR	SPO/GSETD	CEI/FD NO	CONTR NO.		

Form LMSC 26708



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 4. RESPIRATORY - MODE C CONFIGURATION	
CHK		APPD		CODE IDENT NO. 17[illegible]	DOCUMENT NO. III-F-15 REV
SUPV		APPD			
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B SH OF	

Form LMSC 26208

Diffusing capacity is obtained by means of the single breath, carbon monoxide method. This measurement is performed using equipment shown in Fig. 4. T Valve V-4 is opened long enough to admit a pressurized special mixture of 0.3% carbon monoxide, 2% helium, 20% oxygen and 77.7% nitrogen into the balloon portion of the Box-Balloon and also to fill the breathing pipeline. The slide valve located between the Flow Interrupter and Flowmeter #1 is opened to ambient. The four position valve is then turned to position #2 and the subject inspires deeply from the balloon in the box. During this inspiration, the flow of ambient air into the box is equal to the total amount of inhalation from the balloon, and is measured by Volume Integrator #1. As soon as the inspiration has been completed the four position valve is indexed between ports #3 and #4, thereby closing the valve while the subject holds his breath for 10 seconds. At the end of the 10 seconds, the valve is turned to position 4 to vent a small amount of dead space gas, and then the valve is quickly switched to position 3 so that the remainder of this exhalation is collected in the five liter Rebreathing Bag. This bag is then disconnected at a self-sealing coupler and the sample is conveyed to a Godart IA7103 CO analyzer and via a drying compound to a Collins P495 helium analyzer. The results of these analyses are used to calculate Diffusing Capacity.

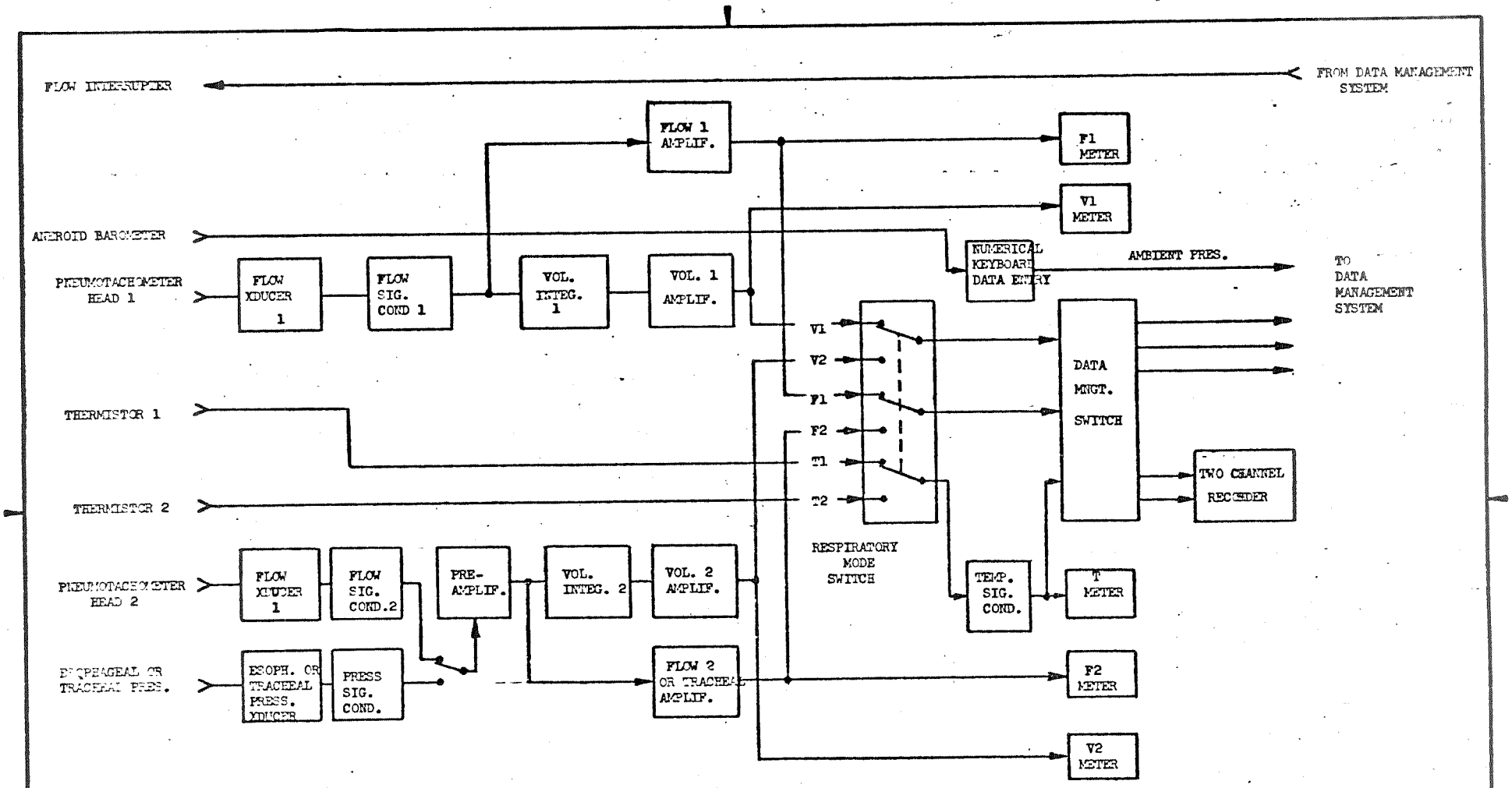
Cardiac output is determined by the carbon dioxide rebreathing method. The Rebreathing Bag is filled with a known mixture of carbon dioxide and the line is flushed with this mixture up to valve position #3. The subject commences breathing with the valve set at position #3 and the carbon dioxide analyzer reading is monitored. The value of interest is the equilibrium point of carbon dioxide in the subject's expired breath with the contents of the rebreathing bag. The cardiac output computation requires this value as well as a prior determination of the subject's carbon dioxide production.

Lung compliance requires the determination of (a) intrapleural pressure, and (b) inspired volume. An esophogeal balloon is swallowed by the subject. Attached to the outside of the balloon is a small plastic tube whose outer end is connected to a differential pressure transducer. The four position valve is turned to #1 and the subject inspires through Flowmeter #1, thereby enabling measurement of the inspired volume. The subject must breath at progressively increased volumes for at least 3 breaths. The pressure in the esophogeal balloon is recorded at the peak of each inspiration. The resultant data is plotted, pressure versus volume, for use in determining lung compliance.

4.2.2 Electrical Equipment. - Fig. 5 shows the electrical equipment employed to measure flow, volume, temperature and pressure. The flow of information is from left to right except for a signal from the Data Management Subsystem to the Flow Interrupter (shown at top). This signal is given when the flow rises to a predetermined valve in either direction.

In general, the similar types of equipment are shown in vertical columns, from the sensors at the left to the analog meters and recorder at the right. Two manually operated switches are shown. The one at the lower left enables a single preamplifier and a single amplifier to be used for either esophageal or tracheal pressure. The other is the respiratory mode switch which is turned to the upper position for Modes A and C and the lower position for Mode B.

A manual keyboard entry is shown to supply the value of ambient barometric pressure to the Data Management Subsystem, so that it may be used in computing mass rates of flow, or accumulated volume at standard temperature and pressure.



ELECTRICAL SCHEMATIC BLOCK DIAGRAM FOR FLOW, VOL., TEMPL & PRESS.

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 5. RESPIRATORY - ELECTRICAL (FLOW,VOL.PRESS)		
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-F-17	REV
SUPV		APPD		SIZE B	SH OF	
SYS ENGR		SPO/GSETD	CEI/FD NO	CONTR NO.		

Form LMSC 26208

The temperature (either #1 or #2, as appropriate) is continuously supplied to the Data Management Subsystem for the same purpose.

SECTION III-F

APPENDIX

MEASUREMENT REQUIREMENTS DATA SHEETS

Measurement Requirements Data Sheets have been prepared for the following Respiratory Subsystem:

Measurement	Page No.
Lung Volumes and Flow Rates	III-F-2A
Alveolar pO_2 and pCO_2	III-F-5A
Respiratory Dead Space, Alveolar Ventilation, and Residual Volume	III-F-8A
Minute Alveolar Ventilation	III-F-12A
Carbon Dioxide Production	III-F-15A
O_2 Consumption	III-F-18A
Respiratory Quotient	III-F-21A
Lung Diffusing Capacity	III-F-23A
Lung Compliance	III-F-26A
Cardiac Output	III-F-29A
Airway Resistance	III-F-32A

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Lung Volumes and Flow Rates

MEASUREMENT DESCRIPTION : Obtain the following pulmonary measurements: Vital Capacity (VC), Timed Vital Capacity (VC_1, VC_3), Inspiratory Capacity (IC), Expiratory Reserve Volume (ERV), Tidal Volume (TV), Minute Tidal Volume (MTV) Maximum Inspiratory Flow (MIF), Maximum Expiratory Flow (MEF), and Maximum Breathing Capacity (MBC).

1. Input signal characteristics — Biphasic inspired and expired air flow and volume waveforms.

2. Electrodes, transducers — Mouthpiece, Mainland pneumotach head, A-W pressure capsule in Greer micromanometer

3. Signal conditioner(s) — Greer micromanometer (M-6), Volume Integrator (Beckman 9873B)

4. Range of measurement — Flow: 0-12 liters/second
Volume: 0-6 liters

5. Frequency of measurement — Once per week

6. Output signal characteristics

analog/digital	Flow and Volume Analog Waveforms (See #13)
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% values

7. Calibration

type & technique	Precalibration of pneumotach head; will provide electrical calibration for flow (1.0 and 5.0 liters/sec.
frequency	Before each series of measurements

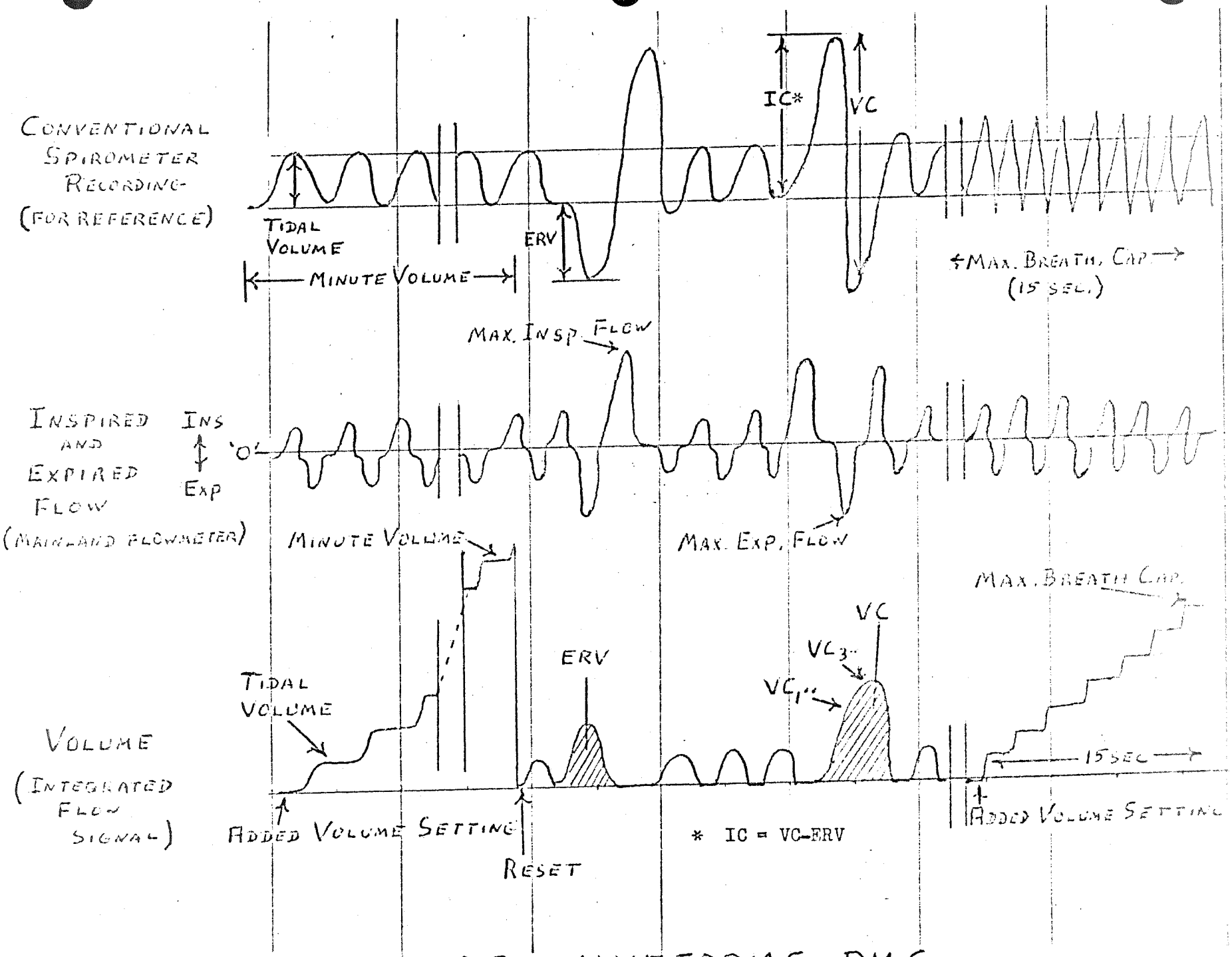
8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, intermittent on respiratory monitor; raw, analog, intermittent on CRT
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digitized, intermittent
manual/programmed A or D switching	Programmed
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	200 sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	3 min./run; approx. 10 mins, total for three runs.

9. Derived quantities

other measurements required simultaneously for calculations	Time base
digital computation	TV, ERV, IC, VC, VC_1, VC_3, MTV, MIF, MEF MBC
display analog/digital; location; updating frequency	All values in digital form on processor readout
recording analog/digital	Digitized & computed values
storage time analog/digital	Until next data dump.

10. Comparison with previous data	Manual in logbooks from printouts
11. Analog/digital display range & resolution/accuracy	Analog waveform ± 4%; total volume 6.0 liters, maximum flow 15 liters per second. Digital ± 2%
12. Printout frequency & other requirements	Once per run



ANALOG WAVEFORMS-PMS

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Alveolar PO_2 and PCO_2 (P_{AO_2} and P_{ACO_2})

MEASUREMENT DESCRIPTION : Obtain measurement of alveolar PO_2 and PCO_2 from gas analyzer curves

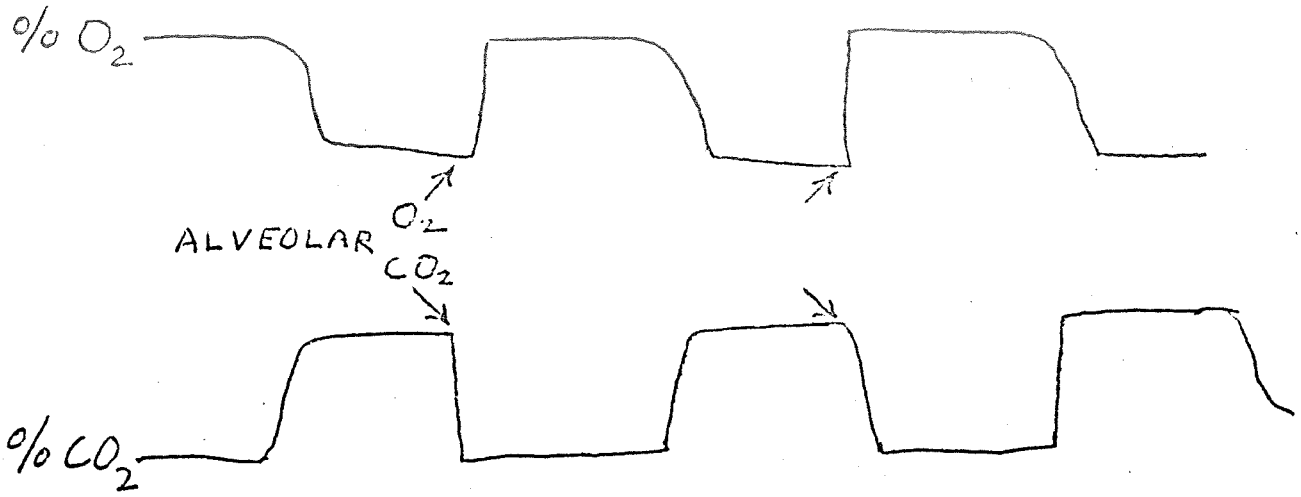
1. Input signal characteristics	Biphasic, repetitive waveform
2. Electrodes, transducers	Mouthpiece; analyzer sampling heads
3. Signal conditioner(s)	CO_2 analyzer - Godart Capnograph, KK 58002; O_2 analyzer Westinghouse Model 211M
4. Range of measurement	PAO_2 = 70-120 mm Hg $PACO_2$ = 20-70 mm Hg
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	Analog waveforms, See #13
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% of true values
7. Calibration	
type & technique	Calibration gases and/or equipment controls
frequency	Before each series of measurements

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Waveform; raw, analog, continuous on Display Monitor and on 2-pen recorder.
recording analog/digital (raw, processed; continuous, intermittent)	Waveform, raw, digitized, continuous.
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100 sps.
storage time analog/digital	Digitized until next data dump.
recording/storage quantity per subject	30 sec./subject, including derived values.

9. Derived quantities	PAO_2 and $PACO_2$
other measurements required simultaneously for calculations	Absolute barometric pressure (P_B) PH_2O = 47 mm Hg.
digital computation	PAO_2 or $PACO_2 = \%O_2$ or $\%CO_2 \times \frac{P_B - PH_2O}{100}$
display analog/digital; location; updating frequency	Digital display of computed values on digital readout: every 10 sec.
recording analog/digital	Digitized average PAO_2 and $PACO_2$ at end of each recording
storage time analog/digital	Digitized until next data dump
10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Digital, PAO_2: 70 to 120 mm Hg; $PACO_2$: 20 to 70 mm Hg Accuracy: Both $\pm$ 2%.
12. Printout frequency & other requirements	Once every 30 sec.

13. Miscellaneous information, details on referenced items, etc.



Analog O_2 and CO_2 analyzer outputs. Minimum value of O_2 and maximum value of CO_2 are to be used for computations.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Respiratory Dead Space (V_D), Alveolar ventilation ($\dot{V}_A$), and Residual Volume (V_R).

MEASUREMENT DESCRIPTION : Obtain the three measurements from inspired and expired air volume and expired nitrogen concentration as indicated on diagrams.

1. Input signal characteristics — Biphasic waveform of inspired and expired air flow. Biphasic waveform of fractional N_2 concentration.

2. Electrodes, transducers — Mouthpiece, Mainland pneumotachometer, pressure transducer (Statham, PM15), N_2 gas sampling head.

3. Signal conditioner(s) — Strain gage coupler(Beckman, #9803), Volume Integrator (Beckman, #9873B), and N_2 gas analyzer(Electro/Med #700 PR)

4. Range of measurement

Dead Space:	100 to 350 ml.
Alveolar ventilation:	0 to 10 %.
Residual volume:	800 to 2000 ml.

5. Frequency of measurement — Once every 1 - 2 weeks.

6. Output signal characteristics

analog/digital	See # 13 (waveforms).
amplitude	0 - 5 volts.
frequency range	N/A.
accuracy/sensitivity	± 2 % per parameter

7. Calibration

type & technique	N_2 analyzer: atmospheric N_2 and/or calibration gas.
frequency	At beginning of each series of measurements.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, continuous on Display Monitor anddon 2-pen recorder.
recording analog/digital (raw, processed; continuous, intermittent)	Raw, analog, digitized, continuous.
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100 sps.
storage time analog/digital	Digitized until next data dump.
recording/storage quantity per subject	10 minutes.

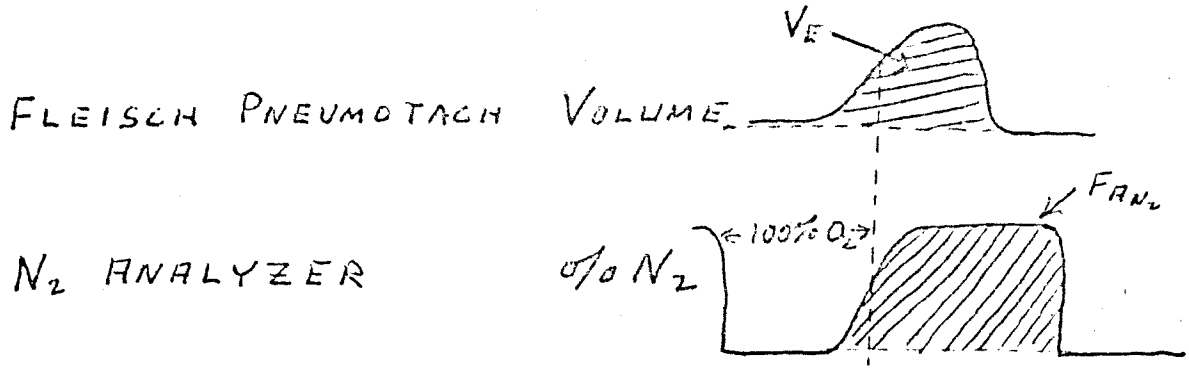
9. Derived quantities

other measurements required simultaneously for calculations	Time base.
digital computation	V_D, $\mathring{V}_A$, and V_R (See # 13); TLC.
display analog/digital; location; updating frequency	All values in digital form on processor readout.
recording analog/digital	Digital values after computation.
storage time analog/digital	Computed values until next data dump.

10. Comparison with previous data	N/A.
11. Analog/digital display range & resolution/accuracy	V_D : 100 - 400 ml, ± 5 %. $\mathring{V}_A$: 0 - 20 % N_2, ± 5 %. V_R : 800 - 2000 ml, ± 5 %.
12. Printout frequency & other requirements	Once per run.

13. Miscellaneous information, details on referenced items, etc.

$$\underline{\text{RESPIRATORY DEAD SPACE}}\ (V_D) = \frac{(F_{A_{N_2}} - F_{E_{N_2}})(V_E)}{F_{A_{N_2}}}$$

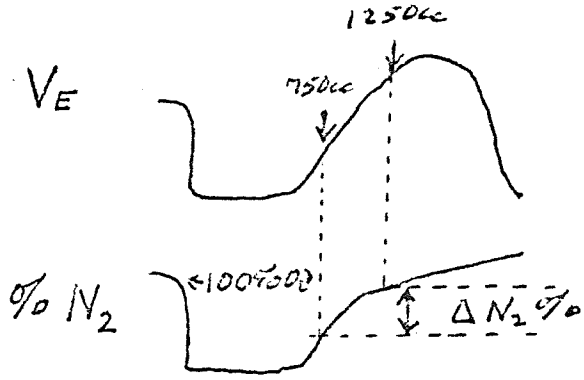


$F_{A_{N_2}}$ = % N_2 IN ALVEOLI

$F_{E_{N_2}}$ = % N_2 IN EXPIRED AIR $\left(\frac{V_{E_{N_2}}}{V_E}\right)$

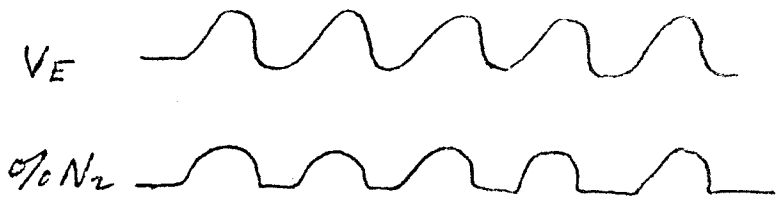
V_E = EXPIRED VOLUME

$$\underline{\text{ALVEOLAR VENTILATION}}\ (V_A) = \%N_{2_{1250cc}} - \%N_{2_{750cc}}$$



13. Miscellaneous information, details on referenced items, etc. (Continued).

RESIDUAL VOLUME $(V_R) = V_{E_{N_2}} \times \frac{100}{80}$



COMPUTATION INVOLVES IN-PHASE MULTIPLIER FUNCTION OF V_E AND $\%N_2$; THE RESULTANT SIGNAL MUST BE TOTALIZED DURING THE 7 MIN MEASUREMENT PERIOD.

$V_R + VC = TLC$

VC = VITAL CAPACITY

TLC = TOTAL LUNG CAPACITY

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM	:	Respiratory
MEASUREMENT GROUP	:	Respiratory
MEASUREMENT	:	Minute Alveolar Ventilation ($\dot{V}_{AMIN}$)
MEASUREMENT DESCRIPTION	:	Obtain measurement of minute alveolar ventilation from total expired volume (V_E) and expired CO_2 (V_{ECO_2})

1. Input signal characteristics	Expired volume - Biphasic repetitive waveform Expired CO2 - Biphasic repetitive waveform
2. Electrodes, transducers	Mouthpiece, Fleish pneumotachometer and pressure transducer (Statham, PM15); gas analyzer sampling head.
3. Signal conditioner(s)	Strain gage coupler (Beckman, #9803), Volume Integrator (Beckman., #9873B); CO_2 gas analyzer (Godart, KK58002)
4. Range of measurement	Normal - 3.0 to 7.0 liters/min. Exercise - 4.0 to 200 liters/min.
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	Analog waveforms
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% per parameter
7. Calibration	
type & technique	CO_2 analyzer - use electrical calibration
frequency	Before each series of measurements

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Waveforms; raw, analog, intermittent on Display Monitor and on 2-pen recorder.
recording analog/digital (raw, processed; continuous, intermittent)	Waveforms; raw, digitized, continuous for 90 seconds.
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	100 sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	Approx. 100 seconds, including derived values

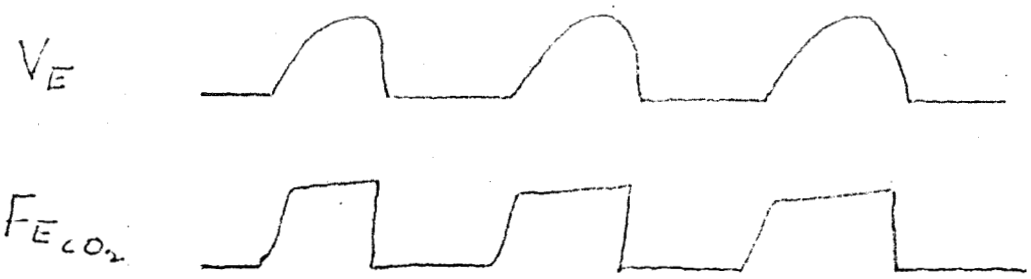
9. Derived quantities

other measurements required simultaneously for calculations	Time base
digital computation	Minute alveolar ventilation ($\dot{V}_{AMIN}$) See #13
display analog/digital; location; updating frequency	Display of derived values on digital readout.
recording analog/digital	Digital values
storage time analog/digital	Digitized until next data dump

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Digital; 3-200 liters/minute ± 5%
12. Printout frequency & other requirements	Once at end of run.

13. Miscellaneous information, details on referenced items, etc.

Sample Waveforms--



Miscellaneous Calculations:

$$V_A = \frac{\dot{V}_{CO2}}{\%\ \text{alveolar}\ CO_2}$$

$$\dot{V}_{CO2} = \dot{V}_E \times F_{E\,CO2}\ *$$

$\dot{V}_E$ is obtained from the totalized expired volume

$F_E\ CO_2$ is obtained directly from the output of the CO_2 analyzer corrected for H_2O vapor

V_E and $F_{E\,CO_2}$ are multiplied continuously during the measurement period

% alveolar CO_2 is the peak CO_2 concentration during the respiratory cycle.

* Also see gas correction factors and "true" CO_2 correction on Measurement Data Sheet

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : RESPIRATORY

MEASUREMENT GROUP : RESPIRATORY

MEASUREMENT : Carbon Dioxide Production ($\dot{V}CO_2$)

MEASUREMENT DESCRIPTION : Obtain measurement of carbon dioxide production from (a) total expired volume (V_E) and (b) percentage of expired carbon dioxide (V_{ECO_2})

1. Input signal characteristics	Expired volume - Biphasic repetitive waveform Expired CO_2 - Biphasic repetitive waveform
2. Electrodes, transducers	Mouthpiece, Fleish pneumotachometer and pressure transducer (Statham, PM15), gas analyzer sampling head.
3. Signal conditioner(s)	Strain gage coupler (Beckman, #9803), Volume Integrator (Beckman, #9873B); CO_2 gas analyzer (Godart, KK58002)
4. Range of measurement	Normal-- 100 to 500 ml Exercise-- 100 ml to 10 liters
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	Analog waveforms
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% per parameter
7. Calibration	
type & technique	CO_2 analyzer - use electrical calibration
frequency	Before each series of measurements

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Expired volume (V_E), and expired CO_2 concentration waveforms; raw, analog, continuous on Display Monitor and on recorder.
recording analog/digital (raw, processed; continuous, intermittent)	Waveforms; raw, analog, continuous for 90 seconds
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100 sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	Approx. 100seconds, including derived values

9. Derived quantities

other measurements required simultaneously for calculations	Time base
digital computation	CO_2 production on breath-by-breath basis and averaged at the end of each 30 seconds
display analog/digital; location; updating frequency	Display of $\dot{V}CO_2$ analog on CRT and displayed in digital form on breath-by-breath basis and averaged value for previous 30 seconds
recording analog/digital	Digital values
storage time analog/digital	Digitized until next data dump

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Digital; 3-200 liters/minute $\pm$ 5% design goal
12. Printout frequency & other requirements	Once at end of run

13. Miscellaneous information, details on referenced items, etc.

Computation:

$$\dot{V}_{E_{CO_2}} = V_E \left(F_{E_{CO_2}} - 0.03\right) \left(\frac{P_B - P_{H_2O}}{760\ (1 + 0.00376\ T)} \right)$$

V_E = expired flow, from integrated flow signal

$F_{E_{CO_2}}$ = fractional concentration of CO_2 in the expired gases, from gas analyzer output

P_B = barometric pressure

T = temperature at flowmeter

"true" CO_2" factor $= F_{E_{CO_2}} - 0.03$

BTPS to STPD correction factor $= \dfrac{P_B - P_{H_2O}}{760\ (1 + 0.00376\ T)}$

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Oxygen Consumption ($\dot{V}_{O_2}$)

MEASUREMENT DESCRIPTION : Obtain measurement of oxygen consumption from expired air analysis.

1. Input signal characteristics	Expired air flow--biphasic, repetitive waveform. Expired CO_2 and O_2 --biphasic, repetitive waveforms.
2. Electrodes, transducers, vest, harness	Mouthpiece, gas analyzer sampling heads, Fleisch pneumotachometer, pressure transducer (Statham, PM15).
3. Signal conditioner(s)	Strain gage coupler (Beckman, #9803) Volume Integrator (Beckman,#9873B), O_2 gas Analyzer (Westinghouse,#211M), CO_2 gas Analyzer (Godart,#KX58002)
4. Range of measurement	Normal-- 150 to 600 ml/minute With Exercise-- 150 ml to 10 liters per minute
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	Analog waveforms
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2 % per parameter
7. Calibration	
type & technique	Calibration gases and/or equipment controls
frequency	Before each measurement

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Expired volume ($\dot{V}_E$), expired O_2 (F_{EO_2}), expired CO_2 (F_{ECO_2}) waveforms, raw analog, continuous on Display Monitor and on
recording analog/digital (raw, processed; continuous, intermittent)	Waveforms, raw, digitized, continuous for 90 seconds.
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	Approx. 100 seconds per subject.

9. Derived quantities

other measurements required simultaneously for calculations	Time base
digital computation	O_2 consumption on breath-by-breath basis and averaged at the end of each 30 seconds
display analog/digital; location; updating frequency	Display of breath-by-breath $\dot{V}_{O_2}$ analog on CRT and displayed digitally for both breath-by-breath and averaged value for previous 30 seconds (computed in ml/min.)
recording analog/digital	Digital values
storage time analog/digital	Digitized until next data dump.

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Digital, 0.15 to 10.0 liters/ min., ± 5% design goal
12. Printout frequency & other requirements	Once at end of run

13. Miscellaneous information, details on referenced items, etc.

Computations:

$$\dot{V}_{O_2}^{*} = K \cdot V_E \left[F_{IO_2} - \left(F_{EO_2} + F_{IO_2} F_{ECO_2} \right) \right]$$

where,

$\dot{V}_{O_2}$ = oxygen consumption in ml/minute

V_E = expired volume, obtained from integrated flow signal (Fleisch pneumotachometer)

F_{IO_2} = fractional concentration of oxygen in the inspired air (O_2 content of ambient air corrected for water vapor)

F_{EO_2} = fractional concentration of oxygen in the expired air, from output of Westinghouse O_2 analyzer

F_{ECO_2} = fractional concentration of carbon dioxide in the expired air, from the output of the Godart CO_2 analyzer.

$$K = \frac{1}{1 - F_{IO_2}}$$

* Correct final computed value to STPD (see pg. III-F-25A)

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Respiratory Quotient (R.Q.)

MEASUREMENT DESCRIPTION : Obtain measurement of respiratory quotient (R.Q.) from oxygen consumed (V_{O_2}) and carbon dioxide released ($\dot{V}_{CO_2}$)

1. Input signal characteristics — Expired volume - Biphasic repetitive waveform
   Expired O_2 and CO_2 - Biphasic repetitive wavefo

2. Electrodes, transducers, vest, harness — Mouthpiece, Fleisch pneumotachometer, pressure transducer (Statham, PM15), gas analyzer sampling heads.

3. Signal conditioner(s) — Strain gage coupler (Beckman., #9803), Volume Integrator (Beckman., #9873B), CO_2 gas analyzer (Godart, KK 58002) O_2 gas analyzer (Westinghouse, 211MO

4. Range of measurement — R. Q. range 0.5 - 2.0

5. Frequency of measurement — Once per 1-2 weeks

6. Output signal characteristics

analog/digital	Analog
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 5% per parameter

7. Calibration

type & technique	See calibration procedure for $\dot{V}_{EO_2}$ and $\dot{V}_{O_2}$
frequency	N/A

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Waveforms, raw, analog, intermittent on display monitor and on recorder.
recording analog/digital (raw, processed; continuous, intermittent)	Waveforms, raw, continuous for 90 seconds
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	100 sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	Approx. 100 seconds

9. Derived quantities

other measurements required simultaneously for calculations	Oxygen consumed ($\dot{V}_{O_2}$) and carbon dioxide production ($\dot{V}_{CO_2}$)
digital computation	R. Q. = $\frac{\dot{V}_{CO2}}{\dot{V}_{O2}}$ averaged value for 60 seconds
display analog/digital; location; updating frequency	Display of computed value on digital readout
recording analog/digital	Digital value
storage time analog/digital	Digitized until next data dump

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Digital, R. Q. range 0.5 - 2.0, $\pm$ 10% design goal
12. Printout frequency & other requirements	Once per computation

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Lung Diffusing Capacity

MEASUREMENT DESCRIPTION : Obtain measurement of lung diffusing capacity, utilizing box-balloon assembly, helium and carbon monoxide analyzers, and Mainland flowmeter---Carbon Monoxide, Single-Breath Technique.

1. Input signal characteristics — Helium and carbon monoxide gas concentrations-- two separate determinations, each stable, non-repetitive signals. Inspired volume-- single waveform

2. Electrodes, transducers, vest, harness — Mouthpiece, He and CO gas sampling heads, Mainland pneumotachometer, and pressure transducer (Statham, PM15)

3. Signal conditioner(s) — Helium gas analyzer (Collins,#495), Carbon Monoxide analyzer (Godart, IA 7103, Strain gage coupler (Beckman, #9873B), Volume Integrator (Beckmen, #9803.

4. Range of measurement — D_{CO} = 10 to 50 ml/min./mm Hg

5. Frequency of measurement — Once per 1-2 weeks

6. Output signal characteristics

analog/digital	Analog
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% per parameter

7. Calibration

type & technique	Gas analyzers- calibration gases and/or equipment controls; precalibration of flowmeters
frequency	Before each series of measurements

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Fractional gas concentrations-- digital, raw, intermittent on Display Monitor Inspired volume-- digital, raw, intermittent on Display Monitor
recording analog/digital (raw, processed; continuous, intermittent)	Digital, raw, intermittent
manual/programmed A or D switching	Signal routing to Display Monitor programmed, manual to 2-pen recorder
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100 sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	Approx. 60 seconds per subject, including derived values.

9. Derived quantities

other measurements required simultaneously for calculations	Residual volume (V_R) corrected to STPD, absolute barometric pressure, and time.
digital computation	D_{CO}
display analog/digital; location; updating frequency	Display of computed values on digital readout; after each measurement.
recording analog/digital	Digitized D_{CO} after each measurement
storage time analog/digital	Digitized until next data dump

10. Comparison with previous data — N/A

11. Analog/digital display range & resolution/accuracy — Digital, D_{CO}; 10 to 50 ml/min/mm Hg $\pm$ 5%

12. Printout frequency & other requirements — Once after each measurement

13. Miscellaneous information, details on referenced items, etc.

-- Procedure Note: Prior to subject involvement in this measurement procedure, the helium-carbon monoxide gas mixture is manually routed to the appropriate gas analyzers, and to the box-balloon assembly. The analyzed fractional gas concentrations are stored for use in the final computation of D_{CO}.

--Computation:

$$D_{CO} = \frac{(VI + V_R)_{STPD} \times 60}{(P_B - 47) \times T} \ln \frac{\frac{F_{A_{He}}}{FI_{He}} \times FI_{CO}}{F_{A_{CO}}}$$

WHERE,

D_{CO}	=	diffusing capacity
V_I	=	volume inspired from box-balloon--from Mainland flowmeter
V_R	=	residual volume, stored from previous measurement
P_B	=	absolute barometric pressure
T	=	time of breath-holding, inseconds
$F_{A_{He}}$	=	fractional concentration of helium in alveoli after breath-holding--obtained from analysis of contents of collection bag
$F_{A_{CO}}$	=	fractional concentration of carbon monoxide in alveoli after breath-holding--obtained from analysis of contents of collection bag
$F_{I_{CO}}$	=	fractional concentration of carbon monoxide in the balloon of the box-balloon assembly
$F_{I_{He}}$	=	fractional concentration of helium balloon of the box-balloon assembly

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Lung Compliance (Lc)

MEASUREMENT DESCRIPTION : Obtain measurement of lung compliance from inspired volume and intrapleural pressure.

1. Input signal characteristics	Inspired volume - biphasic, repetitive waveform Intrapleural pressure - biphasic, repetitive waveform
2. Electrodes, transducers, vest, harness	Mouthpiece, Mainland pneumotachometer head, AW10 capsule in Greer micromanometer, esophageal balloon and pressure transducer (Statham, PM-5)
3. Signal conditioner(s)	Greer micromanometer, Volume Integrator (Beckman #9873B), Strain gage coupler (Beckman, #9803)
4. Range of measurement	Inspired volume - 300 to 4000 ml Intrapleural pressure - minus 5 to minus 30 cm H_2O
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	Analog
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% per parameter
7. Calibration	
type & technique	Precalibration of flowmeter and pressure transducer; will provide electrical calibration of each.
frequency	Before each series of measurements

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Inspired volume and intrapleural pressure - analog, raw, intermittent
recording analog/digital (raw, processed; continuous, intermittent)	Inspired volume and intrapleural pressure, analog raw, intermittent
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	100 sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	Approx. 30 seconds per measurement; 2 measurements per subject.

9. Derived quantities

other measurements required simultaneously for calculations	N/A
digital computation	Lc (see #13)
display analog/digital; location; updating frequency	Digital on processor readout
recording analog/digital	Digital computed value
storage time analog/digital	Until next data dump

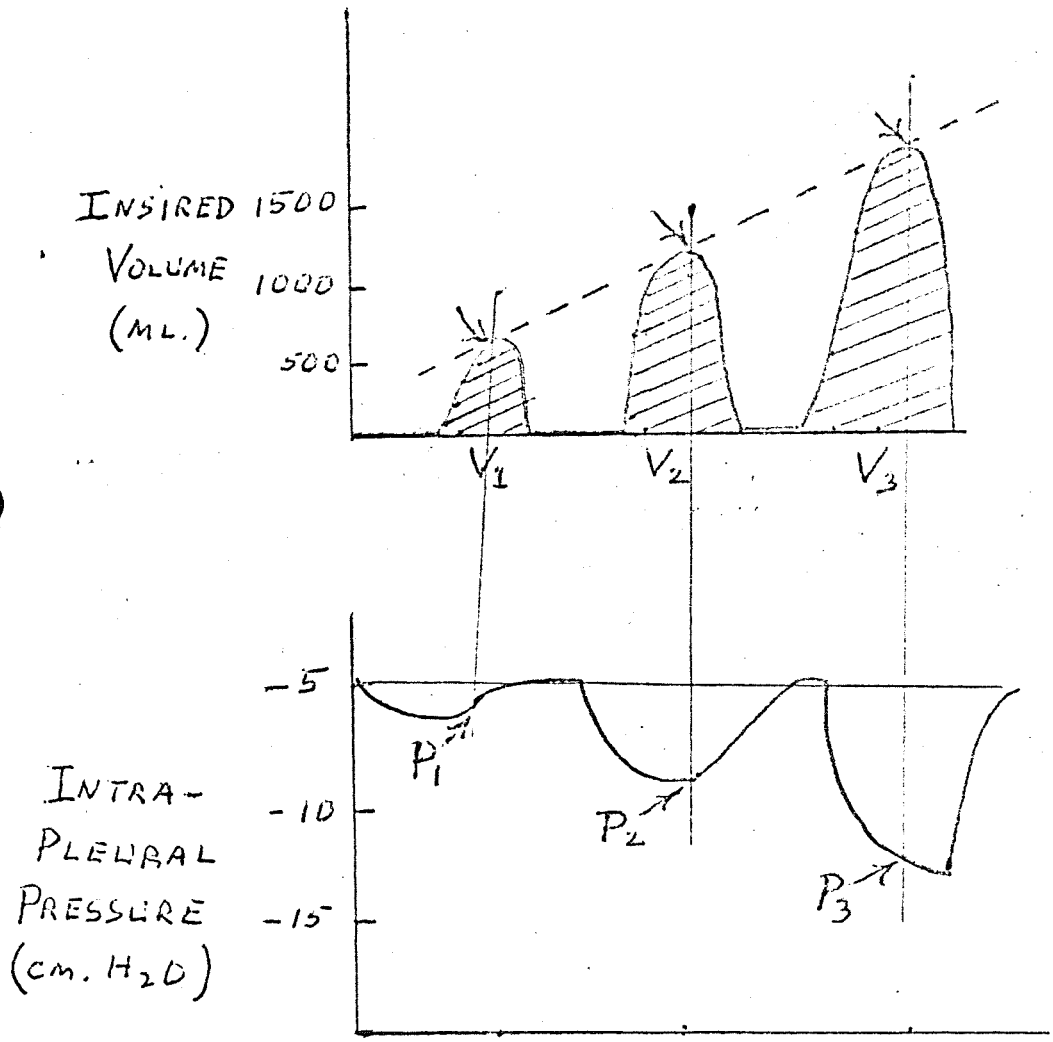
10. Comparison with previous data — N/A

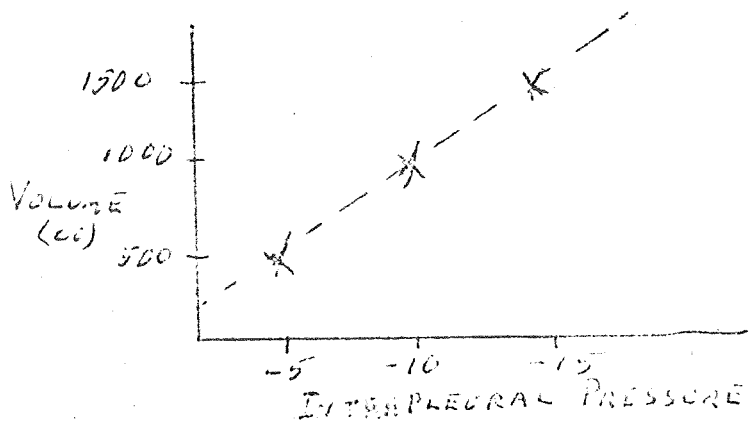
11. Analog/digital display range & resolution/accuracy — Digital, 0.05 to 0.3 liters/cm H_2O $\pm$ 5% design goal

12. Printout frequency & other requirements — Once at the end of each series of measurements

13. Miscellaneous information, details on referenced items, etc.

Note: A pressure-volume curve is constructed from a series of determinations (in the example below, three). The slope of the line connecting the data points represents lung compliance (Lc) in liters per cm H_2O.





MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Cardiac Output (Q)

MEASUREMENT DESCRIPTION : Obtain measurement of cardiac output from analysis of the expired carbon dioxide ($V_{E_{CO_2}}$), alveolar carbon dioxide ($F_{A_{CO_2}}$) and the mixed venous carbon dioxide ($F\bar{v}_{CO_2}$)

1. Input signal characteristics	Inspired and expired CO_2 concentration--biphasic, repetitive waveform
2. Electrodes, transducers, vest, harness	Mouthpiece, CO_2 gas sampling head.
3. Signal conditioner(s)	CO_2 gas analyzer (Godart, KK58002)
4. Range of measurement	3 to 35 liters
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	Analog waveforms
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% per parameter
7. Calibration	
type & technique	CO_2 analyzer--use calibration gases and/or equipment controls.
frequency	Once per run.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Analog, raw, continuous for 10-20seconds on CRT and recorder.
recording analog/digital (raw, processed; continuous, intermittent)	Analog, raw, continous for 10-20 seconds.
manual/programmed A or D switching	Programmed signal routing to Display Monitor and recorder.
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	100 sps
storage time analog/digital	Digitized until next data dump.
recording/storage quantity per subject	45 seconds per measurement, 2 measurements per subject.

9. Derived quantities

other measurements required simultaneously for calculations	Alveolar CO_2 concentration ($F_{A_{CO2}}$), CO_2 production (V_{CO_2})
digital computation	Mixed venous C O_2 concentration
display analog/digital; location; updating frequency	Digital display of mixed venous CO_2 concentraion ($F_{\bar{V}CO_2}$)
recording analog/digital	Digitized values.
storage time analog/digital	Digitized until data dump

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Mixed venous CO_2 concentration-30 to 90mmHg±2% Cardiac output 3-40 liters/minute ± 10% design goal
12. Printout frequency & other requirements	Once at end of measurement.

13. Miscellaneous information, details on referenced items, etc.

Computations:

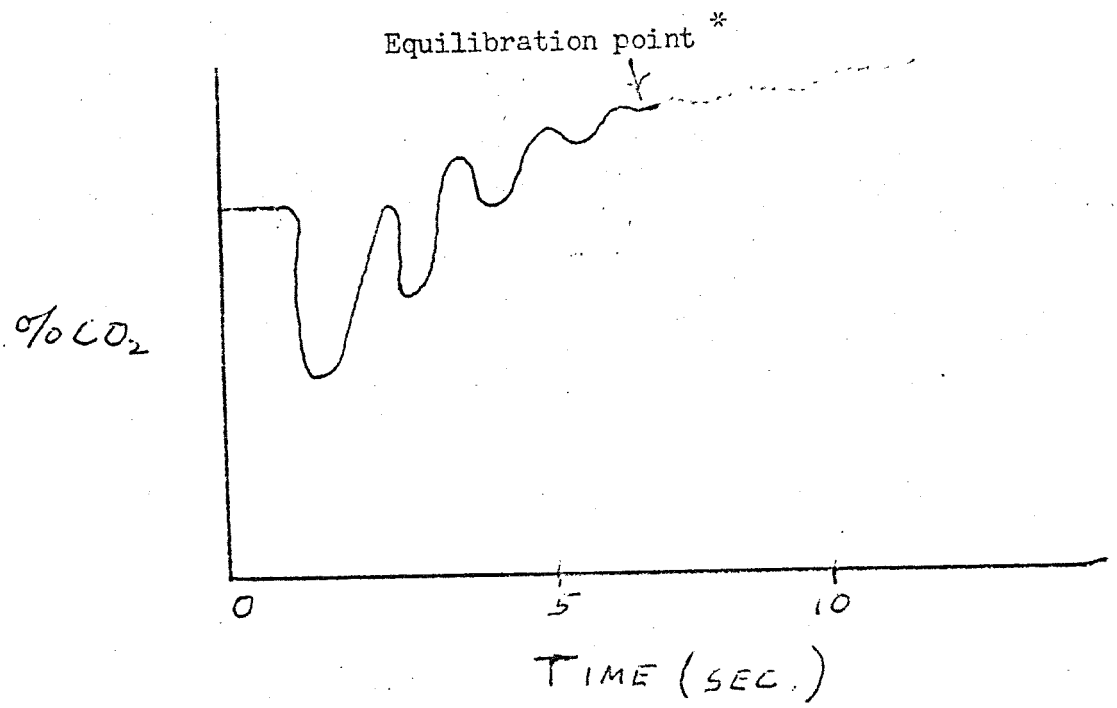
$$Q = \frac{\dot{V}CO_2}{F\bar{v}_{CO_2} - F_{A_{CO_2}}}$$

where,

Q = cardiac output (in liters/minute

$F\bar{v}_{CO_2}$ = fractional concentration of CO_2 in mixed venous blood, obtained from equilibration curve(see below)

$F_{A_{CO_2}}$ = fractional concentration of CO_2 in the alveoli, obtained prior to cardiac output determination



* The "equilibration point" is defined as the fractional concentration of CO_2, at the time when the change in CO_2 percentage is less than 1.5 mm Hg between the subject's expired gases and the contents of the rebreathing bag.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Respiratory

MEASUREMENT GROUP : Respiratory

MEASUREMENT : Airway Resistance (R_A)

MEASUREMENT DESCRIPTION : Obtain measurement of pulmonary airway resistance from the simultaneous detection of tracheal pressure and airway flow (Flow-Interrupter Technique)

1. Input signal characteristics	Airway flow and tracheal pressure- both biphasic, repetitive waveforms.
2. Electrodes, transducers, vest, harness	Airway flow--mouthpiece, Mainland pneumotach head, AW10 capsule in Greer micromanometer. Tracheal pressure--pressure transducer (Statham, PM-5.
3. Signal conditioner(s)	Airway flow-- Greer micromanometer Tracheal pressure— strain gage coupler (Beckman, #9803)
4. Range of measurement	0.2- 10.0 cm H_2O / liter / second
5. Frequency of measurement	Once per 1-2 weeks
6. Output signal characteristics	
analog/digital	Analog -- See #13
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2 % per parameter
7. Calibration	
type & technique	Precalibration of pneumotach head; will provide electrical calibration for both flow and pressure
frequency	Once, prior to each series of measurements.

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Airway flow and tracheal pressure-- Both analog raw, and intermittent.
recording analog/digital (raw, processed; continuous, intermittent)	Airway flow and tracheal pressure-- Both analog raw, and intermittent.
manual/programmed A or D switching	Programmed signal routing to Display Monitor and to 2-pen recorder.
manual/verbal data entry	Subject identification and measurement number.
A/D conversion frequency	100 sps
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	Approx. 30 seconds per measurement

9. Derived quantities

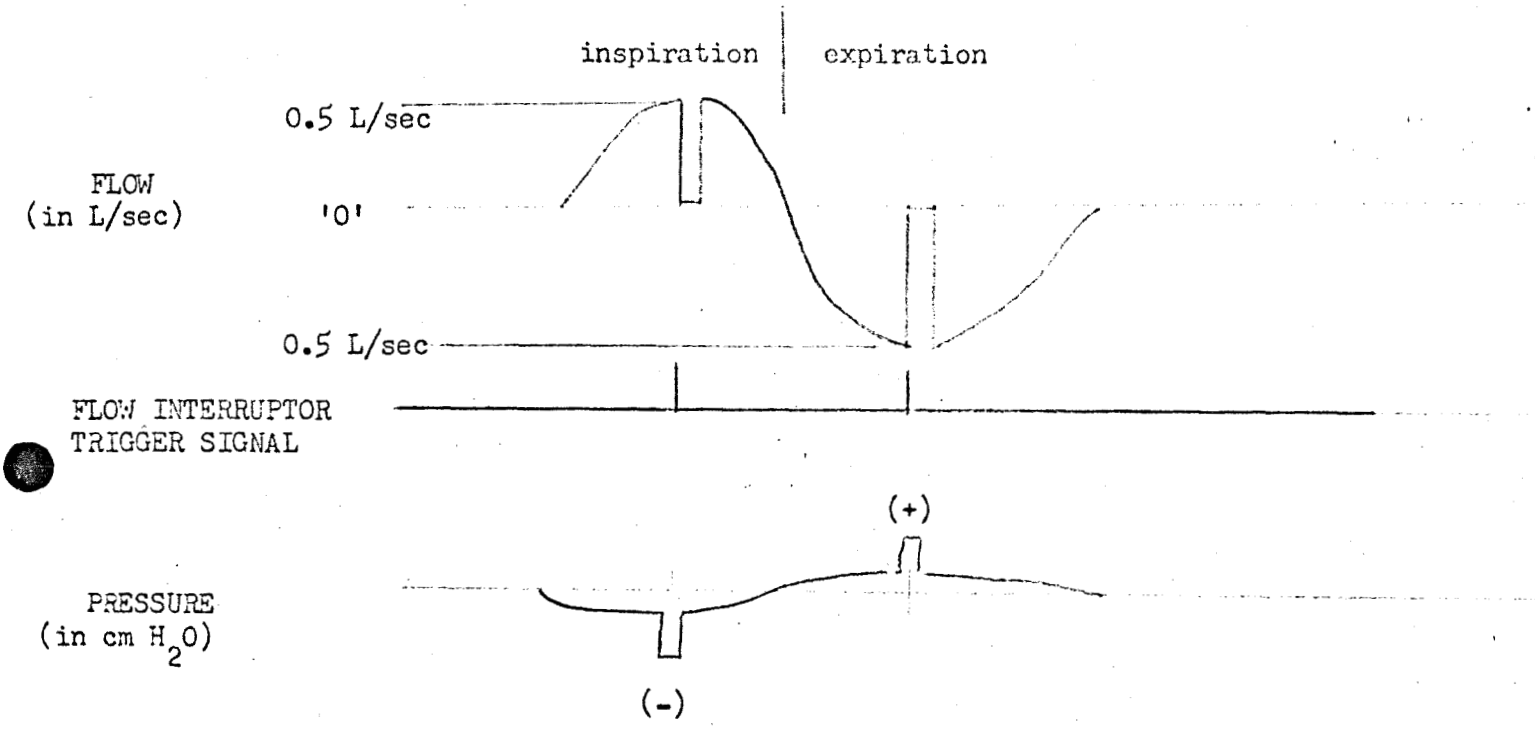
other measurements required simultaneously for calculations	N/A
digital computation	R_A (see #13)
display analog/digital; location; updating frequency	Digital on processor readout, after each measurement
recording analog/digital	Digital computed values
storage time analog/digital	Until next data dump

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Digital, 0.3 to 10.0 cm H_2O /liter/sec., $\pm$ 5%.design goal
12. Printout frequency & other requirements	Once at the end of each measurement.

13. Miscellaneous information, details on referenced items, etc.

Procedural Note:

During this measurement the subject is instructed to breath normally. The air flow is interrupted during the breathing cycle at flow rates of 0.5liters per second. The trigger for the flow interruption is controlled by a flow detection circuit. The two values necessary for the computation of airflow resistance are: flow rate--this will be constant at 0.5 liters per second, and alveolar pressure--detected during the flow interruption period. See below.



Computation:

$$\text{Airway resistance} = \frac{\text{pressure}}{\text{flow}}$$

SECTION III-G

IMELMS FUNCTIONAL BREADBOARD PERFORMANCE/DESIGN REQUIREMENTS

METABOLISM & NUTRITION SUBSYSTEM

METABOLISM & NUTRITION

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

- 3.1 Performance
  - 3.1.1 Functional
    - 3.1.1.1 Overall System Requirements
    - 3.1.1.2 Measurement Requirements
    - 3.1.1.3 Muscle Strength & Size
    - 3.1.1.4 Body Mass
    - 3.1.1.5 Specimen Mass
    - 3.1.1.6 Total Body Water
    - 3.1.1.7 Inflight Bone Densitometry, Gastric pH and Pressure
  - 3.1.2 Operability
- 3.2 Interface Requirements
- 3.3 Design and Construction
  - 3.3.1 Sensors and Signal Conditioners
    - 3.3.1.1 Muscle Strength Unit
    - 3.3.1.2 Body Mass Measurement Unit
    - 3.3.1.3 Specimen Mass Measurement Unit
    - 3.3.1.4 Total Body Water
  - 3.3.2 Displays and Control
  - 3.3.3 Calibration Requirements
  - 3.3.4 Power Requirements

4.0 DESCRIPTIVE DEFINITION AND BLOCK DIAGRAMS

APPENDIX - MEASUREMENT REQUIREMENTS DATA SHEETS

1.0 INTRODUCTION

This document establishes the requirements for the performance and design of the Metabolism & Nutrition Subsystem, together with the requirements necessary for providing interfaces with other FBB subsystems.

A number of measurements belonging in this measurements group were included in Section III-D, Dynamic Physiological Monitor and Section III-F, Respiratory Subsystem. This division was necessary to obtain logical equipment grouping based on operation, design, and data management requirements. The measurements discussed in this document are to be obtained by means of peripheral equipment, which is not an integral part of either the DPM or the Respiratory Subsystem.

The outputs of this peripheral equipment are to be displayed at the PBDM station on the Display Monitoring Scope and/or on the Digital Displays, where appropriate after computation by the Data Management Subsystem. Other results are read off visually and are entered manually via the Numerical Data Entry Keyboard for recording only. A large number of measurements are of a biochemical nature, and are discussed in Section III-I, Biochemical Preparation and Analysis Subsystem.

2.0 APPLICABLE DOCUMENTS

Section III-A contains all applicable documents.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional.

3.1.1.1 Overall System Requirements. - The Metabolism & Nutrition Subsystem must be capable of detecting specific measurement changes, using non-invasive techniques with peripheral equipment. Most data required digital display after computation, following either manual data entry, or, in one case, following reading off the maximum value on a traced force profile. The subsystem therefore requires an interface with the computer to realize the computational requirements. No control provisions will be required on the PBDM panel.

3.1.1.2 Measurement Requirements. - The Metabolism & Nutrition Subsystem must be capable of measuring the following parameters:

- Energy metabolism (continuous O_2 and CO_2 analysis with breath-to-breath sensitivity) at various levels of activity, with the subject breathing either ambient air or 100% oxygen.

- o Core (ear canal) temperature
- o Average skin temperature
- o Caloric intake
- o Muscle size and strength
- o Balance studies (fluid, nitrogen, mineral, electrolyte)
- o Total body water
- o Body mass

The Energy Metabolism (O_2 consumption and CO_2 production) are derived by means of the Respiratory Subsystem and are, therefore, discussed under Section III-F. Ear Canal Core Temperature and Average Skin Temperature require the use of body-worn signal conditioners and vest/harness combinations. These measurements have been covered in Section III-D, Dynamic Physiological Monitor. Caloric intake date will be entered via the Numerical Data Entry Keyboard. The Balance Studies, dealing with the intake of fluids and solids, are biochemical measurements, and are discussed in Section III-I, Biochemical Preparation & Analysis Subsystem.

The data requirements for the remaining measurements, Muscle Strength, Muscle Size, Body Mass, Specimen Mass, and Total Body Water are delineated in Section III-G Appendix.

3.1.1.3 Muscle Strength & Size. - The Muscle Strength measurement must be capable of providing force profile records, and a maximum force readout during each profile, while the subject is performing a series of standardized exercises against resistance. These exercises include, but are not necessarily limited to, squat, dead lift, forearm curl, military press, standing bench press, and rowing or cycling against resistance. They constitute various combinations of isotonic and isometric efforts, and are intended to measure a possible decrease in strength of different sections of the body's musculature as the result of long-term weightlessness exposure. The force exerted by the subject varies between zero to 400 pounds. The output of a force transducer can be used to provide a record of the force profile. Muscle Size will be determined by means of a tape measure, placed around various and precisely determined anatomical locations on the extremities.

3.1.1.4 Body Mass. - A method to accurately measure total body mass in weightlessness is required to determine weight loss or gain. The range of measurements extends from 100 to 250 lbs, with an accuracy of $\pm$ 0.1% or better. A nondeliverable prototype LMSC unit similar in principle to the NASA-Thornton body mass measurement device will be used.

3.1.1.5 Specimen Mass. - A smaller version of the device used to measure body mass is required to allow accurate measurement of the mass of ingested solids and excreted bulk. The range of measurements extends from 0.5 to 1000 grams, with an accuracy of 0.5% or better. A nondeliverable LMSC unit similar in principle to the NASA-Thornton specimen mass measurement device will be used.

3.1.1.6 Total Body Water. - In order to be able to determine if a loss of body weight is due to dehydration or tissue loss, it is necessary to be able to measure the water content of the body. One method consists of having the subject consume a known amount of tritiated water, and to determine the concentration of tritium in the urine after a pre-determined waiting period. Although this is the most accurate method, the use of radioactive material and a more elaborate procedure, requiring more complex equipment, are considered objectionable, especially if the measurement has to be repeated at frequent intervals. A second method involves the ingestion of a known amount of ethanol. After a predetermined waiting period to allow complete absorption of the alcohol, the breath-alcohol concentration is determined by means of some colorimetric method. The Kitagawa technique, using glass gas detector tubes appears most suitable for spaceflight application. The method requires further validation.

3.1.1.7 Inflight Bone Densitometry, Gastric pH and Pressure. - Only data handling procedures will be included in the FBB provided that NASA supplies the signal output requirements.

3.1.2 Operability. - Section III-A FBB System Requirements Document contains applicable Operability Requirements.

3.2 Interface Requirements

The Metabolism & Nutritional subsystem data output is routed to the Data Management subsystem through direct cabling in the case of force measurements using the Exer-Genie and load cell and mass measurement. The total body water measurement data is read off by an observer and placed into the Data Management subsystem through the Numerical Data Entry panel. Digital readouts present the data, either directly as in the case of the force measurement, or derived information for mass measurement and total body water.

3.3 Design and Construction

The Metabolism & Nutrition subsystem will provide measurement data using peripheral equipment. This peripheral equipment consists of: Muscle Strength Unit; Body Mass Unit; Specimen Mass Unit and Total Body Water. Data outputs from the first three units will be made available to the PBDM station through a suitable cable interface. Data from the last measurements is entered manually via the Numerical Data Entry Panel. The body and specimen mass measurement units are non-deliverable equipment. Data outputs from these units will be identical to the NASA-Thornton instruments, and the FBB Data Management System will be designed to completely interface with those instruments.

3.3.1 Sensors and Signal Conditioners. -

3.3.1.1 Muscle Strength Unit. - The Muscle Strength Unit consists of an isometric-isotonic exercise device, (Exer-Genie), a load cell for measuring force, a bridge amplifier, and a mounting platform. The Exer-Genie is a small metal cylinder through which a specially braided nylon line can be pulled. Convenient wooden handles or stirrups can be attached to the end of the line, and the force required to pull the line through the cylinder can be varied from zero to 400 pounds by rotating the outer sleeve of the cylinder. The rotation

causes the line to be wrapped around an internal capstan or snubbing post. Friction produced by this snubbing action supplies the necessary resistance when the line is pulled.

Quantitative measures of force, in pounds, are obtained by interposing a load cell between the Exer-Genie and its point of attachment. Three units make up the load cell assembly: A tatham UC4 White (bidirectional) force transducer, a Statham UL4 - 500 Load Cell Accessory to cover a force range of 0 to 500 lbs., and a Statham SC1100 Bridge Amplifier.

Principal characteristics of the load cell assembly are:

Load range	0-500 lbs.
Maximum displacement	0.10 mm
Load limits	$1\frac{1}{4}$ times rated range
Amplifier Power Input	115 v 60 Hz
Signal Input	12 mv/volt nominal
Signal Output	0-10 v DC open circuit, or 0-5 ma DC short circuit for 16 mv/v transducer full-scale output

The signal output will be carried to the PBDM through a 6-foot 4-conductor shielded cable and routed to the computer for recording. A force profile is required, so time indexing is necessary.

The exercise profile to be followed will be dependent upon whether the apparatus is attached to the floor, the wall, or some other point. During pulling of the cord, the body assumes various positions, depending upon the groups of muscles selected for exercise. The exercise regime to be followed includes four basic exercises:

- Combination life (includes deadlift, the squat, forearm curl, and military press in a single continuous motion)
- Standing bench press
- Rowing against resistance
- Bicycling against resistance

3.3.1.2 Body Mass Measurement Unit. - Mass measurements from 5 to 250 lbs will be accomplished with the LMSC Body Mass Measurement Unit. The output of this device is similar to the NASA-Thornton equipment, although two different programs will have to be provided to accommodate data management for both systems. The input to the electronic timing device is provided by the interruption of a light path as the unit oscillates on its track. The first impulse triggers the integral cycle counter and initiates the count through the pulser. After the desired number of cycles, a signal from the pulser gate stops the counter. Two bi-stable multivibrations are connected as a ripple counter with the first

section pulsed by a light-sensitive transistor. One output from each of the multivibrators is fed to an AND gate, which provides an output at the end of the desired number of cycles.

The cycle counter output will be carried to the PBDM coumputer, which will perform the necessary computation to convert time to mass.

3.3.1.3 Specimen Mass Measurement Unit. - Specimen mass measurements from 500 milligrams to 1000 grams will be accomplished with the LMSC unit. The output of this device is similar to the NASA-Thornton device, although two separate programs will have to be provided to accommodate both. The principle of operation is identical to that described above, with the cycles counter output carried to the PBDM computer for the necessary timing and computation to convert time to mass.

3.3.1.4 Total Body Water. - Total Body Water will be measured by converting the breath-alcohol concentration, after consumption of a standard amount of alcohol, to the concentration of alcohol in the body fluids.

The measurement utilizes an Unico No. 400 Precision Gas Detector (pump), a supply of Unico No. 104A Ethanol gas detector tubes (Kitagawa), and a supply of 100 proof ethanol. The latter is non-deliverable. To operate the Gas Detector it is necessary to break off the tips of a fresh detector tube, insert tube tip marked with a red dot into pump inlet, and pull out the pump handle, which automatically pulls a 100 cc gas sample through the reagent bed. To measure the breath alcohol concentration, the subject exhales alveolar air into the other end of the tube while the pump handle is being pulled out. The detector tube contains a chemical reagent which absorbs and reacts with the gas or vapor being analyzed. A color change is produced, the length of which varies according to the concentration of the material being measured. The length of the stain is measured against a calibration chart, provided with each set of tubes. Conversion factors and validity of this method require further investigation. An accuracy of at least .01 mg (per ml of body water) would be required.

3.3.2 Displays and Controls. - All measurement data assigned to the Metabolic and Nutrition Subsystem is normally transferred to the computer for recording: a signal output for muscle strength; cycle counter output carried to the computer for necessary timing and computation to convert time to mass and subsequent recording or digital readout and printout is desired; and quantitative evaluation for Total Body Water entered into computer through numerical Data Entry keyboard.

3.3.3 Calibration Requirements. - Calibration of the load cell involved in Muscle Strength measurement will be accomplished using a known mass. Body mass measurement and specimen mass measurement equipment will be calibrated using a known mass tied down to the mass platforms.

Total body water breath analyzer equipment are pre-calibrated with each set of tubes provided with a calibration chart.

3.3.4 Power Requirements. - The load cell used in the Muscle Strength evaluation requires 115 v input. Total Body Water determination requires no power.

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

4.1 Conceptual Design

4.1.1 Design Objectives. - The Metabolism & Nutrition Subsystem will be designed to measure and/or display data on Muscle Strength and Size, Body Mass, Specimen Mass, Total Body Water, Inflight Bone Densitometry, and Gastric pH and Pressure. Interconnection will be provided with the Data Management Subsystem for data handling and/or processing. Signal conditioning is required only for the Muscle Strength measurement as the remaining measurements are either self-contained with data output made available to the PBDM station or require visual interpretation and manual entry of data.

4.1.2 Design Concept. - The Metabolism & Nutrition Subsystem consists of Muscle Strength measurement equipment, Breath Analyzer kit for Total Body Water evaluation and cable assemblies. There is no requirement for a separate display panel or control. Display where required will be presented on the PBDM Station Digital Readout assembly.

Cable assemblies will be provided to pick up data output from the NASA/Thronton Body and Specimen Mass Measurement Units. This data will be fed to the Data Management computer for processing and digital presentation. Inflight Bone Densitometry and Gastric pH and Pressure data output when defined by NASA may be connected to the PBDM Station. It is assumed that the signal will be properly amplified and be within 0-5v with input impedance less than 200Ω.

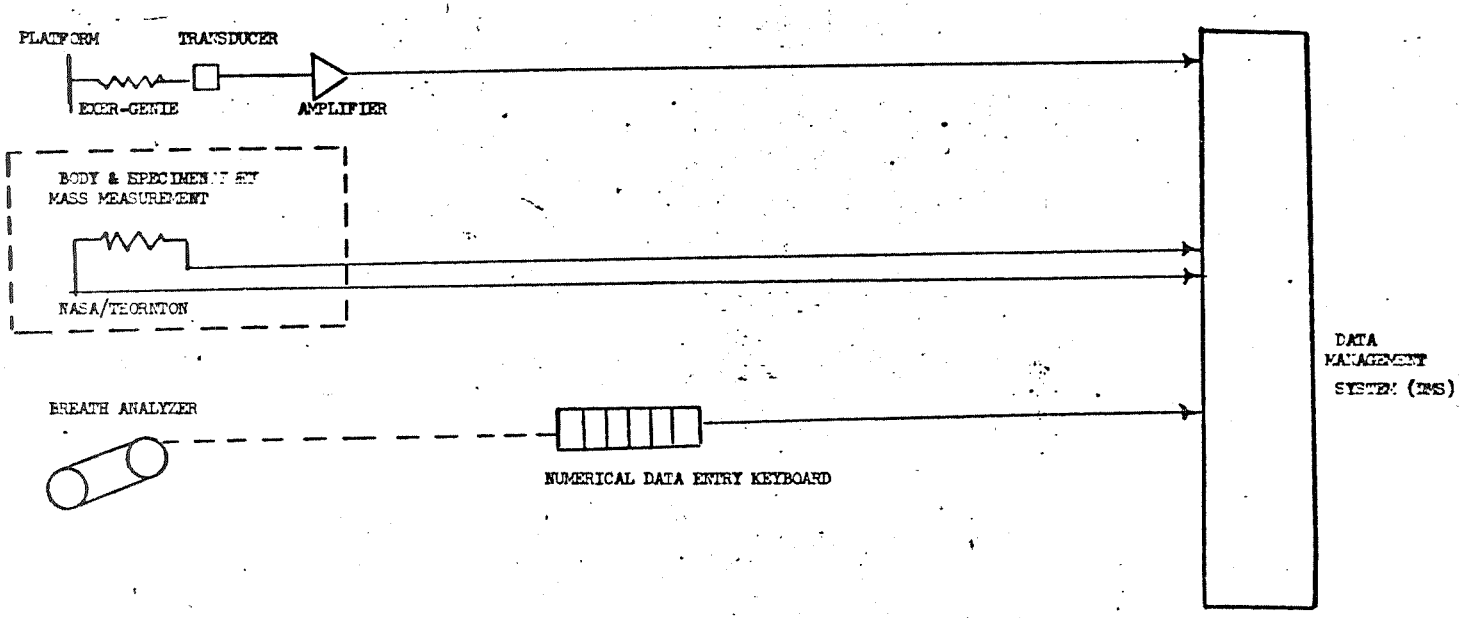
4.2 Block Diagrams

4.2.1 Equipment Elements. - LMSC will develop two equipment items - (1) Muscle Strength Evaluation Unit, and (2) Total Body Water Analysis Kit. The Muscle Strength Evaluation Unit consists of an resistive exercise device (Exer-Genie), load cell transducer, and amplifier. A suitable mounting platform will be provided together with a cable assembly. The Total Body Water Analysis Kit consists of Unico No. 104A Ethanol gas detector tubes (Kitagawa) and a supply of 100 proof ethanol.

LMSC will provide a cycle counter output which will be similar to the output of the NASA/Thornton mass measurement units by using in-house units that operate on the same principle.

Fig. 1 illustrates the overall equipment block diagram for the Metabolism and Nutrition Subsystem. The dotted outline indicates the non-deliverable equipment. As shown, direct interface occurs between the measurement equipment and the PBDM Data Management System with the exception of the Total Body Water measurement which requires inputing data through the Numerical Data Entry Keyboard.

4.2.2.1 Total Body Water Analysis Procedure. - This measurement requires breaking off the tips of a fresh detector tube, inserting the tube tip marked with a red dot into pump inlet and pulling out the pump handle, which automatically pulls a 100 cc gas sample through the reagent bed. The subject exhales alveolar



SCHEMATIC BLOCK DIAGRAM

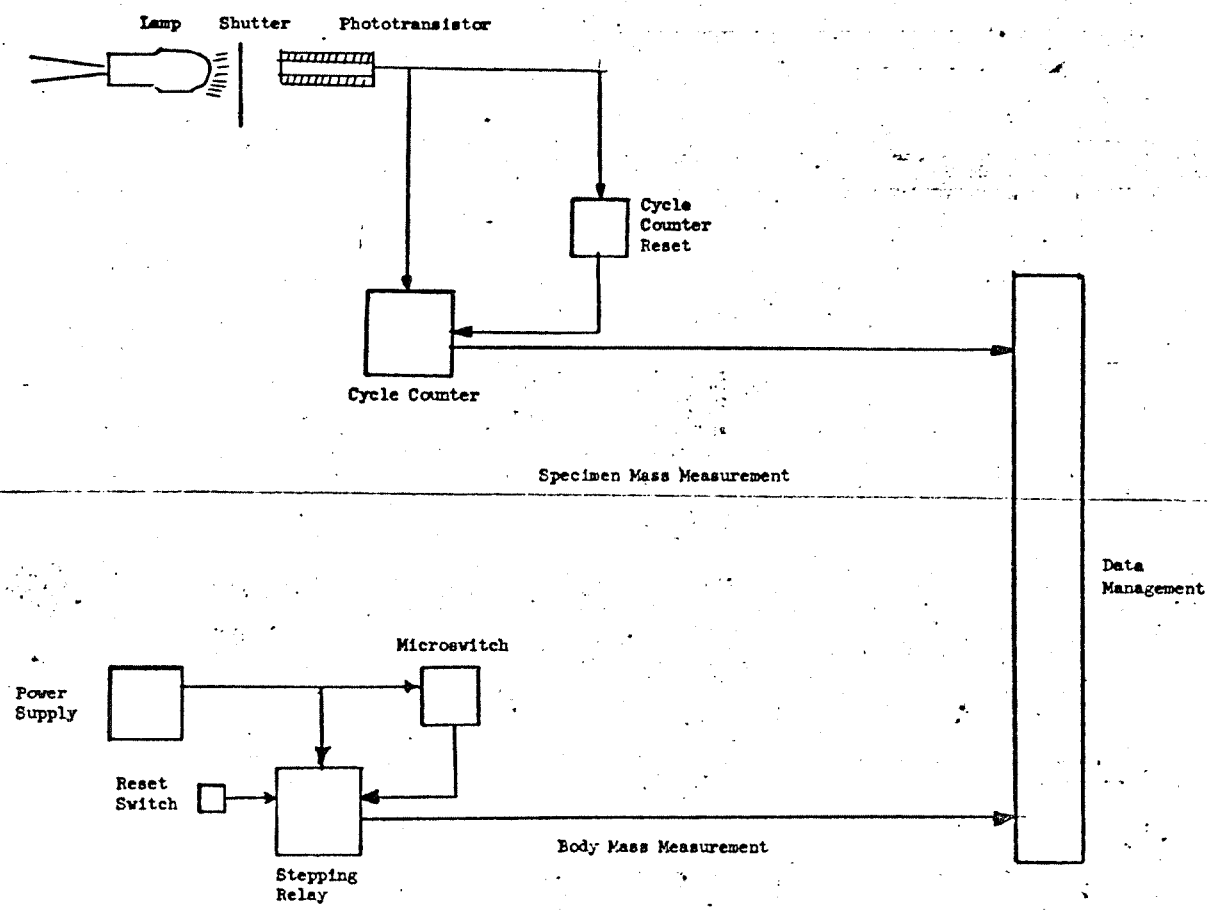
ORIGR DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA		TITLE FIGURE 1. METABOLISM & NUTRITIONAL SUBSYSTEM	
CHK	APPD			CODE IDENT NO. 1[illegible]	DOCUMENT NO. III-G-8 / REV
SUPV	APPD			SIZE B / SH OF	
SYS ENGR	SPO/GSETD	CEI/FD NO	CONTR NO.		

Form LMSC 2620B

air into the other end of the tube while the pump handle is being pulled out. A color change is produced, the length of which varies according to the concentration of the material being measured. The subject refers to a calibration chart which yields values for various lengths. This data is then entered into the PBDM Data Management Subsystem for further processing and evaluation.

4.2.2.2 Exer-Genie. - The Exer-Genie Controllable force exerciser is atta attached to a force transducer which feeds through a signal conditioner into the data management system.

4.2.2.3 Body and Speciman Mass Measurement. - Two oscillating devices for measuring mass feed signals into the data management system. The body mass measurement device is used for determining the mass of personnel. The speciman mass measurement device is used for specimens of much smaller mass. The principle in both cases is to measure the time required for a number of linear oscillation cycles for which the measured mass determines the period. This time is then converted to the corresponding mass, or weight based on a 1-g environment. The lamp, shutter and phototransistor shown in Fig. 2 are used to detect the beginning of each oscillation cycle of the speciman mass measurement device. A microswitch performs the same function in the body mass measurement device. An electronic counter and a stepping relay are used to count the desired number of oscillations for the speciman and body mass measurement devices, respectively. The corresponding time intervals are measured by an electronic timing device and the masses (or weights) are computed using the device calibrations. Provisions are also provided to manually enter digital data into the data management system.



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 2. BODY AND SPECIMEN MASS MEASUREMENT SYSTEM	
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-G-10 / REV
SUPV		APPD		SIZE B	SH 1 OF
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.		

Form LMSC 2620B

SECTION III-G

APPENDIX

MEASUREMENT REQUIREMENTS DATA SHEETS

Measurement	Page No.
- Muscle Strength	III-G-2A
- Body Mass Measurement	III-G-5A
- Specimen Mass Measurement	III-G-8A
Total Body Water (Ethanol technique)	III-G-11A

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Metabolism & Nutrition

MEASUREMENT GROUP : Metabolism & Nutrition

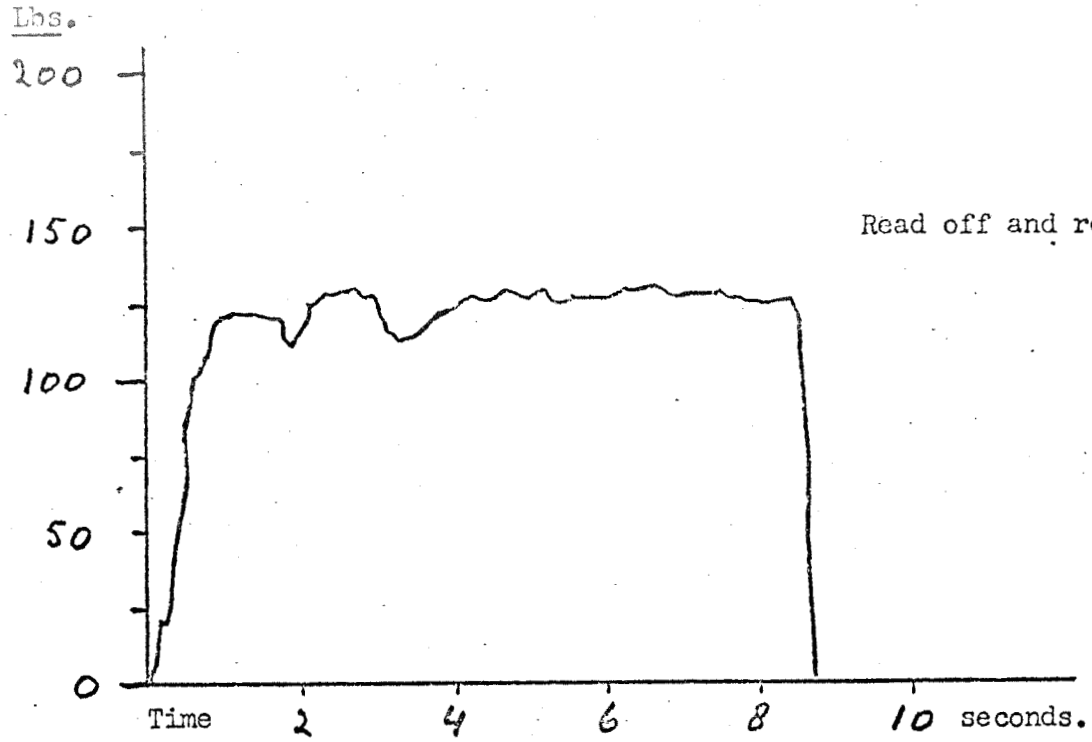
MEASUREMENT : Muscle Strength

MEASUREMENT DESCRIPTION : Obtain force profile and record maximum force during performance of standardized exer-genie maneuvers.

1. Input signal characteristics	Biphasic, slowly moving waveform
2. Electrodes, transducers	Exer-genie exerciser and tension type load cell
3. Signal conditioner(s)	Load cell driver and output amplifier
4. Range of measurement	0-25- lbs.
5. Frequency of measurement	Once per 1 - 2 weeks
6. Output signal characteristics	
analog/digital	Analog force profile waveform
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	± 2% of true value
7. Calibration	Pre-calibrated
type & technique	
frequency	

8. Data handling	
display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, analog, intermittent waveform on Display Monitor and on 2 pen recorder
recording analog/digital (raw, processed; continuous, intermittent)	Raw, analog, digitized, intermittent waveform
manual/programmed A or D switching	Signal routing to Display Monitor programmed; Manual to 2 pen recorder
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	100 sps.
storage time analog/digital	Digitized waveform until next data dump
recording/storage quantity per subject	Approx. 12 runs 10 seconds each
9. Derived quantities	Maximum force during each run
other measurements required simultaneously for calculations	N/A
digital computation	Readout only
display analog/digital; location; updating frequency	Digital display of max. force during each run on processor readout
recording analog/digital	Max. force in digitized format
storage time analog/digital	Digitized until next data dump
10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	Analog and digital displays 0-250 lbs, ± 2% digital, ± 4% analog
12. Printout frequency & other requirements	Once for each run

13. Miscellaneous information, details on referenced items, etc.



Read off and record maximum force.

Typical example of force profile during "military bench press" exercise.

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Metabolism & Nutrition

MEASUREMENT GROUP : Metabolism & Nutrition

MEASUREMENT : Body Mass Measurement

MEASUREMENT DESCRIPTION : Determination of body mass by measuring the period of three cycles of free oscillations in the z-axis, with the subject strapped down on a special low friction linear spring device.

1. Input signal characteristics — Timer start and stop pulses

2. Electrodes, transducers — Photo-electric cell as a high resolution zero crossing detector

3. Signal conditioner(s) — Six decade digital timer and counter.

4. Range of measurement — 100-250 lbs.

5. Frequency of measurement — Once per 1 - 2 weeks

6. Output signal characteristics

analog/digital	Time only in digital format
amplitude	0-5 volts (?)
frequency range	N/A
accuracy/sensitivity	0.1 % accuracy

7. Calibration

type & technique	Pre-calibrated with standard weights
frequency	N/A

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, digital, intermittent time on Digital Readout
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digital time, intermittent
manual/programmed A or D switching	Signal routing programmed
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	N/A
storage time analog/digital	Digitized until next data dump
recording/storage quantity per subject	5 seconds for each measurement, to be repeated three times for each subject

9. Derived quantities	Body Mass
other measurements required simultaneously for calculations	N/A
digital computation	Period ^{2} = A + B Mass
display analog/digital; location; updating frequency	Mass in digitized format on Digital Readout after each run
recording analog/digital	Mass in digitized format
storage time analog/digital	Digitized until next data dump
10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	100-250 lbs, ± .1%
12. Printout frequency & other requirements	After each measurement

13. Miscellaneous information, details on referenced items, etc.

The exact conversion formula for the Thornton device has yet to be obtained from the NASA

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Metabolism & Nutrition

MEASUREMENT GROUP : Metabolism & Nutrition

MEASUREMENT : Specimen Mass Measurement

MEASUREMENT DESCRIPTION : Determination of specimen mass by measuring the period of five cycles of free oscillations in a single axis, with the specimen firmly attached to a low friction linear spring device

1. Input signal characteristics	Timer start and stop pulses
2. Electrodes, transducers	Photoelectric cell as a high resolution zero crossing detector
3. Signal conditioner(s)	Six decade digital timer and counter
4. Range of measurement	0-500 grams
5. Frequency of measurement	Several times daily
6. Output signal characteristics	
analog/digital	Time only in digital format
amplitude	0-5 volts
frequency range	N/A
accuracy/sensitivity	.01% accuracy preferred
7. Calibration	
type & technique	Pre-calibrated with standard weights
frequency	N/A

8. Data handling	
display analog/digital (raw, processed; local, remote; continuous, intermittent)	Raw, digital, intermittent time on Digital Readout
recording analog/digital (raw, processed; continuous, intermittent)	Raw, digital time, intermittent
manual/programmed A or D switching	Signal routing programmed
manual/verbal data entry	Subject and specimen identification and measurement number
A/D conversion frequency	N/A
storage time analog/digital	Digitized until next data dump
recording/storage quantity per specimen.	5 seconds for each measurement, to be repeated three times for each specimen
9. Derived quantities	Specimen Mass
other measurements required simultaneously for calculations	N/A
digital computation	Period ^{2} = A + B.mass + C.mass^2 + ——
display analog/digital; location; updating frequency	Mass in digital format on Digital Readout after each run
recording analog/digital	Mass in digitized format
storage time analog/digital	Digitized until next data dump
10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	0-500 grams, ± 0.01% accuracy
12. Printout frequency & other requirements	After each measurement

13. Miscellaneous information, details on referenced items, etc.

The exact conversion formula for the Thornton device has yet to be obtained from the NASA

MEASUREMENT REQUIREMENTS DATA SHEET

SUB-SYSTEM : Metabolism & Nutrition

MEASUREMENT GROUP : Metabolism & Nutrition

MEASUREMENT : Total Body Water (Ethanol technique)

MEASUREMENT DESCRIPTION : Determine total body water by measuring breath ethanol concentration 30 minutes after ingestion of standardized amount of 100 proof ethanol.

1. Input signal characteristics — Visual observation only

2. Electrodes, transducers — Unico No. 400 Precision Gas Detector (pump)

3. Signal conditioner(s) — Unico No. 104A Ethanol gas detector tubes (Kitagawa)

4. Range of measurement — Once per 1-2 weeks

5. Frequency of measurement

6. Output signal characteristics

analog/digital	N/A
amplitude	N/A
frequency range	N/A
accuracy/sensitivity	N/A

7. Calibration

type & technique	N/A
frequency	N/A

8. Data handling

display analog/digital (raw, processed; local, remote; continuous, intermittent)	N/A
recording analog/digital (raw, processed; continuous, intermittent)	Measure length of discolored section of reagent column, and enter concentration on data entry heyboard.
manual/programmed A or D switching	N/A
manual/verbal data entry	Subject identification and measurement number
A/D conversion frequency	N/A
storage time analog/digital	Digitized value until next data dump
recording/storage quantity per subject	Minimal, repeated at 20, 30 and 45 minutes after ingestion of ethanol

9. Derived quantities

	Total Body Water
other measurements required simultaneously for calculations	Volume of 200 proof (100%) ethanol ingested; provisionally established at 25 ml.
digital computation	Total body water = $\frac{25}{\%\text{ breath alcohol}}$
display analog/digital; location; updating frequency	Digital value of above equation on Processor Readout
recording analog/digital	Digital values of the three determinations
storage time analog/digital	Digitized until next data dump

10. Comparison with previous data	N/A
11. Analog/digital display range & resolution/accuracy	40,000 to 80,000, ± 1%
12. Printout frequency & other requirements	Three values for each measurement

13. Miscellaneous information, details on referenced items, etc.

Presently available standard Kitagawa tubes(Unico, Type No. 104A - ethanol) have a range of 0.04 to 5%. Their sensitivity for the low concentrations of interest for this measurement must be considerably improved, while the upper limit may be reduced to 1%.

BEHAVIORAL SUBSYSTEM III-H

SECTION III-H

IMBLMS FUNCTIONAL BREADBOARD (FBB) SYSTEM PERFORMANCE/DESIGN

BEHAVIORAL SUBSYSTEM

BEHAVIORAL

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

- 3.1 Performance
  - 3.1.1 Overall System Functional Requirements
    - 3.1.1.1 Overall Measurement Requirements
    - 3.1.1.2 Overall Procedural Requirements
    - 3.1.1.3 Individual Test Requirements
- 3.2 Interface Requirements
  - 3.2.1 Behavioral Measurement/PBDM Station Interface
    - 3.2.1.1 Activity Centralization
    - 3.2.1.2 Means for Self-Administration
    - 3.2.1.3 Control of Extraneous Stimuli
  - 3.2.2 Subject/Equipment Interfaces
  - 3.2.3 Behavioral/Date Management Interfaces
    - 3.2.3.1 Visual
    - 3.2.3.2 Auditory
    - 3.2.3.3 Psychomotor
    - 3.2.3.4 Complex Behavior
- 3.3 Design and Construction
  - 3.3.1 Vision Tester
    - 3.3.1.1 Test Materials
    - 3.3.1.2 General Configuration
    - 3.3.1.3 Power Requirements
  - 3.3.2 Audiometer
  - 3.3.3 Performance Panel
  - 3.3.4 Critical Tracking Task

4.0 DESCRIPTIVE DEFINITION AND BLOCK DIAGRAMS

APPENDIX - BEHAVIORAL PROCEDURES

1.0 INTRODUCTION

This document establishes the requirements for the performance and design of the Behavioral Measurement Subsystem together with interface requirements with the other subsystems. The Behavioral Measurement Subsystem consists of a vision tester, audiometer, performance panel with critical task tracking, and auditory and visual communication and recording equipment. Control of stimuli, procedures scoring, and the capability for revision of the test elements are provided through the Data Management Subsystem interface.

2.0 APPLICABLE DOCUMENTS

Section III-A FBB System Requirements document contains all applicable documents.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Overall System Functional Requirements. - The Behavioral Test Element shall consist of a set of measurements which assess representative aspects of on-going mission related behavior. The techniques shall have descriptive, diagnostic, and predictive value, and be compatible with mission operations and spacecraft hardware. The selected tasks are based on the following criteria:

- Selected tasks must be acceptable to those who must perform them
- Measures to be included must reflect critical behavior
- Requirements for equipment should be minimized
- Measures must be sensitive to slowly changing long-term trends, as well as sharp changes in the level of performance
- The selected tasks should show a high level of reliability over repeated administrations
- The conditions under which the tasks are administered should be controlled and repeatable
- Administration time should be as short as possible
- Performance scoring should be objective and should require little or no effort on the part of a test evaluator
- The characteristics of the tasks must be readily modified to provide many "equivalent" forms of each task
- Amount of specialized instruction should be minimized
- The tests should be self-administered, if at all possible

3.1.1.1 Overall Measurement Requirements. - The range of behavior to be assessed, the major test categories, and characteristic equipment are given in Table 1.

3.1.1.2 Overall Procedural Requirements. - Testing, with the exception of Work Behavior Measures, Individual and Interpersonal Measures, and Gross Body Movement Measures, will be accomplished through the use of an integrated test apparatus which permits the subjects to self-administer all tests. Each test will be conducted from the PBDM station, which is capable of programming all necessary test events, driving display devices, and recording and processing responses. Selection of the test(s) to be conducted during a given test session will be made by appropriate entries inserted by the subject at the PBDM station.

TABLE 1

MEASUREMENT TECHNIQUES AND MAJOR

EQUIPMENT ELEMENTS FOR BEHAVIORAL TESTS

CATEGORY	SUBCATEGORY	DESCRIPTION OF MEASUREMENT	Voice Link and TV	Audiometer	Vision Tester	Performance Panel: Meters	Performance Panel: Lights/Buttons	Performance Panel: Digit Displays	Performance Panel: Light Matrix	Performance Panel: Critical Task Tester
Sensory	Visual	Acuity			X					
		Depth perception			X					
		Adaptation			X					
		Photostress			X					
		Phorias			X					
		CFF			X					
		Color matching			X					
	Auditory	Pure tone threshold		X						
		Speech intelligibility index		X						
Psychomotor	Fine Motor Abilities	Arm and hand steadiness								X
		Wrist and arm speed					X			
	Gross Positioning Abilities	Response orientation					X			
		Arm-movement speed					X			
		Multilimb coordination					X			
	Gross Body Movement	Static strength	Derived from Physiological Measures							
		Dynamic strength								
		Gross body coordination								
		Stamina								
	Continuous Control	Critical task tracking								X
Complex Behavior	Perceptual, Cognitive	Rate of gain of information					X			
		Complex perceptual process					X		X	
	Monitoring	Visual monitoring					X			
		Probability monitoring				X				
		Auditory monitoring		X						
	Complex Mental Processes	Memory processes						X	X	
		Mediational processes					X	X		
	Work	Time and motion study	X							
Individual and Interpersonal Behavior	Open Verbal Communication		X							
	Written Communication		X							
	Operational Evaluation Reports		X							
	Debriefing Reports									

Test initiation will be under command of the subject. In the case of single tests or multiple tests conducted in sequence, each test will be initiated by a separate command from the subject. In the case of multiple tests conducted concurrently, initiation of the test battery will be commanded by the subject with coordination of the component tests being accomplished by automatic programming. When a command for test has been implemented, the subject will be presented with a signal indicating "Test in Progress". This signal will remain present until the test is completed, at which time it will terminate. For those tests which involve discrete trials, a "Ready" signal shall be presented to the subject prior to the beginning of each trial; a "Trial in Progress" signal shall be presented at the start of each trial, remain present during the trial, and terminate at the end of the trial; and any response occurring outside the trial period shall be rejected.

3.1.1.3 Individual Test Requirements. - The following sections delineate the functional requirements for each individual behavioral measurement. The organization of the tests proceeds from measures of simple sensory functions to measures of more complex higher order processes.

3.1.1.3.1 Vision Tests. - The visual functions to be measured shall include: acuity, binocular depth perception, dark adaptation, photostress, phoria, CFF, and color matching. The functional requirements for each test element are delineated below:

Visual Acuity Test. - This test provides a measure of the subject's visual acuity, i.e., a measure of his ability to resolve detail in the visual field. The test consists of presenting the subject with a test field of known brightness which contains calibrated test materials. Each set of test materials consists of a number of test patterns, in which the critical detail is oriented in a different direction. The minimum size test pattern for which the subject can correctly indicate the orientation of the critical detail is taken as the threshold value.

Stereoscopic Depth Perception Test. - This test provides a measure of the subject's ability to judge depth, based on an angular disparity of a stereopair of images. The test consists of presenting the subject with a test field of known brightness, containing a calibrated set of stereo images. The smallest angular disparity for which the subject indicates a perception of depth is taken as the threshold value.

Adaptation Test. - This test provides a measure of the rate at which the sensitivity of the subject's visual system adjusts from the prevailing luminance level to a condition of darkness, over a period of 20-30 minutes. The test consists of presenting the subject with a darkened visual field after he has become light adapted to a visual field of known brightness. The darkened field contains a red fixation point. A test patch is presented intermittently. Its brightness is increased from some minimal value to a point at which it is just detectable by the subject. The latter indicates detection of the test patch and resets the brightness of the test patch in preparation for another measurement. The successive brightness levels thus obtained, constitute, when plotted as a function of time, a measure of the subject's dark adaptation rate.

Test of Photostress. This test measures the sensitivity of the eye to sudden changes in light energy. It consists of presenting the subject with an adaptation field of known brightness, containing a fixation point at the center of the field. At the end of a predetermined exposure period, the subject is subjected to a brief, high intensity flash of light, and immediately thereafter is presented with a test patch. The time for the test patch to become visible is taken as the index of photostress. Throughout the test period, the subject continues to observe the test field, preventing his eyes from becoming light adapted.

Phoria. Phoria tests measure the tendency of the eyes to deviate from a coincident line of regard when the stimulus to fusion is low. This is accomplished by presenting separate images to the two eyes and measuring the apparent respective position of the images. The subject will view test slides and report the apparent position of the figure elements. The reported positions is converted to a measure of phoria in terms of angular deviation of the line of regard from normal.

Critical Flicker Fusion. - This is a measure of the ability of the visual system to temporarily resolve successive flashes of light which may vary in intensity, duration, and frequency. The test will be performed by requiring the subject to observe a sequence of test stimuli and adjust flash frequency until the point of fusion is reached. The critical flicker frequency will be taken as a measure of performance.

Color Matching Test. - This test provides a measure of the subject's subjective judgement of color brightness. The test consists of presenting the subject with standard colored test patches in one portion of the visual field and an adjustable achromatic grey scale in the other portion of the field. The subject adjusts the grey scale to the point where its judged brightness matches that of the colored portion, denotes acceptance of the match, and terminates the trial. Luminance values of the grey scale obtained from the subject's settings constitute the measure of his subjective judgement of color brightness.

3.1.1.3.2 Audiometric Measurement. This test provides a measure of the subject's absolute auditory thresholds and, by derivation, his speech frequency thresholds. The test consists of presenting the subject, monaurally, by means of a calibrated headset, a sequence of pure tones of prescribed frequency with a programmed variation in signal intensity. During the presentation period for each test frequency, the subject compensates for the programmed changes in intensity by adjusting a control to maintain the tone at a just audible level. Recordings of these adjustments provide the basis for determining threshold values at each frequency.

3.1.1.3.3 Psychomotor Measures. - The following measurements represent techniques for assessing simple psychomotor processes which require minimal higher order thought processes.

Arm-Hand Steadiness. - This test is a measure of the ability to make precise positioning movements where strength and speed are minimized. The subject is required to hold the hand and arm steady while fully extended and unsupported, without locking the elbow. The measure of performance is the number of excursions of the extended arm beyond the limits of a minimal target area.

Wrist-Finger Speed. - This is a measure of the ability to make rapid repetitive tapping movements between two adjacent target areas, using the fingertips of the preferred hand. As a measure of performance the number of contacts with the target areas is measured during specified time periods.

Response Orientation. - This is a measure of the ability to make rapid directional discriminations and correct orientation of movement patterns. The subject is presented with non-spatial stimulus and is required to make a movement in the appropriate direction as indicated by prior instruction. The cumulative response time for a series of correct responses is taken as the index of performance.

Speed of Arm Movement. - This is a measure of the ability to make gross discrete arm movements where accuracy is not a prime requirement. The subject moves the extended arm from one target area to a distant target area. The response measure is the amount of time to make single descrete responses.

Multilimb Coordination. - This is a measure of the ability to coordinate the movements of a number of limbs simultaneously and requires the subject to make a series of control movements using both hands or hands and feet simultaneously. Performance is measured in terms of response time and accuracy in performing the component tasks.

Static Strength. - This is a measurement of the maximum force which a subject can exert for a brief period of time where the force is exerted continuously up to this maximum against external objects. This ability will be measured by requiring the subject to exert maximum force against a force sensor such as a dynamometer. The time-force pattern and the maximum force level exerted shall be taken as measures of performance.

Dynamic Strength. - This is the ability to exert muscular forces repeatedly or continuously over time, representing muscular endurance and resistance to fatigue. It will be measured during a task which requires use of a set of muscles whose function is to propel, support, or move the body for prolonged periods. Operation of a bicycle ergometer is typical of such a task. The measure of performance shall be the time-force pattern of response and the maximum output levels achieved over time.

Gross Body Coordination. - This is a measure of the ability to coordinate simultaneous action of different parts of the body while making gross body movements. This measurement will be made in conjunction with the performance of other IMBIAC tests when such a combination is feasible. Measurements will be made by time and motion techniques. The measure of performance will be time and accuracy of performance.

Stamina. This is a measure of the capacity to continue maximum effort requiring prolonged exertion over time, and in physiological terms is known as cardiovascular endurance. No separate measure of this capability will be required but it shall be derived from measures of the cardiovascular system.

Critical Tracking Task. - Performance on this task reflects the functioning of the subject's continuous control capabilities and thus, indirectly, the precision and temporal aspects of his motor responses, as well as the perceptual and mediational aspects of his information processing. The task consists of manual compensatory tracking of an increasingly unstable controlled element, up to the point at which control is lost. The controlling responses of the subject are accomplished by means of a small, hand operated control stick. Performance is scored in terms of the level of instability at which control is lost, yielding a measure of the subject's effective time delay when tracking.

3.1.1.3.4 Measures of Complex Performance. - These tests represent measures of complex behavior involving perception, decision making, memory, and conceptual functions.

Rate of Gain of Information. - This is a measure of the amount of information, expressed in bits, which the human subject can process. It reflects the temporal characteristics and storage capacity of the Central Nervous System. This ability is measured by requiring the subject to make choice responses to multiple choice situations and measuring reaction time as a function of number of stimulus alternatives.

Visual Pattern Perception. - This task tests basic processes important in pattern perception as an index of the general level of awareness of the subject. A 6 x 6 cell matrix is used to present patterns of varying complexity and similarity or dissimilarity at a fixed rate. When three successive pattern displays are presented to the subject, he is required to indicate whether the second or the third pattern was the same as the first.

Discrete Signal Monitoring. - Performance on this task reflects the monitoring, vigilance, and attention processes operative during watchkeeping behavior. The task consists of detection of the onset of normally "off" light signals, and detection of the cessation of normally "on" light signals. Detection time is measured. Failure to respond to a signal change within a fixed period is considered a "miss." The signal changes to be detected are presented randomly with respect to the type of change, the display affected, and the time of occurrence. This test will normally be conducted simultaneously with the performance of another task in the test battery. Performance is scored for each type of signal in terms of number of correct responses, number of failures to respond, and time to respond.

Probability Monitoring. - Performance on this task reflects the functioning of the subject's vigilance, attention, perceptual and mediational processes. The task consists of monitoring four analog meters whose pointers are driven in random patterns about a mean value at the center of the scale and detecting the introduction of a bias into the readings of any one of the meters. Detection time is measured. Failure to respond to the biased condition within this fixed period is considered a "miss" and the display is automatically reset to its normal condition. The signals to be detected are presented randomly. This test will normally be conducted simultaneously with the performance of another task in the test battery. Performance is scored in terms of number of correct responses, number of failures to respond, total number of responses, and time to respond.

Memory Processes.- Performance on this task reflects the functioning of learned mental processes and short term memory. The task consists of solving a series of arithmetic problems each of which involves the mental addition of two numbers and the mental subtraction of a third number from the remembered sum of the first two. Each problem is presented for a fixed time. The subject must indicate his solution prior to the disappearance of the problem from the display. Performance is scored in terms of the number of answers recorded and the number of correct answers.

Mediational Processes. - Performance on this task reflects the functioning of non-verbal mediational processes such as the filtering, storage, and encoding of information during problem-solving behavior. The task consists of solving a series of three problems. The subject must deduce the transformation which was applied to one sequence of five numbers in order to generate a second set. He applies this transformation to the second sequence in order to generate a third and tests to see if this third sequence is correct. Performance is measured in terms of the number of sequences solved, the time required per sequence and the number of errors per sequence.

Work Measurement. - Performance of routine complex tasks which relate to spacecraft systems operation shall be assessed by time and motion study techniques. Means shall be provided for observing and recording the actions involved in selected tasks in a manner which permits analysis of spatial and temporal characteristics of the ongoing behavior.

3.1.1.3.5 Individual & Interpersonal Behavior. - These measures are directed towards assessing complex individual adjustment and interpersonal relations.

Open Verbal Communication. - Direct voice communication with the astronauts aboard the spacecraft via voice link to the ground is required as a means of assessing status and as a basis for interrogation and flexible communication. Measure of performance may be qualitative, or may be quantitative and systematic for specific mission segments.

Written Communication. - This technique provides a means of recording and later assessing personal and private attitudes, opinions and observations relative to individual and interpersonal behavior. Qualitative judgements, content analyses, and systematic analysis of verbal structure and handwriting will serve as measures of performance.

Operational Evaluation Reports. - This technique provides a means of evaluating mission related attitudes and evaluation of function through systematic, structured, and time sampled ratings of relevant operational activities, equipment, provisions and personal equipment. The measure of performance shall be the verbal report of the subject being analyzed by systematic ground based techniques.

Debriefing Records. - This measurement category shall include a variety of post-flight evaluation techniques including performance tests, interviews and reviews of operational flight procedures and events. Systematic objective techniques shall be employed where possible to evaluate and analyze results.

3.2 Interface Requirements

3.2.1 Behavioral Measurement/PBDM Station Interface. - For the most part, Behavioral Tests will be conducted at the PBDM Station. Interface requirements involve the centralization of the operator's activities, the provision of means for the self-administration of the tests, and the insulation of the subject from extraneous conditions. Concurrent behavioral and physiological measurement will be required in some cases.

3.2.1.1 Activity Centralization. - This requirement includes provision of:

- o A focal location from which the subject performs the tests
- o An integrated arrangement of display devices for presenting test stimuli and other test information
- o An integrated arrangement of control devices by which the subject can make the required responses
- o Space and fixtures within the display-control area for mounting and supplying inputs to peripheral test equipment when in use
- o Readily accessible storage space for peripheral test equipment when not in use
- o Easy access to the means for recording identifying information prior to test
- o Easy access to the means for commanding test programs and test events; and
- o The capability for conducting certain physiological measurements (EEG, EKG, etc.) simultaneously with behavioral measurements without procedural interferences

3.2.1.2 Means for Self-Administration. - This requirement includes provision of:

- o Means by which the subject may insert into the record the necessary identifying information prior to test
- o Means by which the subject may command and initiate test programs and test events
- o Automatic means for programming all necessary test events, driving display devices, and recording and processing

3.2.1.3 Control of Extraneous Stimuli. - This requirement includes:

- o Suppression of any non-test stimulus arising from operation of PBMS equipment which might serve as a cue for response during test performance

- Elimination of any requirement for actions other than those involved in the test being performed

- Suppression of extraneous stimuli in the environment while a test is being conducted

3.2.2 Subject/Equipment Interfaces. - The following subject/equipment interfaces will exist during performance of Behavioral Tests at the PBDM station.

- Pre-test entering of identifying information

- A pre-test commanding of specific test programs and procedures

- Vision Testing scoring

- Auditory scoring

- Critical Tracking Task scoring

- Performance Measurement Evaluation and scoring

- Observation of subject during work

- Voice link and hard copy logs

3.2.3 Behavioral/Data Management Interfaces. - The data management system (DMS) will provide the means for setting up a particular test element, controlling the nature and timing of stimulus presentations and procedural steps as required by the individual tests, recording, computing, and presenting test results, and identifying test, time and subject.

The following subsections outline the test procedures involved in carrying out the Behavioral measurements. Appendix A contains detailed procedural steps.

3.2.3.1 Visual. - The test subject will call up the appropriate test procedures by inserting commands into the computer. The subject will initiate individual tests by activation of a start signal. Test sequences will be computer programmed and each stimulus item or mode will be identified with respect to the nature of the test, the particular stimulus material, and its order of appearance in a series. The subject's responses will be compared to this coded information and dependent measures computed and stored for display.

3.2.3.2 Auditory. - A pre-programmed Békésey type audiometer will be employed. The device automatically prepares a plot of threshold amplitude versus frequency for each ear separately and sequentially, as it cycles through its program. The Data Management interface requires start and stop commands, a means of designating which ear is being tested, and a record of stimulus amplitude versus frequency.

3.2.3.3 Psychomotor. - In general, fine motor abilities testing procedures require the test subject to call up the appropriate test procedures by inserting a command into the data processing system. Subject will initiate test start sequence. The data management interface provides ready signals and start.

Gross positioning abilities and gross body movement testing procedures are similar to those above. Some measurements such as the multilimb coordination will involve simultaneous task performance. Other measurements such as static strength and dynamic strength will require utilization of supporting test equipment such as the ergometer, and Exer-Genie.

The Critical Tracking Task utilizes a self-contained unit. As such, its interface with the DMS consists of: Test setup command-turn on, warm up, and select program for timing and measurement and measurement sensing, storage and readout. Each trial run is initiated by the subject who first commands the computer to set up the test. The trial is initiated by the subject after "Test in Progress" signal comes on. The trial ends when the subject loses control. He then commences a new trial after a 15 second rest. After 5 trials, the series is completed. The DMS provides a measure of performance in terms of the mean λ value over the 5 trials.

3.2.3.4 Complex Behavior. - In general the processor will control the overall timing and sequencing of the tests, selection of the stimulus elements and perform calculations required. For rate of gain of information testing, the processor will be required to program the test stimuli and perform calculations of the regression equations for analyzing the resulting data. During the complex perceptual processes evaluation, the processor will generate the standard and test patterns, provide scoring, and presentation of knowledge of results to the operator. Visual monitoring will be controlled by the data management system by presenting on-off control on lights which will be programmed to change state for a specified time period. Probability monitoring will be accomplished similarly with the DMS driving analog meters. Auditory monitoring requires the subject to call up this test via insertion of a command in the DMS. The DMS will control the presentation of test stimuli which shall consist of a tone presented in a regular sequence of "beeps" and program which presents signals at an average rate of 8 per hour. The DMS will control overall timing and sequencing of the memory processes test, generate the test problems, perform scoring and presentation of knowledge of results to the operator. Mediational Processes will be accomplished using the DMS to provide different 5-digit sequences as problem units, evaluate the subject's responses and score results.

3.3 Design and Construction

The Behavioral Measurement Subsystem will incorporate equipment that has had prior testing acceptance, display arrangements that optimizes subject interface, and accepted testing procedures. Commercial equipment will be used wherever possible and development of unique or new stimulus material will be minimized. The Behavioral Measurement Subsystem consists of four major testing units (1) Vision, (2) Auditory, (3) Performance Panel, and (4) Critical Tracking Task Unit. Table 1 summarizes the equipment associated with specific measurements.

3.3.1 Vision Tester. - This unit will be an integrated device and will contain all sources of stimuli, all necessary subject positioning aids, optics, test stimuli, illumination control, controls and displays, programming logic, and computer interface. It will permit the subject to perform independently each of the vision tests included in the test battery.

The vision tester consists of a binocular viewing system for films or slides for stimulus presentation, supplemented by an optical wedge and balance, and a shutter system for luminance and temporal control of the test conditions. Supplementary elements provide for head fixation, artificial pupil, near/far viewing, and pretest adaptation level. Tests will be set up by computer inset. All responses are made by simple non-visual potentiometer adjustment or switch closures while the subject views the presented material.

3.3.1.1 Test Materials. - Acuity test materials will consist of calibrated Landolt "C"s or "E"s. Contract between symbol and background will exceed 100%. Figures will be produced on transilluminated film strips or slides. Test stimuli must be arranged in random order with respect to position of the gap in the "C"s or orientation of the "E"s. Gaps will be oriented at 1 of 4 values, 90 degrees apart with the top of the field designated 0 degrees.

Stereoscopic Depth test materials will consist of Binocular stereoscopic images on filmstrips or slides. The test stimuli will be a calibrated series of images which appear to stand out from the background reference plane, as a result of calibrated differences in stereoscopic viewing angle between each pair. Test materials will be arranged in random order with respect to magnitude of the stereoscopic angle and position on the slide. Increments in angle will be in minutes over the acuity of 20-10 to 20-40 range.

Adaptation test materials consist of (1) a red fixation point subtending 1/4 degree located in the center of a monocular field, (2) a preadaptation field homogeneously illuminated and subtending 10 degrees and (3) a test patch subtending 2 degrees coincident on center with the fixation point. An artificial pupil 2 mm in diameter is required in the eyepiece. White light will be used.

Photostress test materials are identical with those for adaptation except for the addition of the stresser. This will be a brief flash of light (50 ml, 0.1 - 1.0 seconds) introduced at specific times nominally at the rod-cone break and thereafter when the observer has recovered sensitivity to that level.

Phorias test materials will consist of calibrated binocular test frame. The view to one eye shall be a red arrow or line, either vertical or horizontal. The view to the other eye shall be a corresponding achromatic linear (vertical or horizontal) scale with scale positions represented by numbers.

Critical Flicker Frequency test materials will consist of an intermittent achromatic circular test patch, monocularly presented, subtending 1° of arc. The test patch illumination shall be fixed at a value between 5 to 20 ml. The stimulus shall be presented at frequencies in the range of 20-50 cps with a nominal duty cycle of 10% on, 90% off. The target shall be presented against a uniform dark surround. The subject will be capable of continuously adjusting flicker frequency during the trial.

Color Matching test materials will consist of circular colored test patches of 2 degrees centered in the right half of the test field and a neutral grey patch of 2 degrees, centered in the left portion of the field. The six colors shall correspond to Kodak Wratten filter values 6, 9, 25, 57, 61, and la. The brightness of the grey scale shall be under control of the subject.

3.3.1.2 General Configuration. - The subject must be comfortably positioned with respect to the binocular eyepiece, which is designed to accept different interocular distances. Means must be provided for maintaining head position. The eyes must be shielded from all light except that from the test materials. The subject must have access to the controls while the head remains fixed in viewing position. The device must be positionable to accommodate individual size/shape variations. Overall package size should be minimized, and be within 15" height, 10" width and 20" depth. Internally, the device must be configured to provide a binocular view of the test materials. Means must be provided for occluding the view from either eye or both, as determined by the computer program.

3.3.1.3 Power Requirements. - The Vision Tester will require 115 v, 60 Hz, and DC regulated power. Two 0 to 5 volt analog signals will be required to drive continuous functions. Control signals will be + 3.5 v DC. The input impedance will not be less than 1000 ohms. All signal returns must be electrically isolated from the case and all input and output leads must be twisted pairs.

3.3.2 Audiometer. - A Tracor ARJ-4A automatic recording audiometer is selected for the auditory measurements. This device offers subject-controlled test records of the hearing thresholds automatically. No special training is needed. Major characteristics of the system are:

Power:	115 volts, 60 Hz
Frequencies:	Automatically programmed or manually selected: 500, 1000, 2000, 3000, 4000, and 6000 Hz
Dimensions:	$9\frac{1}{2}$" x 12" x 21"
Weight:	32 pounds

Output signals will be presented to the Data Management System for recording and/or computational service if required.

3.3.3 Performance Panel. - This unit will consist of a set of displays, controls, and interfacing equipment to permit conduction of all psychomotor and complex performance testing, with the exception of the continuous control tasks which will be conducted with the Critical Tracking Task Unit.

The subject must have the capability to command and execute any test singly and specific tests in combination with others. The device will consist of an assembly of lights, pushbuttons, meters, digital readouts, and response keys arranged on a modular panel (See Fig. 1). It will use components which are space-oriented, particularly with respect to physical envelope and functional performance characteristics. It will include signal processing components between display elements and interface elements with the DMS.

The performance panel as illustrated in Fig. 1 provides space for the critical task tester, the TV Microscope Monitor, and the remote video recorder control panel.

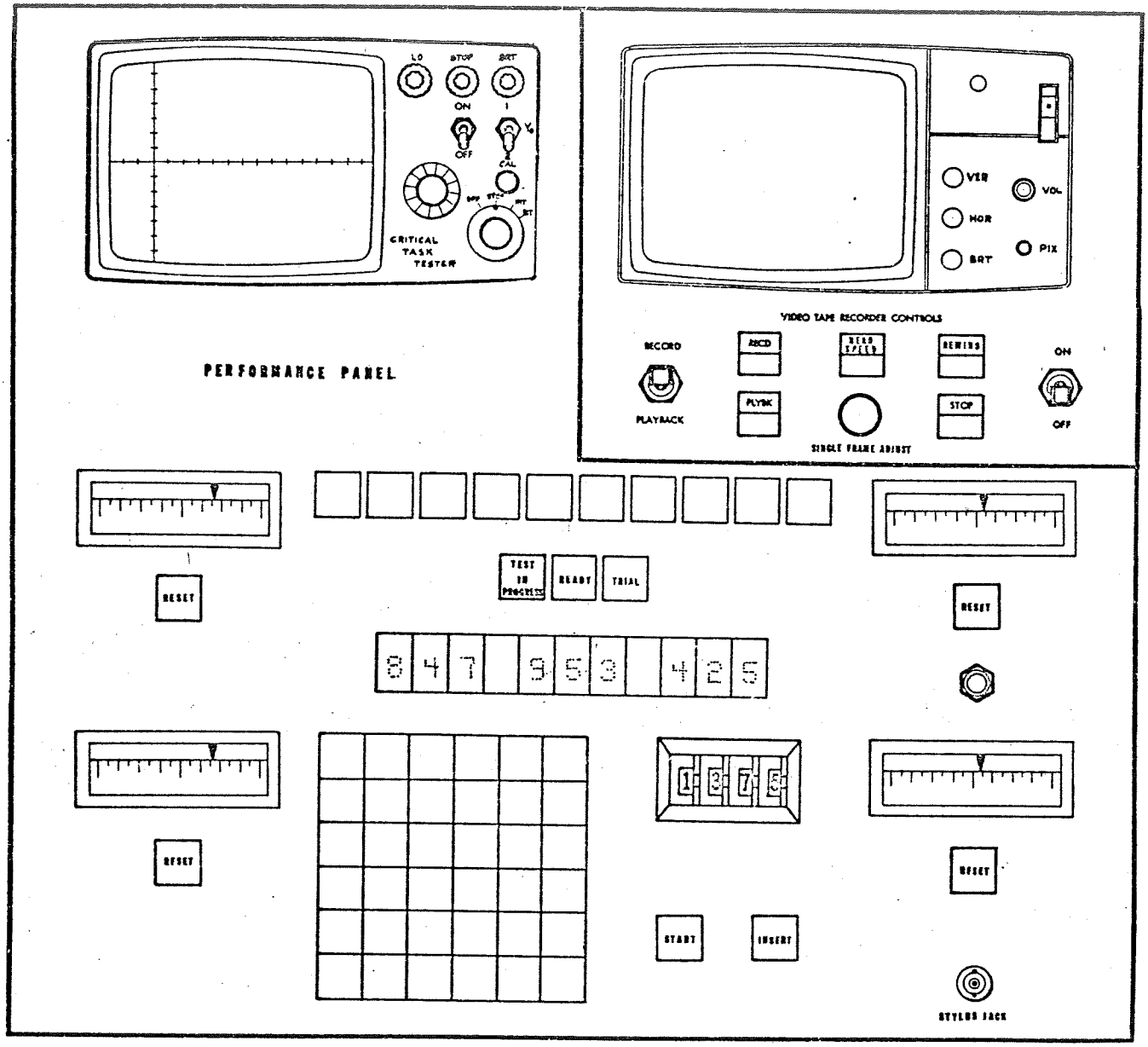


Fig. 1 Performance Panel

The equipment directly related to performing the behavioral measurements are as follows:

- Three signals - Test in Progress, Ready, and Trial. These will be centrally located on the panel. Digital displays, mechanical flags or lights are acceptable.

- An array of ten lights, of same color, should be arranged horizontally and equally spaced from one another.

- An array of 11 digital displays will be arranged horizontally, parallel with the lights. Means shall be provided to indicate the grouping of digits into 3 sets of 3 each or 2 sets of 5. Providing 11 digital displays will permit calling up 3 sets of 3 each by blanking out two of the displays, while blanking out the middle display will provide the 2 sets of 5. The Hewlett-Packard Solid State Display Unit HP 5082-7000 is recommended. Associated with the digital displays will be a four place digital thumbwheel switch for setting up answers to arithmetic problems. A pushbutton is also required for inserting the digit sequence into the Data Management System after it has been set up on the digital switches.

- Four analog meters with approximately 2 in. scales will be located symetrically on the panel and as far apart as the panel dimensions permit. Associated with each meter will be a small pushbutton.

- A 6 x 6 display matrix containing 36 square cells will be provided. The total matrix size will be in the order of 4 to 6 inches on a side. Each cell must be programmable to be either dark or light.

- A pushbutton will be provided on the display panel to be used by the subject in initiating a self-paced test.

- The primary response keyboard will consist of 10 pushbuttons operating "no-bounce" microswitches. This keyboard will be located on the workshelf surface of the console, immediately in front of the performance panel area. The position of the keys will be arranged to fit under the fingers and thumbs of the relaxed right and left hands. The right and left thumb switches should be located 3-4 inches apart on center.

- A 2-axis bang-bang control will be located on the workshelf surface in the central or right hand position, or it may be located protruding from the lower portion of the performance panel. The axes of travel will be oriented 90° apart at 0°, 90°, 180°, and 360° with respect to the subject's line of sight. Stick deflection will be positive and in the order of $15\text{-}30^{\circ}$ from center. Movement in more than one axis at a time is not permitted. A four position toggle switch with maintained and momentary switching will meet the requirements.

- The auditory monitoring tasks requires a tone generator, timing device to provide signal temporal characteristics, a headset for the subject, and a response key to indicate detection of a signal. This response key will also be used for the visual monitoring task.

- The arm hand steadiness task requires a stylus and hole. The subject will attempt to maintain the stylus steady in the hole without touching the periphery. The hole will be located on the performance panel.

3.3.4 Critical Tracking Task. - The critical tracking task consists of 3 assemblies, e.g., (1) a display assembly, (2) a hand controller assembly, (3) an electronics power supply, and associated cabling.

The display is a 5" CRT. An error to be nulled will be displayed as the continuous deviation of a bar of light from a horizontal reference line on the face of the CRT.

The manipulator assembly comprises a control force stick, infinite resolution electromagnetic pickup, Hz oscillator, and control switch. This assembly will be self-contained and stowable when not in use.

The computer assembly unit is essentially a self-contained microcircuit analog computer which provides a first order divergent element displayed as the critical task on the face of a CRT, and circuits for automatically increasing the instability of the controlled element.

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

4.1 Conceptual Design

4.1.1 Design Objective. - The Behavioral Subsystem will be designed as an integrated test apparatus permitting self-administration of most tests. Major categories of testing are: Sensory, Psychomotor, Complex Behavior, and Individual and Interpersonal Behavior. Commonality of equipment will be emphasized. Control of stimuli, repeated test administration procedure, scoring, and capability for modification of the test elements will be a function of the Data Management Subsystem. Signals and power requirements will be provided through the computer wherever possible.

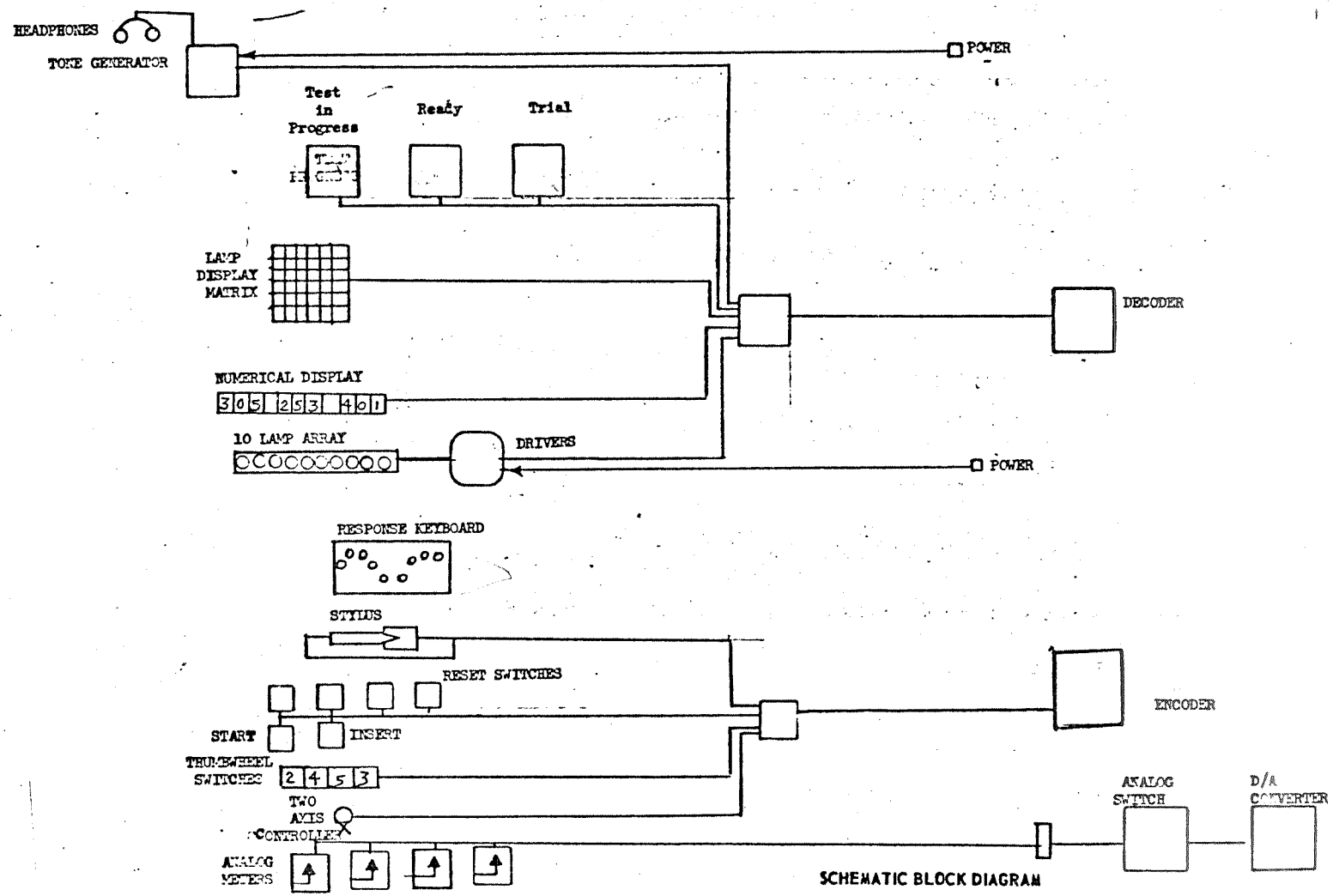
4.1.2 Design Concept. - Four major testing units will be employed: (1) Vision Tester, (2) Audiometer, (3) Critical Tracking Task Unit, and (4) Performance Panel. The first three items are essentially self-contained units requiring power and control signals via interconnecting cable assembly. The Performance Panel will be an integral part of the PBDM Station and will consist of a Display Panel and Response Keyboard mounted in the Control area of the PBDM.

4.2 Block Diagrams

4.2.1 Equipment Elements. - The Performance Panel Display elements include a 6 x 6 lamp display matrix, a 10 lamp linear array, status display lamps, an 11 digit numerical display, and four analog meters. In addition, an auditory monitoring signal is provided through a headset.

Control and response elements include a 3 digit thumbwheel switch, a 10 switch keyboard, a two axis switch controller, a steadiness test stylus, and several response and control push button switches.

4.2.2 Functional Operation. - Fig. 2 illustrates the equipment arrangement for the Performance Panel. The upper group of equipment receives decoder signals from the Data Management Computer, the middle group transmit data to the encoder which is connected to the Data Management Computer. The lower group of four analog meters are operated through the D/A conversion and Analog Switching of the Data Management Subsystem. All power supply (5v level) is being supplied by the Data Management Subsystem with the exception of the neon lamp which will be supplied with 115v PBDM station power and the auditory tone generator which requires +15v. The functional operation of the Vision Tester Audiometer, Vision Tester, and Critical Tracking Task Unit is discussed in Section III-H Appendix under measurement test procedures. These procedures illustrates the multiple use of the same equipment for various measurements.



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 2. PERFORMANCE PANEL	
CHK		APPD			
SUPV		APPD		CODE IDENT NO. 1[illegible]	DOCUMENT NO. III-E-19 REV
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B SH OF	

Form LMSC 26208

Section III-H

APPENDIX

BEHAVIORAL MEASUREMENT TEST PROCEDURES

Section | Page No.

A.1 VISION TESTER

A.1.1 Visual Acuity
A.1.2 Depth Perception
A.1.3 Dark Adaptation
A.1.4 Photostress
A.1.5 Phorias
A.1.6 Critical Flicker Fusion
A.1.7 Color Matching

A.2 AUDITORY MEASUREMENTS

A.3 PSYCHOMOTOR AND MENTAL FUNCTIONS

A.3.1 Arm-Hand Steadiness
A.3.2 Wrist-Finger Speed
A.3.3 Response Orientation
A.3.4 Speed of Arm Movement
A.3.5 Multilimb Coordination
A.3.6 Static Strength
A.3.7 Dynamic Strength
A.3.8 Gross Body Coordination
A.3.9 Stamina
A.3.10 Critical Tracking Task
A.3.11 Rate of Gain of Information
A.3.12 Complex Perceptual Processes
A.3.13 Visual Monitoring
A.3.14 Probability Monitoring
A.3.15 Auditory Monitoring
A.3.16 Memory Processes
A.3.17 Mediational Processes
A.3.18 Work Measurement
A.3.19 Individual and Interpersonal Measures

Section III-H

Appendix

BEHAVIORAL MEASUREMENT TEST PROCEDURES

This section presents detailed test procedures for the 27 Behavioral measurements.

A.1 Vision Tester. - The test subject will call up the appropriate test procedures by inserting commands into the data processing system. The subject will initiate individual tests by activating a start signal. Test sequences will be computer programmed and each stimulus item or mode will be identified with respect to the nature of the test, the particular stimulus material, and its order of appearance in a series. The subject's responses will be compared to this coded information and dependent measures computed and stored for display.

A.1.1 Visual Acuity. - The subject will call up the test procedures by inserting appropriate commands into the DMU. A signal will be provided to the subject to indicate that the system is ready. The DMU will command a binocular view. The subject will activate a start command. The test sequence will be pre-programmed and each stimulus item will be identified as appropriate with respect to angular size of the acuity target critical detail and orientation of the resolution detail. The subject will respond by indicating the orientation of the critical detail as one of four positions and this response will be compared to the actual position. The response will be stored within the DMU until the entire test sequence is completed. The DMU will compute average or threshold values. The DMU will command the brightness of the adaptation field, and program the sequence of stimulus events providing a different order of presentation of each trial with the same subject. The DMU will program a signal to indicate termination of the test series.

A.1.2 Depth Perception. - The subject will command the test setup via the DMU. The DMU will program the selection of the appropriate test materials, present a binocular view, command the appropriate fixed luminaces for the stimulus illumination, and present a ready signal when the system is set up. The DMU will store data on the sequence and nature of the individual test items. It will present a signal that the test is in progress after the subject indicates test initiation. The subject will respond by indicating whether each specific test stimulus is or is not in the background reference plane of the field of view. After all test stimuli have been presented, the DMU will present a test termination signal, and will calculate the subject's threshold from the series of responses.

A.1.3 Dark Adaptation. - The subject will command the test setup via the DMU. After a ready signal is presented by the DMU, the subject will initiate the test. The DMU will control the presentation of a monocular preadaptation field for a duration of four minutes at a level of 30 ft L. After this period,

the DMU will present a test start signal, program the appropriate test stimuli, activate a fixation point, and set the test patch luminance at a sub-threshold level. The subject will activate a control to increase the test patch luminance to a point where it is just visible. When this control is released, the DMU will produce a signal which causes reduction of test patch luminance until the point where the subject overrides this command and again causes an increase. This procedure will continue for a period of up to 30 minutes. The DMU will take stimulus intensity over time as the dependent measure presenting these data in graphic or tabular form. A signal indicating test termination will be presented after the 30-minute test period.

A.1.4 Photostress. - The subject will call up appropriate test procedures by inserting commands into the DMU. He will receive a ready signal when the system is operative, whereupon he will insert a start command. The DMU will control the presentation of the same stimulus as for the adaptation test. When a preselected level of adaptation is achieved, as indicated by the average intensity of the test patch over a 2-minute test period, a test flash will be introduced for a brief time period (1-5 seconds). The DMU will set the luminance at the computed average value and the subject will report when it is visible. A series of 5 such test flashes will be presented with timing between them dependent on recovery of the critical level of sensitivity. Subsequent to the presentation of the test series, a termination signal shall be presented. The DMU will store data with respect to the intensity of the test stimulus versus time, the time of occurrence of the test flashes.

A.1.5 Phorias. - The subject will call up the test procedures by inserting appropriate commands into the DMU. A signal will be provided to the subject to indicate that the system is ready. The DMU will command a binocular view. The subject will insert a start command. The test sequence will be preprogrammed and each stimulus item will be identified as to horizontal or vertical phoria. The subject will respond by indicating the position of the critical detail relative to a background scale. This response will be compared to the actual position. The response will be stored within the DMU until the entire test sequence is completed. The DMU will program a signal to indicate termination of the test series. The DMU will compute average or threshold values. The DMU will command the brightness of the adaptation field.

A.1.6 Critical Flicker Fusion. - The subject will command the test setup via the DMU. After a ready signal is presented by the DMU, the subject will initiate the test. The DMU will control the presentation of a monocular pre-adaptation field for a duration of four minutes at a level of 30 ft. L. After this period, the DMU will present a test start signal, set the test patch brightness level, and program the appropriate test stimuli. The stimulus will consist of a blinking light of fixed magnitude and duty cycle. The subject will adjust a control until the flicker disappears. He will then signal trial termination. The DMU will use flicker frequency (e.g., motor speed) as the dependent measure.

A.1.7 Color Matching. - The subject will command the test setup via the DMU. The DMU will provide a signal indicating the test is ready and the subject will initiate the test when ready through insertion of a start command. The DMU will present each of 6 color patches at a fixed luminance in a different random

order for each test sequence on a given subject. The DMU will also present a neutral gray test patch whose luminance is initially set at a value different from the colored patch, this value to randomly vary with respect to the successive trails. The subject will adjust the apparent brightness of the test patch until he is satisfied it matches the brightness of the colored patch, whereupon he will signal the system to record the value. The DMU will extinguish the two test stimuli, and then present the next pair for observation. When all six matches have been made three times each, the DMU will terminate the test and provide an indication to the subject. The measure of performance will be the average luminance setting of the neutral test patch for each colored match.

A.2 Auditory Measurements. - A pre-programmed Bekesey type audiometer will be employed. The device automatically prepares a plot of threshold amplitude versus frequency for each ear as it cycles through its program. The DMU interface requires start and stop commands, a means of designating which ear is being tested, and a record of stimulus amplitude versus frequency.

A.3 Psychomotor and Mental Functions.

A.3.1 Arm-Hand Steadiness. - The subject initiates the test via the DMU. The DMU presents a test ready signal. The subject inserts a "test start" command. The DMU times 3 trials of 10 seconds each, with five-second inter-trial intervals. Ready and start signals are presented before each trial. The subject is given a test terminate signal. The DMU counts the number of contacts of the stylus with the rim during each trial, the duration and distribution of contact durations to .01 seconds accuracy.

A.3.2 Wrist-Finger Speed. - Subject calls up the test. The DMU indicates when setup is ready. Subject inserts test start command. The DMU presents 3 trials of 10 seconds each, with 5 second intertrial intervals, each trial preceded by a ready signal and a start signal. Subject alternately taps two switches as rapidly as possible and DMU counts the number of contacts on each trial.

A.3.3 Response Orientation. - Subject inserts test command via DMU. DMU presents test ready signal. Subject initiates start of test sequence. DMU presents a ready signal, trial signal and then a series of 24 lights of 4 colors in random order. Subject must position a control to 1 of 4 proper locations to extinguish each light in sequence. Then a new light appears. DMU scores total time to extinguish the series of lights.

A.3.4 Speed of Arm Movement. - Subject calls up test via DMU. DMU indicates test is ready. Subject initiates test start sequence. The DMU presents a ready signal, and a trace signal. Subject taps 2 switches in sequence. DMU scores time between the taps on each of ten separate self-paced trials and computes mean, scoring to .001 seconds accuracy.

A.3.5 Multilimb Coordination. - The task will involve simultaneous performance of the critical tracking task and the response orientation task with certain modifications. The subject will set up for the task and receive a test-in-progress signal. He will initiate the trial, which will start after a 5-second time delay, permitting him to grasp the controls. The critical tracking

task will proceed to loss of control. At the same time, the subject will be making responses as in the response orientation task. When loss of control occurs, the trial shall stop. Data shall be in the form of time to loss of control, the value of lambda, when control was lost, and the number of correct responses made on the response orientation task.

A.3.6 Static Strength. - This measure shall be made in conjunction with use of the Exer-Genie. After test setup command, the subject will exert maximum pull against the device with both hands when a ready signal is given. The time-force pattern shall constitute the measure of performance. Five successive trials constitute a test series.

A.3.7 Dynamic Strength. - This measure shall be taken in conjunction with use of the bicycle ergometer. After inserting a test setup command, the subject shall perform a series of trials following the procedure outlined in Metabolism and Nutrition Section, operating on ready, start and stop signals presented by DMU control. The record of performance shall be output of the ergometer during each trial. The exact measure is contingent on the final design characteristics of the ergometer with respect to its primary purpose.

A.3.8 Gross Body Coordination. - This is a secondary measure and shall be derived from the time and motion TV measures. There is no DMU interface other than video taping.

A.3.9 Stamina. - This measure shall be obtained from cardiovascular system measures. There is no additional DMU requirements.

A.3.10 Critical Tracking Task. - The CTT is a self-contained unit. As such, its interface with the data management system consists of: test setup command - turn on, warm up, and select DMU program for timing and measurement, and measurement sensing, storage, and readout. Each trial run is initiated by the subject who first commands the DMU to set up the test. The trial is initiated by the subject after "Test in Progress" light comes on. The trial ends when the subject loses control. He then commences a new trial after a 15 second rest. After 5 trials, the series is completed. The DMU provides a measure of performance in terms of the mean value of time over the 5 trials.

A.3.11 Rate of Gain of Information. - The computer will control the overall timing and sequencing of the test, selection of the stimulus elements, and perform calculations of the regression equations for analyzing the resulting data. The computer will generate a test in progress signal. It will then control the presentation of stimuli as follows. The subject will make a series of choice reactions in response to visual stimuli. He will be presented with blocks of stimuli, each appearing for 50 milliseconds at intersignal intervals of 750 to 3500 milliseconds. The intersignal intervals shall vary in steps of 500 milliseconds and shall be programmed in a random order. Choice reactions shall involve 1, 2, 4 or 8 stimuli. The order of presentation from among the 2, 4 or 8 alternatives shall also be random. The signal choice block of trials shall always precede and follow the 2, 4 and 8 alternative situation. One hundred trials will be given for the single choice situation, 300 shall be given for the multiple choice situation. The number of choices shall be indicated to the subject prior to each block of trials by presenting a set of signals indicating which will be the stimulus lamps. For each multiple choice situation, the frequency of appearance of individual signal lights shall be

nearly equal. In summary, the sequence shall be as follows:

- o Test in Progress signal
- o Simple single choice reaction time block indicated
- o Ready signal
- o Stimulus appear for 50 msec.
- o Interstimulus interval (one of 7, e.g., 750, 1250, 1750, 2250, 2750, 3250, 2750 msec)
- o Next stimulus (one of 2, 4, or 8, randomly selected)
- o Steps 2-6 repeated for next number of choices
- o Steps 2-6 repeated for last set of choices
- o Block of simple single choice trials indicated and run
- o Signal test termination
- o DMU calculates regression equation fitting to each individual point, not the means

The entire test should be preceded by a warm up run at 1, 2, 4, 8 alternatives, with 20 responses each following the same sequence as given above.

A.3.12 Complex Perceptual Processes. - The computer will control overall timing and sequencing of the test, generation of the standard and test patterns, scoring, and presentation of knowledge of results to the subject. The computer will produce the test patterns according to the following requirements.

Test materials consist of standard figures drawn at random on the 6 x 6 matrix, with the constraint that each column height appears once only in each pattern. These figures, the test patterns, are identical to the standard pattern except that the test patterns are rotated 90, 180, or 270° from the standard at random. There need be only one sequence of constrained standard patterns, but rotation of the test patterns and the answer sequence (e.g., none, 1 or 2, or same or different) must be random with respect to the standard patterns. "Different" test patterns will all differ by 2 columns of the six.

The order of stimulus presentation is as follows: There is a 5-second presentation of the standard figure followed by a 2 second "off" period. This is followed by a 2-second display of a test pattern, another 2-second "off" period, then a second test pattern is displayed for 2 seconds. After a 15-second response period, a new standard target is presented, and the sequence repeated. The subject is permitted to respond only during the response period. If the subject responds before the 15 second period terminates, a signal will go on and remain activated until the end of the problem period. Just prior to termination of the test period, the subject is informed whether his response

was correct or incorrect by a brief signal (1/2 second). The measure of performance is the number of correct responses for the series of trials.

A.3.13 Visual Monitoring. - The DMU will control 5 normally "on" and 5 normally "off" lights, which will be programmed to change state for a 2-minute duration. These changes occur randomly at a rate of ten per hour and at intervals varying from 2.5 to 10 minutes, distributed equally over the 10 lights. The subject will respond by inserting a signal when the change is detected. The DMU will measure the response time to each change of state, and will score 120 seconds if no response is given. Response times are measured to .1 seconds accuracy. Incorrect responses will be counted.

This is a computer paced task. The test will be accomplished in accordance with the following sequence of events.

- o Command for test transmitted to computer
- o Computer selects program
- o "Test in Progress" light comes on
- o Change from "normal" condition occurs in one of the monitored indicators

(Change goes undetected)

- o Two minutes after Step 4, indicator resumes "normal" condition. (Return to Change goes undetected).

(Change is detected)

- o Operator activates pushbutton; indicator resumes "normal" condition. (Return to Step 4).

(Test period ended).

- o "Test in Progress" light goes off; indicator lights which are on go off.

NOTE: Although this test may be conducted independently for a fixed period, it will normally be conducted simultaneously with the conduct of another test. In such cases, the start, finish, and duration of this test will be determined by the start, finish, and duration of the accompanying test.

A.3.14 Probability Monitoring. - The DMU shall drive 4 displays, each consisting of a moving pointer and a linear meter scale of approximately 2 inches. Scale marks shall indicate a center, ± 20% and ± 40%. The pointers shall move in a normally distributed random fashion with a mean frequency of 5 cycles per minute centered at zero and a one sigma corresponding to ± 10% on the scale.

At random times, not to exceed nine per hour, one pointer shall be biased so that the mean of the distribution is shifted to center around the ± 10% point. The direction of the bias shall be randomly selected with respect to meter the stable indication, as shall the sequence of meters on which the bias appears. The bias shall be introduced over a 10 second interval in a linear fashion, and shall remain for 120 seconds. Failure of the subject to detect this shift within the allotted time period shall cause the bias to be abruptly removed. If the bias is detected, activation of the subject's response button shall cause the bias to be immediately removed.

The DMU shall permit the following measures to be made:

- o Number of false responses
- o Number of correct responses
- o Number of mean response time for correct responses
- o Number of mean response time for incorrect responses.

This is a computer paced task. The test will be accomplished in accordance with the following sequence of events:

- o Command for test transmitted to computer
- o Computer selects program
- o "Test in Progress" light comes on
- o Bias occurs in the readings of one of the meters

(Bias goes undetected)

- o Two minutes after Step 4, meter resumes normal condition.

(Return to Step 4)

(Bias detected)

- o Operator activates switch; pointer stabilizes at current mean
- o Operator releases switch; meter resumes normal condition

(Return to Step 4)

(Test period ended)

- o "Test in Progress" light goes off; pointers on all meters return to zero

NOTE: Although this test may be conducted independently for a fixed period, it will normally be conducted simultaneously with the conduct of another test. In

such cases, the start, finish, and duration of this test will be determined by the start, finish, and duration of the accompanying test.

A.3.15 Auditory Monitoring. - The subject will call up this test via insertion of a command in the DMU. The DMU will control the presentation of test stimuli, which shall consist of a tone presented in a regular sequence of "beeps". The program presents these signals at an average rate of 8 per hour. The tone duration is .25 seconds on with .80 seconds between tones. The critical signal is an off-period of 1.30 seconds.

The DMU will measure the response time to the signal to .10 seconds up to 30 seconds when a miss shall be scored. False responses shall also be counted.

This is a computer paced task. The test will be accomplished in accordance with the following sequence of events:

- o Headset removed from stowage, connected to equipment and fitted to head
- o Command for test transmitted to computer
- o Computer selects program
- o "Test in Progress" light comes on
- o Recurrent "beep" begins
- o Subject monitors recurrent "beep"
- o Critical signal occurs
- o Recurrent "beep" continues

(Critical signal undetected)

- o Return to Step 6

(Critical signal undetected)

- o Subject activates pushbutton (Return to Step 6)

(End of test)

- o "Test in Progress" light goes off; recurrent "beep" ceases
- o Headset removed from head, disconnected from equipment, and returned for stowage

NOTE: Although this test may be conducted independently for a fixed period, it will normally be conducted simultaneously with the conduct of another test. In such cases, the start, finish, and duration of this test will be determined by the start, finish, and duration of the accompanying test.

A.3.16 Memory Processes. - The DMU will control overall timing and sequencing of the test, generate the test problems, perform scoring, and presentation of knowledge of results to the subject.

Materials for this test consist of possible arithmetic problems. Each problem unit will consist of two 3-digit numbers (to be added), a third 3-digit number (to be subtracted from the sum of the first two), and a 4-digit number (the answer). Different problem groups will be run during successive test sessions.

The order of events and timing is as follows:

- o Command for test transmitted to computer
- o Computer selected test program
- o "Test in Progress" signal comes on
- o Thirty-second waiting period
- o Initial number display appears (3 sets of 3 digits as above)
- o Subject attempts solution
- o Subject sets up answer on the thumbwheel switches
- o Subject inserts answer recording button
- o If correct number display disappears; if incorrect, it remains until Step 10
- o Number display disappears 19 seconds after on-set. (Not dependent upon completion of Steps 7 and 8.)
- o Computer evaluates answer and presents "Correct" signal for one second if answer is correct.
- o Next number display appears (20 seconds after on-set of previous number display)

(Steps 6 through 12 repeated 88 times)

(Repeat Steps 6 through 11)

- o "Test in Progress" signal goes off (one second after disappearance of number display)

A.3.17 Mediational Processes. - The DMU will provide 120 different 5-digit sequences. Each problem unit consists of a Phase I sequence, a Phase II

sequence, and a Phase III sequence conforming to the following constraints: (1) each sequence is made up of digits from 1 through 5 with no digit repeated, (2)the Phase II sequence must differ from the Phase I sequence, (3) the same transformation which relates the Phase I and Phase II sequences must relate the Phase II and Phase III sequences, and (4) the transformation which relates the sequences must involve three or more elements. A typical problem is presented below:

1st sequence	2 4 1 3 5
2nd sequence	4 1 3 5 2
3rd sequence	1 3 5 2 4

The first transformation shifts the first digit to last place and advances all other digits one position to the left. Thus a positional transformation is effected. Problem units are recorded in blocks of 3 such that each problem block contains one problem with a 3-element transformation, one problem with a 4-element transformation, and one problem with a 5-element transformation. Four problem blocks, selected at random from the total population of 39 blocks, are presented during each test session.

This is a self-paced task in the sense that completion of one problem initiates the next. The test will be accomplished in accordance with the following sequence of events:

- Subject commands test setup via DMU
- DMU sets up test program
- "Test in Progress" signal is presented
- Problem Phase I and II are presented on digital display
- Thirty seconds later trial signal is presented
- Subject makes first response - error
- Ready signal does not come on, computer rejects response
- Subject makes new response - correct
- Ready signal comes on indicating next response is to be made
- Subject makes response for next transformation
- Cycle repeats as in Steps 6 - 9
- After all5 places have been correctly transformed, "Trial in Progress" signal is removed
- After 30 second break digital displays present next problem set
- Program repeats for 12 problem blocks
- "Test in Progress" signal terminated

A.3.18 Work Measurement. - Time and motion studies will be carried out using the onboard TV system. There is no interface requirement with the DMU, other than video taping.

A.3.19 Individual and Interpersonal Measures. - There are no interface requirements with the DMU other than audio recording.

15APR1969

BIOCHEMICAL SUBSYSTEM III-I

Section III-I

IMBLMS FUNCTIONAL BREADBOARD

PERFORMANCE/DESIGN

REQUIREMENTS

BIOCHEMICAL PREPARATION

AND ANALYSIS

BIOCHEMICAL PREPARATION
AND
ANALYSIS

1.0 INTRODUCTION

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

3.1 Performance
3.1.1 Functional
3.1.1.1 Overall System Requirements
3.1.1.2 Measurement/Technique Requirements
3.1.1.3 Specimen Requirements
3.1.1.4 Measurements - Bleeding Time
3.1.2 Operability
3.1.2.1 Safety
3.2 Interface Requirements
3.2.1 Experiment Equipment/Measurement Station Interfaces
3.3 Design and Construction
3.3.1 Mechanical
3.3.1.1 Module Sizing Requirements
3.3.1.2 Structural Requirements
3.3.2 Instrument Requirements
3.3.2.1 Electrometer
3.3.2.2 Isotope Counter
3.3.2.3 Hematocrit
3.3.2.4 Colorimeter
3.3.2.5 Microscope
3.3.2.6 Refractometer
3.3.2.7 Support Equipment Requirements
3.3.3 Displays and Controls
3.3.4 Calibration
3.3.5 Power Requirements

4.0 DESCRIPTIVE DEFINITION AND BLOCK DIAGRAMS

1.0 INTRODUCTION

This document establishes the overall performance and design requirements of the IMBLMS FBB Biochemical Preparation and Analysis (BPA) Station. The BPA Station will be designed to:

- o Perform clinical laboratory measurements in essentially the same procedural and data handling sequence as projected for the Flight IMBLMS.
- o Determine measurement feasibility and accuracy under operational constraints
- o Demonstrate centralized experimenter control
- o Evaluate the handling, storage and display of measurement data

The BPA station contains elements for conducting colorimetric, radioisotopic, microscopic, potentiometric, impedance, refractometric, microbiologic and test-tape measurements, and the ancillary equipment and supplied required to prepare specimens for "on-board" analysis, and/or storage for "post-flight" analysis.

2.0 APPLICABLE DOCUMENTS

Section III-A System Requirements Document contains all the applicable documents.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional. -

3.1.1.1 Overall System Requirements. - The BPA will be conducted separately from the PBDM station and will consist of a centralized console supported by biochemical supplies, measurement equipment including display and control provisions, and equipment necessary for identifying, labeling, and preservation of urine and blood samples. Interconnection cabling provisions will be provided for transmitting data from the BPA station to the PBDM station although normally data will be recorded manually and entered via the numerical data entry keyboard at the PBDM station. → Make automatic for flight

Measurement techniques utilized will be adaptable for use in a zero gravity environment with major emphasis on the use of colorimetry, ion specific electrode measurements, microscopy, hematocrit, radioisotope, refractometry, and test-tape determination. The required accuracy and range of values required for each test will be defined and used to evaluate the results obtained during subsequent testing.

3.1.1.2 Measurement/Technique Requirements. - The measurement/technique selection for the BPA station is based upon the list of measurements established by NASA. These measurements/techniques are identified in Table I. Specific measurement requirements are tabulated in Table II. The techniques in relation

TABLE I

IMBLMS FBB-BPAS MEASUREMENTS

Specimen Handling, Identification	Blood, Urine, Smears
Microscopy	Blood - RBC, WBC, Differential, Reticulocytes, RBC Morphology Urine - Urine Sediment Other - Microbial Smears
Ion Specific Electrode	Blood - pH, pCO_2, pO_2 Plasma - Na^+, K^+, Cl^- Urine - Na^+, K^+, Cl^-
Radioisotopic	Blood - Red cell mass Red cell survival Plasma - Plasma Value
Impedance	Blood - Hematocrit
Colorimeter	Blood - Osmotic fragility, Hemoglobin Plasma - Glucose Calcium, Phosphorous Urine - Calcium, Phosphorous
Refractometry	Plasma - Total Protein Urine - Specific Gravity
Test-Tapes	Urine - pH, Protein, Glucose, Bile, Blood
Miscellaneous	Blood - Bleeding Time, Coagulation Time Bicarbonate Urine - Color

TABLE II

	Frequency of Measurement (Times/week)	Range of Measurement Low	High	Accuracy	Calibration	Secondary Standards
I. ROUTINE HEMATOLOGY						
Hemoglobin	2	8	20 (gm/%)	± 0.5 gms/100 ml	Optical Filter	1
Hematocrit	2	35	55 (%)	± 2%	Electronic	1
Red Cell Count	2	2	7 (million)	*	N/A	N/A
White Cell Count	2	2	20 (K)	*	N/A	N/A
Differential	2	0	90%(%)	*	N/A	N/A
Red Cell Morphology	2	N/A	N/A	*	N/A	N/A
II. URINALYSIS						
Volume	2	0	3000 (ml/day)	± 5%	N/A	N/A
Specific Gravity	2	1.001	1.030 (gm/ml)	± .002	N/A	N/A
Test Tapes						
pH	2	1	4	*	N/A	N/A
Glucose	2	1	4	*	N/A	N/A
Protein	2	1	4	*	N/A	N/A
Bile	2	1	4	*	N/A	N/A
Blood	2	1	4	*	N/A	N/A
Sediment Exam.	2	N/A	N/A	*	N/A	N/A
III. OTHER EXPERIMENTAL						
Other Hematologic						
Bleeding Time	2	N/A	N/A	*	N/A	N/A
Coagulation Time	2	N/A	N/A	*	N/A	N/A
Reticulocytes	1	0.3	10%	*	N/A	N/A
Red Cell Frag.	1	0.24±	0.50±	±	Optical Filter	N/A
Specific Ion Electrodes						
pH, Blood	1	7.1	7.6	± 0.02	Std. Solns(2)	N/A
pCO_2 Blood	1	20	70 (mm)	± 2 mm**	Std. Solns(2)	N/A
pO_2 Blood	1	20	150 (mm)	± 2 mm**	Std. Solns(2)	N/A
Na	1	120	160.0 (meq/l)	± 3 meq/l**	Std. Solns(2)	N/A
K	1	2	7 (meq/l)	± 0.2 meq/L**	Std. Solns(2)	N/A
Cl	1	80	120 (meq.l)	± 5 meq/L**	Std. Solns(2)	N/A
Colorimetric						
Glucose	1	50	200 mg/100 ml	±5 mg/100ml**	Optical Filter	1
Ca	1	7	12 mg/100 ml	±0.2mg/100ml**	Optical Filter	1
Phosphate	1	1	8 mg/100 ml	±0.5mg/100ml**	Optical Filter	1
Radioisotopic						
Red Cell Mass	1	11 ml/kg	40 ml/kg	± 5% **	Electronic	N/A
Red Cell Survival	1	20%	100%	± 5% **	Electronic	N/A
Plasma Volume	1	9 ml/kg	70 ml/kg	± 5% **	Electronic	N/A
Miscellaneous						
Microbial Smears	1	N/A	N/A	*	N/A	N/A
Plasma Protein	1	5gms/100ml	10gms/100ml	±0.2 gms/100 ml	N/A	N/A

* Dependent on Operator Proficiency
** Design Goal

Would Like

to blood and urine specimen handling are represented in Figures 1 and 2.

3.1.1.3 Specimen Requirements. - The measurements will be performed on whole blood, obtained by venipuncture; peripheral blood, obtained during the performance of a bleeding time test; plasma obtained from whole blood by centrifugation and urine. When an anticoagulant is indicated, the anticoagulant of choice will be sodium heparin. It is estimated that 10-15 ml of whole blood will be adequate fro FBB-BPAS measurements.

Important concept

Sequence of Measurements. - The sequence of measurements are given in Figures 3, 4 and 5. The blood sequence is dictated by a requirement for fresh, non-anticoagulated blood for the performance of the differential count, rapid blood pH and blood gas measurements, and completion of whole blood measurements before treatment to obtain plasma. The sequence of measurements on urine is relatively unimportant and can follow sequentially.

The microbiological measurement sequence should be initiated with fresh samples to assure a greater chance for microbial growth and enumeration and thus, increase the reliability of the procedure.

Collection of Specimen-Blood. - The venipuncture site will be prepared by cleaning and disinfecting the area with a prepackaged disposable alcohol sponge. Blood will be collected without stasis from an anticubital vein into a sterile disposable plastic syringe fitted with a sterile disposable 1 1/2 inch 21 gauge needle. The venipuncture site will then be occluded with a compression bandage until bleeding has stopped. Blood from the disconnected needle will be used for the differential and reticulocyte preparations. Blood from the syringe will be expressed into an evacuated flexible plastic container previously coated with sodium heparin. The container will be equipped with a hand operable valve to permit maintenance of the vacuum and containment of the specimen. The blood and heparin will be mixed by kneading the container.

OK

Better to Shake ?

Plasma will be obtained by centrifugation, after all measurements requiring whole blood are complete. An agglutinating agent, e.g., photohemagglutinen will be added to the blood container, and mixed by kneading. The mixture will be centrifuged, a clamp applied at the plasma:red cell interface, and the plasma expressed into a second, previously evacuated container. The red cells may be preserved for further testing.

Peripheral blood will be obtained from an ear-lobe which has been disinfected with a prepackaged disposable alcohol sponge. Bleeding will be induced with a prepackaged disposable lancet. Blood from the clotting time test, the RBC count and WBC count will be collected from this wound followed by the performance of the bleeding time test.

Microbiological Preparation. - Samples for microbiological examination will be collected by the swab sampling technique since this technique is most adaptable to variations in sample material, location and configuration. Swab samples will be taken of the throat, skin and environmental areas such as food preparation, eating and personal hygiene areas. The swab material will be used to prepare prepackaged, sterile microscopic slides and to inoculate prepackaged selected culture media for the determination of growth characteristics and/or enumeration of microbial numbers. Sample identification will be controlled through the use of pre-labeled materials.

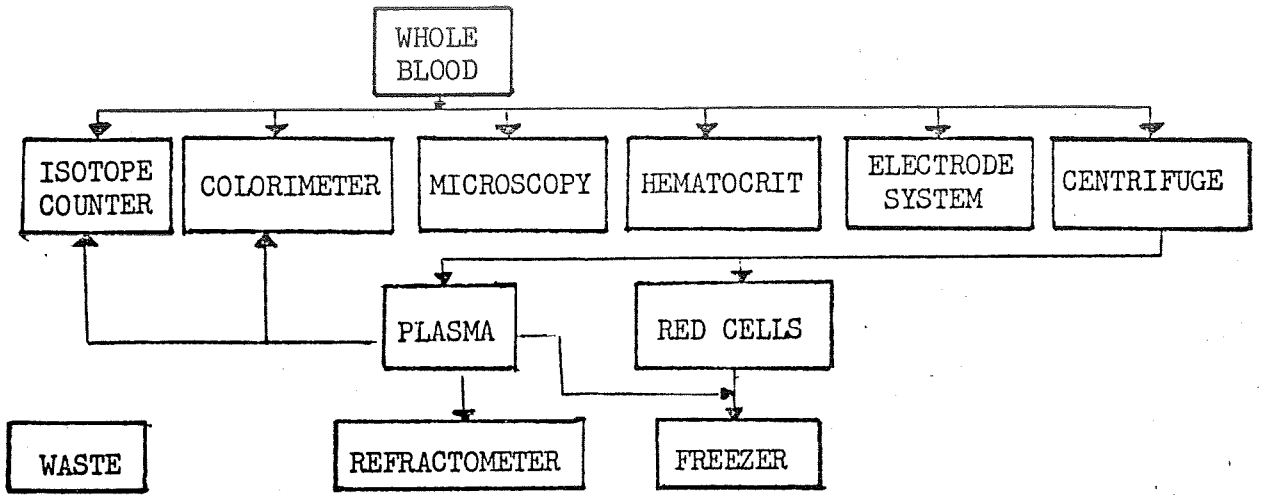


Fig. 1 Blood Sample Flow

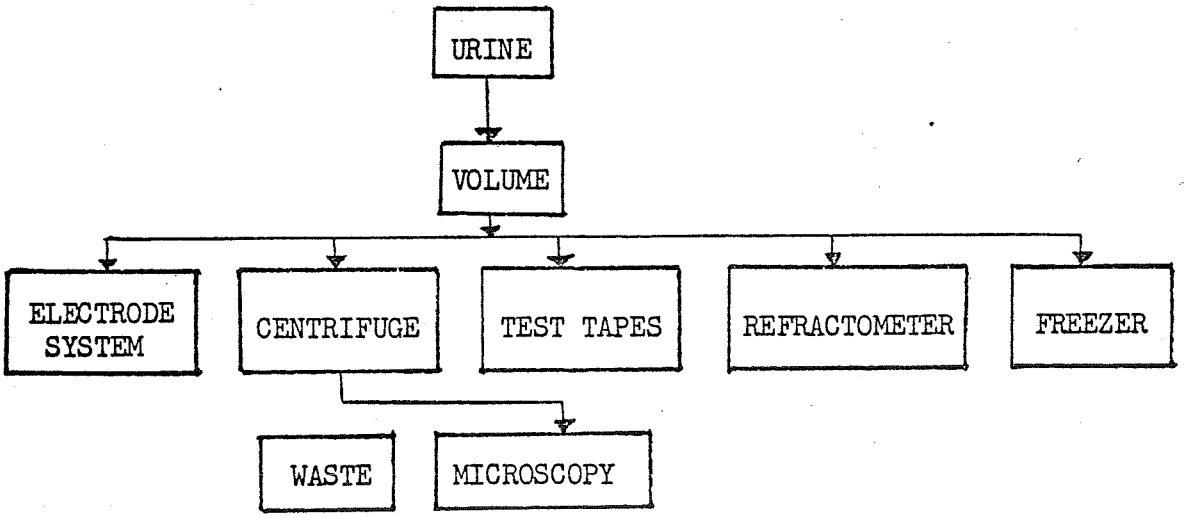


Fig. 2 Urine Sample Flow

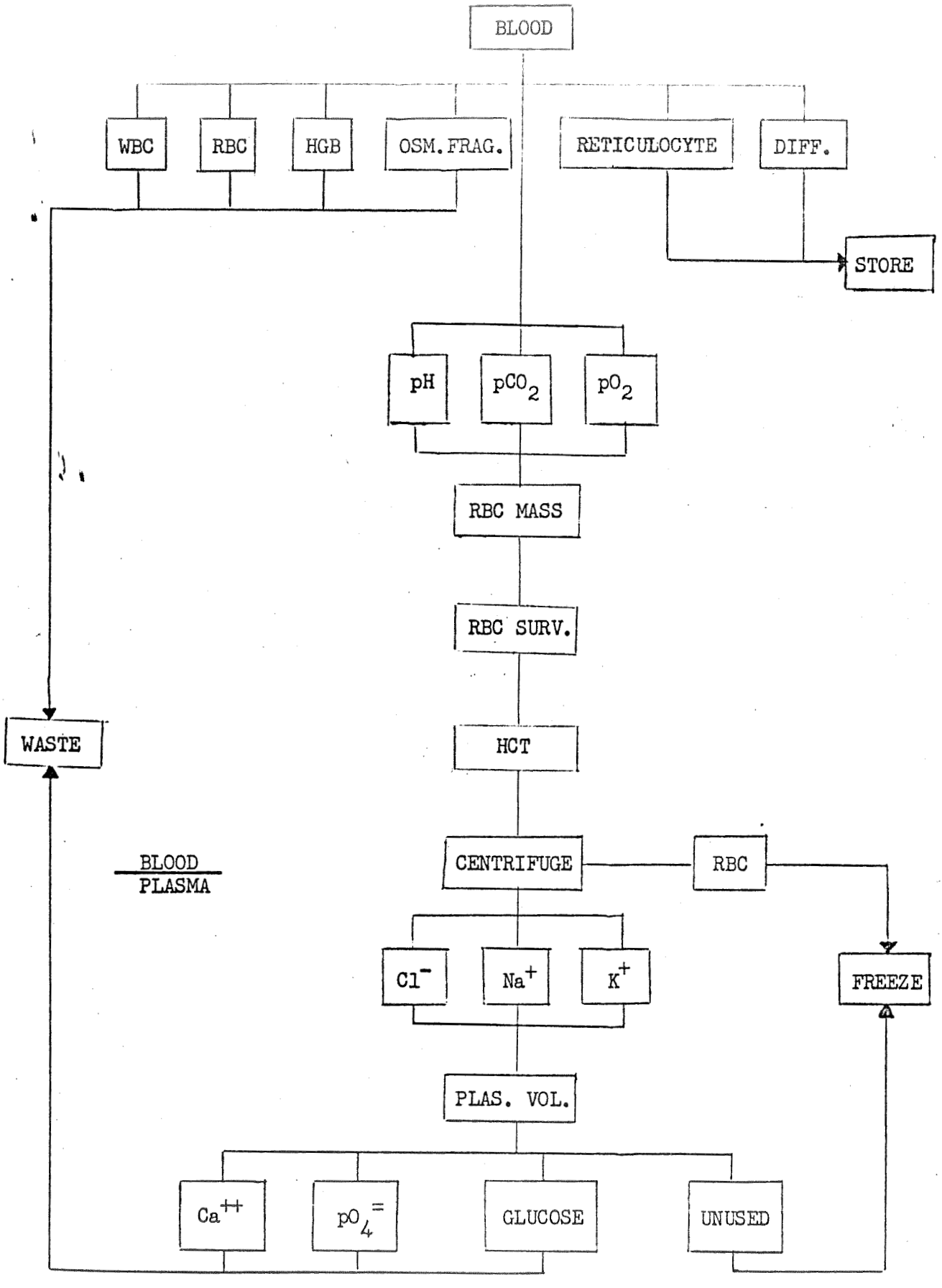


Fig. 3 Blood Handling Sequence

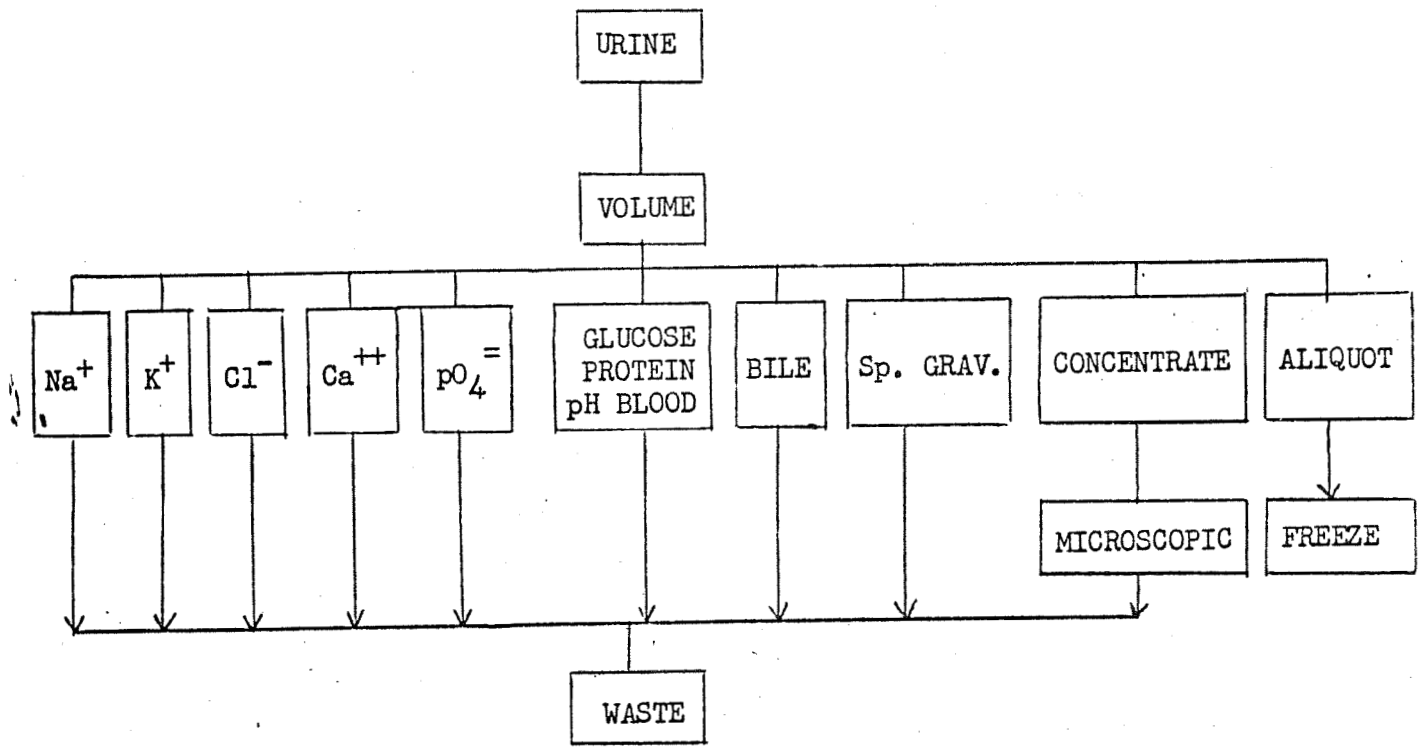


Fig. 4 Urine Handling Sequence

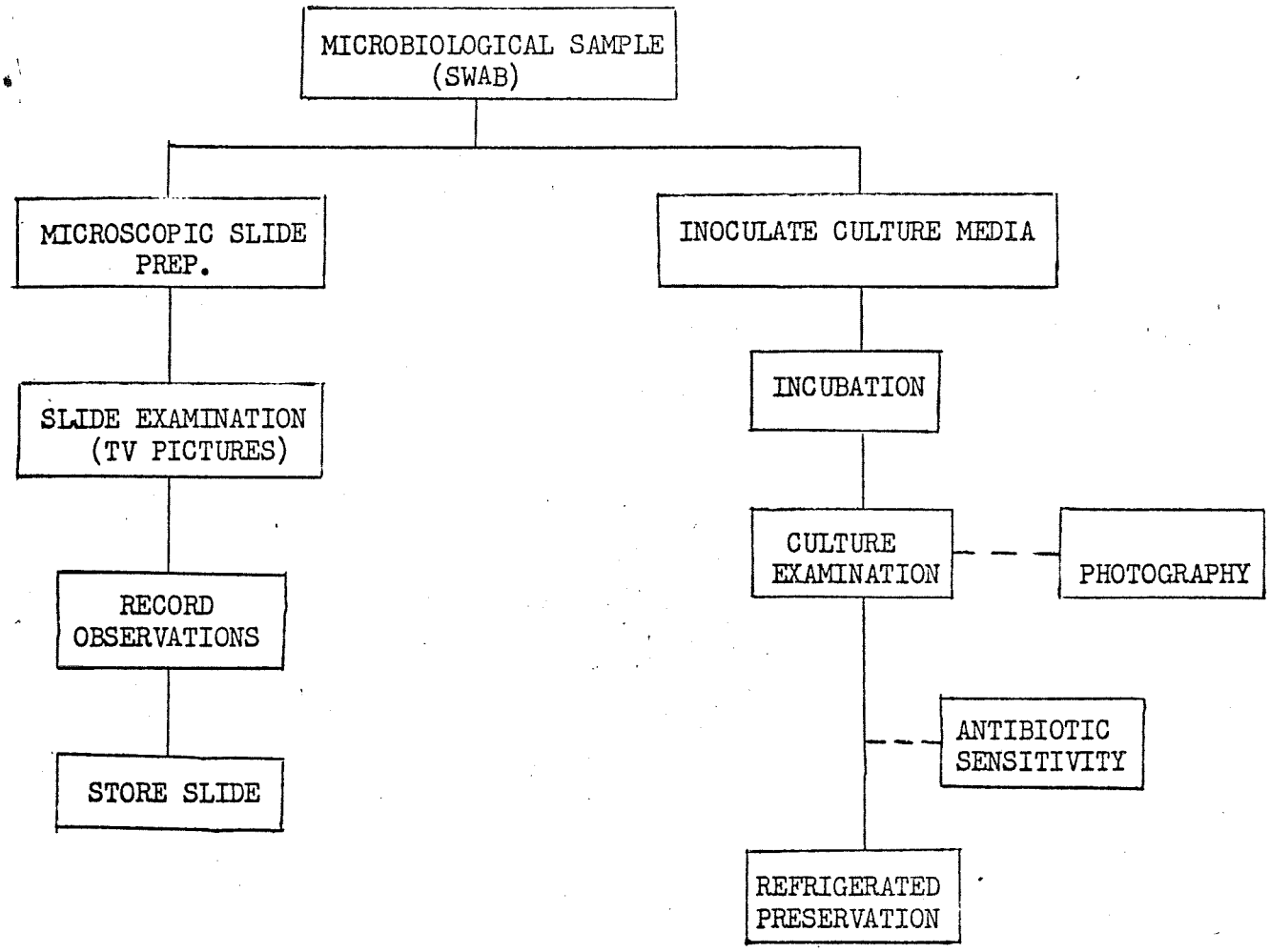


Fig. 5 Microbiological Measurement Sequence

3.1.1.4 Measurements. - Bleeding Time. - The Duke Procedure for bleeding time determination will be used. From the time bleeding first appears from an ear-lobe puncture, the blood directly from the wound will be blotted every 30 seconds. The time elapsed until bleeding stops will be measured using the console interval timer. The data will be recorded in the manual log and/or memo recorder for later entry into the Data Management System via the Numerical Data Keyboard.

Coagulation Time. - Blood from an ear-lobe puncture wound will be collected in a suitable tube. The blood will then be agitated manually with a wire. Using the console interval timer, the time elapsed until the first coagulation strand is observed will be measured. The data will be recorded as noted for Bleeding Time.

Differential Count and RBC Morphology. - A drop of fresh blood from the tip of the collection needle will be placed at one end of a microscope slide. The slide will be placed in a device containing a flexible wiper for the preparation of the smear. The slide will be positioned in a holder-staining device and stained with Wright's stain. The slide-staining device will permit total containment of reagent. After the stained smear is prepared, it may be read at a convenient time with the microscope. Counts will be accumulated on a mechanical counter.

Reticulocyte Count. - A drop of blood will be drawn into a disposable pipet, followed by a solution of brilliant cresyl blue or new methylene blue. A drop of the mixture will be expressed onto a microscope slide and smeared and stained as in 3.1.1.4. The blood-stain mixture remaining in the pipet will be discarded.

Red Cell Count, White Cell Count. - Blood for the red cell and white cell count may be obtained from the ear-lobe puncture. The proper amount of blood will be measured in a capillary pipet and mixed with premeasured reagent-diluent. At some convenient time, the mixtures can be expressed into Specific hemocytometers for cell enumeration. Counts will be accumulated using a tally counter.

Blood pH, pO_2, pCO_2 and Bicarbonate. - The flexible plastic container will be attached to a plastic block containing electrodes for the estimation of these parameters. Blood will be drawn from the container into the electrode block by applying a vacuum to the distal end of the block. These measurements should be made as soon as possible after the specimen is obtained to avoid loss of the gases and changes in pH. Following the completion of these measurements, the blood will be forced back into the blood container for further analyses. Bicarbonate will be calculated from values obtained for pH and pCO_2.

Red Cell Mass and Survival. - Measurement of these parameters is the next logical step in the sequence of measurement. The parameters are estimated by measuring the radioactivity emitted from Cr^{51} labeled red blood cells. This will be accomplished by placing the specimen container in the well of the scintillation detector and counting the radioactivity in the portion of the container exposed to the detector.

Hematocrit. - The hematocrit is a measurement of the ratio of red cell volume to total blood volume. It will be estimated by measuring the resistance of whole blood, which is proportional to the red cell volume. Blood will be aspirated into a conductivity cell, the hematocrit measured and the blood discarded into the waste disposal system.

Plasma Electrolytes, Na^+, K^+, Cl^-. - These plasma parameters will be estimated by attaching the plasma container to a plastic block containing ion selective electrodes for sodium, cations and chloride. Potassium values will be derived from the sodium and cation measurements. Following the completion of these measurements, the plasma will be forced back into the plasma container for further analyses.

Plasma Volume. - Plasma volume is estimated by measuring the dilution of a known amount of radioiodinated serum albumin (RISA) in the blood. Since this material distributes in the plasma compartment, the estimation of the radioactivity in a known volume of plasma and the apparent dilution calculated from this value, will permit the derivation of total plasma volume. The plasma specimen container will be placed in the well of the scintillation detector and the radioactivity in the portion of the container exposed to the detector will be counted.

Colorimetry. - Colorimetric estimations will be made for hemoglobin, red blood cell osmotic fragility, plasma glucose, calcium and phosphorous and urine calcium and phosphorous. Aliquots will be removed from the respective containers by aspiration into reaction vessels, reagents added and the color of the reaction product measured at the proper wavelength. The entire reaction system will be self-contained to prevent dispersion of reagents into the atmosphere. Following the colorimetric measurements the reaction system will be discarded. Good

Urine Electrolyte Na^+, K^+, Cl^-. - These urine parameters will be measured as discussed under Plasma Electrolytes. Provisions will be made for dilutions, if necessary.

Urine Glucose, Protein, pH, Blood. - These measurements will be made by exposing reagent impregnated test-tapes to the urine specimens. The test-tapes will be contained in clear plastic tubing with fittings to permit attachment to the urine container on the proximal end and a vacuum source on the distal end. Reaction will be read up to 30 seconds after the tape is exposed to the specimen. The tape and tape containers will be discarded after use.

Urine Bile. - Provision will be made to encapsulate a standard reagent tablet so that urine may be applied and the reaction observed. The tablet and table container will be discarded after use.

Urine -- Microscopic Examination. - Urine will be placed in an evacuated flexible plastic container, constructed with a constriction at the distal end. The urine will be centrifuged in an orientation to permit all sediment to collect in the constricted portion of the container. This area will be clamped and the sediment removed with a hypodermic needle. A drop of this material will be placed on a slide for microscopic examination. The urine, container and slide will be discarded after use.

Refractometry. - Refractometry will be used for the determination of urine specific gravity and plasma total protein concentration. A drop of the urine or plasma will be placed on the prism of the refractometer and the value determined from the internal scales. The prism may be cleaned with a disposable tissue.

Microbiological Evaluation. - A microscopic slide will be prepared from each swab sample by smearing an area of the slide with matieral on the swab. The slide will be fixed, placed in a holder-staining device and stained with a

simple stain, e.g. crystal violet. The stained smear will be examined microscopically for types of microbial cells present and their relative abundance.

Immediately after the smear preparation, the same swab will be used to inoculate several types of prepared, prepackaged culture media which have been stored under refrigeration in compartmentalized plastic dishes. The dishes of inoculated culture media will be incubated for a prescribed time period and then examined for microbial growth characteristics and/or enumeration of colonies. These observations will be recorded and the dishes returned to refrigerated storage for future examinations.

Provision will be made for conducting antibiotic sensitivity testing, not as a routine but only to assist in determining antibiotic therapy or in the identification of a predominating organism. When required, a pre-selected, prepackaged antibiotic sensitivity test agar medium will be inoculated with the microorganism(s) under consideration. Antiobiotic containing paper discs will be placed on the inoculated medium surface and the dish incubated for a prescribed time before observing for zones of inhibition to the antibiotics.

3.1.2 Operability. - Section III-A FBB System Requirements Document contains applicable Operability requirements together with those noted herein.

3.1.2.1 Safety. - Shielding of the radioisotope storage module will be designed to provide an exposure rate of less than 0.666 milliroentgens/hour at six inches. The waste disposal module will be designed to avoid physical injury and environmental contamination, from reaction, specimen handling and culture products.

3.2 Interface Requirements

Interface requirements of the BPA Station are due to functional, physical and procedural relationship between the BPA equipment, operator and all systems, equipments, and facilities required to accomplish BPA test objectives.

3.2.1 Experiment Equipment/Measurement Station Interfaces. - The BPA Station will provide suitable sample handling and measurement capabilities for the experiment equipment. It will provide for identifying and labeling all specimens. Preservation and storage of blood, urine, plasma and microbiological material at cryogenic temperatures will be provided. A waste disposal capability will be provided at the station. Reagents and supplies will be provided. The incubator will interface with the blocks for specific ion electrodes to maintain the electrodes and specimen chamber at 38° ± 1°C.

Date will be logged or audio recorded for later manual entry into the PBDM system. Audio jacks will be provided on the console. Data interfacing will be required for the derivation of potassium values from the sodium and cationic electrode outputs. Values for RBC mass and survival and plasma volume must be corrected for hematocrit.

3.3 Design and Construction

3.3.1 Mechanical. -

Ion specific electrodes must be maintained at a constant temp to operate properly.

3.3.1.1 Module Sizing Requirements. - A primary requirement for the FBB-BPAS is to group related displays and controls. The modular arrangement based on this criteria establishes a basic module size of 19 x 19 inches (frontal area). Equipment not meeting this size or not adaptable to mounting on slide rails will be hard mounted and removable by conventional techniques, such as quick-opening fasteners, screws, etc.

3.3.1.2 Structural Requirements. - Removable modules will be provided with electrical cables of sufficient length and flexibility and further be provided with a protective coating over the length which is expected to be handled during insertion and removal operations. The design of the module and its rack will include provisions to align the module, if necessary, in such a manner that accurate alignment can be checked and possible adjustment can be performed without the removal of components, cabling or plumbing. Good

Equipment containers will be provided with sufficient screen covered holes to provent pressure buildup and to provide an adequate path for air flow. In addition, the vent holes in the structural body will be provided with a fine mesh filter screen to prevent debris from entering the interior or the module.

3.3.2 Instrument Requirements. -

3.3.2.1 Electrometer. - The electrometer will be utilized for the performance of pH, pO_2, pCO_2, Na^+, K^+, and Cl^- measurements and must present output signals from the electrodes through a switching matrix. The instrument must provide full scale deflection over a range of 50 millivolts with a design goal system accuracy of $\pm$ 1.0 millivolts. The system precision goal will be $\pm$ 1 millivolt. Readout must be presented on a meter, and be readily interpretable from normal operating position. The instrument will be capable of operation on 110 v $\pm$ 10%, 60 Hz. Analog signals from the meter will be ranged from 0-1.4 volts. Beckman prototype ACDM amplifiers will serve as the electrometers.

3.3.2.2 Isotope Counter. - The isotope counter will be utilized for the performance of red cell mass, red cell survival and plasma volume studies. The red cell parameter will be estimated using Chromium - 51; plasma volume using Iodine-125 labeled serum albumin. The counter must be capable of discrimination between these two isotopes since they may both be present in the specimen being studied.

The counter to be incorporated into the FBB-PBAS is an Abbott Model 101. The detector must accept a cylindrical specimen container and be operable in an orientation 90° from vertical. The counter will provide a high speed scaler to accumulate output pulses of the pulse height analyzer during the counting period. Total count will be indicated on a Nixie tube dispaly on the console panel. Control of the scaler will be exercised by an electronic timer with an accuracy of $\pm$ 0.5 Hz for each counting period.

The instrument will be capable of generating a 10 Hz test signal to check the function of all components except the scintillation detector and high voltage power supply. A source of Ba^{133} will be provided as a system check.

3.3.2.3 Hematocrit. - The electronic hematocrit is a device for the determination of the relative concentration of red cells in blood by resistance measurements. The device operates on the principle that red blood cells act as electrical insulators while serum acts as a temperature dependent conductor. The

Colorimetry Reaction Vessels

resistance of a calibrated volume of blood is a function of the relative concentration of the red blood cells.

The YSI electronic hematocrit device will be incorporated into the FBB-BPAS. The device will have the capability for the operation and measurement of a constant volume of blood into a measurement cell. This blood will be at approximately the same temperature as the calibrating thermistor-resistor combination. Good

The electronic circuit will incorporate a 10,000 cycle oscillator which drives a bridge circuit. One arm of the bridge will be the sample cell and another arm the thermistor-resistor combination for temperature compensation. The output of the bridge circuit will be amplified and displayed on a microammeter.

3.3.2.4 Colorimeter. - The colorimeter will be utilized for the analyses of hemoglobin, red blood cell osmotic fragility, glucose, calcium and phosphorus. The instrument will be internally voltage stabilized. Wavelengths between 400 and 650 nm can be selected and the bandwidth will be approximately 15 nm. Wavelength selection will be accomplished by movement of a wheel which will move a glass wedge interference filter. The colorimeter will use a tungsten light source of fixed focus. Control will include an on-off dark current control knob to actuate the instrument and for zero adjust; a blank control for 100% T adjust; and a shutter control to cut off light from the phototube for zero adjust.

The colorimeter cuvette chamber will be modified, as a design goal, to accept colorimetry reaction vessels, thus eliminating a need for specimen transfer. The Beckman-Spinco spectro-colorimeter will be the instrument used in the FBB-BPAS. out STAND IN

3.3.2.5 Microscope. - The microscope will be used for the examination and enumeration of the formed elements of the blood, urinary sediment and microorganisms. The microscope will be monocular with wide field eyepiece (10X) and an Abbe double lens type condenser with iris diaphragm. Illumination will be provided by self-contained batteries or an external 3-3.5 volt power supply. The microscope will be equipped with 10X, 40X and 100X (oil immersion) achromatic objectives. The Nikon Model H will be used in the FBB-BPAS.

3.3.2.6 Refractometer. - The refractometer will be used for the determination of urinary specific gravity and plasma total protein. The instrument will be temperature compensated between 16 and 38°C and will have internal scales for both specific gravity and total protein. Tables will be provided to correct these values to plasma total water.

3.3.2.7 Support Equipment Requirements. Electrode Blocks. - The electrode blocks will be designed to contain electrodes for (1) pH, pCO_2, pO_2, and reference, and (2) sodium, cations, chloride and reference. These electrodes will be easily accessible for servicing and/or replacement. The specimen electrode interfaces will be membranes to minimize cleaning requirements and interspecimen contamination.

Incubator. - The incubator will be designed to serve as a microbiological support unit and as a constant temperature source for the electrode blocks. The microbiological support unit will be designed to be accessible on rails with clamping or support devices for individual culture plates. Temperature will be maintained at 36° ± 1°C.

Centrifuge. - The centrifuge will be utilized for the separation of the formed elements of blood from the plasma and for the concentration of urinary sediment. Sedimentation will take place in a plane perpendicular to the floor and parallel to the console. Centrifuge cups will accommodate the flexible specimen handling container, and will be fitted with clamping devices to hold the cups and containers in position during testing in earth gravity. The instrument will operate on 115 ± 10% volts, 60 Hz.

Interval Timer. - An interval timer will be required for the timing of stain exposure and chemical reactions. The timer will be electronic and measure elapsed time in minutes.

Waste Disposal. - The waste disposal unit will be modified for discarded solid supplies, e.g. syringes, sponges, colorimeter reaction vessels, etc., and liquid wastes, e.g. blood, urine, stains, waste solutions, etc. The waste container will be provided with separate access ports for liquid waste and solid waste. The liquid wastes will be trapped prior to lyophilization. The volatile materials would be exhausted to space in a flight unit but can be trapped during testing of the FBB-BPAS. The vacuum source will also be available to the solid waste container to lyophilize any surface liquid waste.

Storage. - The FBB-BPAS will provide suitable storage space for supplied needed for the conduct of the required measurements. Separate non-refrigerated space will be provided for microbiologic supplies, radioisotopes, colorimetry reaction vessels, refractometer, breathalyzer, etc. These storage areas will be provided with rail mounted pull-out shelves for facile access to the contents. When appropriate, clamping devices will be provided in the storage compartment for the various items or supplies enclosed therein.

Refrigeration will be required to simulate the flight procedural sequence particularly in the case of storing prepackaged culture media. Microbiological growth investigations requiring post-flight analysis will require the storage of dishes that have been cultured. Standard laboratory refrigeration storage area, approximately 8 in. x 8 in.x 15 in., can be utilized. This will be a non-deliverable item.

Many of the FBB measurement specimens can be preserved for considerable periods by deep freezing if an endocellular cryophylactic agent such as glycerol or dimethylsulfoxide is added to prevent disruption by ice crystals of any formed elements, particularly in blood. A cascade type compressor freezer will be provided which is capable of -100°C. A coding system to identify the subject, time in flight, and type of sample will be developed to enable positive identification of each sample upon return for post-flight analysis.

3.3.3 Displays and Controls. - BPA Station controls for actuation, adjustment, etc., will be in a position to be available to the operator from his operational position. In cases where commercial equipment is designed to be serviced or adjusted by rear access, and these controls cannot be extended to the front panel, the equipment will be extendable, permitting alignment from a front position.

3.3.4 Calibration. - Calibration of the FBB-BPAS will serve two purposes. One is to demonstrate that the equipments utilized in the BPA Station are operational and the second, to define the slope of a curve defining instrument response versus concentration or activity levels. Those equipments lending

themselves to operational checks are the colorimeter, electronic hematocrit, and the radioisotopes counter. The colorimeter will be checked by supplying a standare, non-deteriorating filter or solution. The electronic hematocrit will include a calibrating control on the face of the instrument panel which will permit adjustment to a known level. The radioisotope counter will incorporate a panel switch which will permit the generation of a 10 Hz internal test signal to demonstrate an operational status. In addition to checks of this type, which demonstrate the operational status of an instrument, there is also a requirement for test calibration to define the slope of the response curve. Calibrating gases are required: 5% CO_2, 12% O_2, Balance N_2. 10% CO_2, Balance N_2.

3.3.5 Power Requirements. - The BPA Station will be designed to operate from a source of 115V $\pm$ 10%, 60 Hz.

4.0 DESCRIPTIVE DEFINITION & BLOCK DIAGRAMS

4.1 Conceptual Design

4.1.1 Design Objective. - A major objective is to provide a centralized station for measurement, display, and control of biochemical measurements. The BPA station will contain elements for conducting colorimetric, radioisotopic, microscopic, potentiometric, impedance, refractometric, microbiologic and test-tape measurements, and the ancillary equipment and supplies required to prepare specimens for "on-board" analysis, and/or storage for "post-flight" analysis.

4.1.2 Design Concept. - The BPA Station design consists of a three bay console designed to house all equipment elements with the exception of a freezer which will be a separate installation. The BPA Station is designed to be operated by one crew member. Data will normally be displayed and manually recorded and subsequently transferred to the PBDM Station for data handling and transmission. Provisions will be made for electrical interconnection between the two stations in the event that data can be transmitted more efficiently by that method.

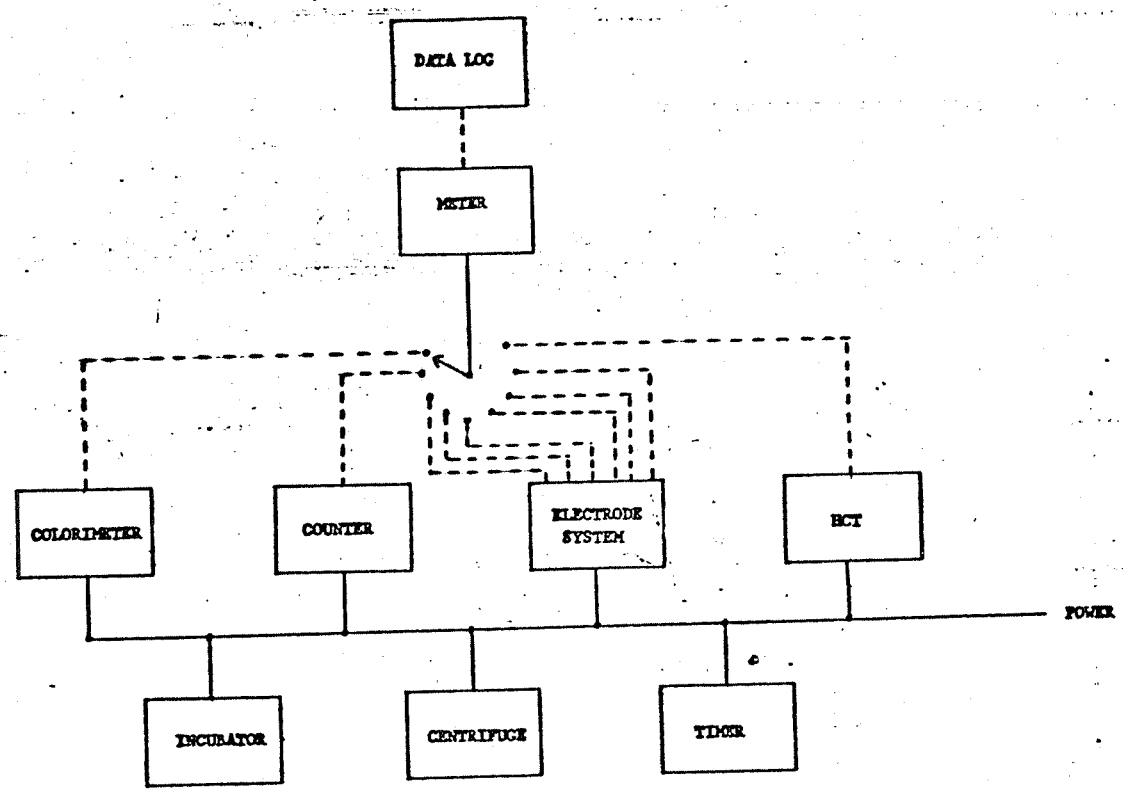
Force automation

4.2 Block Diagram

4.2.1 Equipment Elements. - The BPA system is made up of the measuring and support equipments needed to perform the required analyses. The analytical equipment includes a colorimeter, a radioisotope counter, an electrode system, and an electronic hematocrit. The support equipment includes an incubator, a centrifuge, a timer, and a freezer. These equipments are illustrated in Fig. 6. Each device is supplied with a source of 115V, 60 Hz power. It will be a design goal to route the various analog and digital signals from the measuring devices into a digital volt meter through a nine position switch. Data will then be logged, either manually or through an audio recorder.

4.2.1.1 Electrode Subsystem. - Each of the measuring devices will have a single output routed through the switch except for the electrode subsystem. The electrode subsystem is illustrated in Fig. 7. It contains a sodium electrode, a potassium electrode, a chloride electrode, an oxygen electrode, a CO_2 electrode, a pH electrode, and reference electrodes. These electrodes are located in a temperature control block supplied by the same heat source as the bacteriological incubator. Signals from each of the electrodes will be routed through its own electrometer, thus making it an easily replaceable module. Signals will be taken from electrometers through the main switch into the digital voltmeter. The electrometers used in the electrode subsystem will be Beckman ACDM prototype units and will serve to replace the pH meters traditionally used for such measurements.

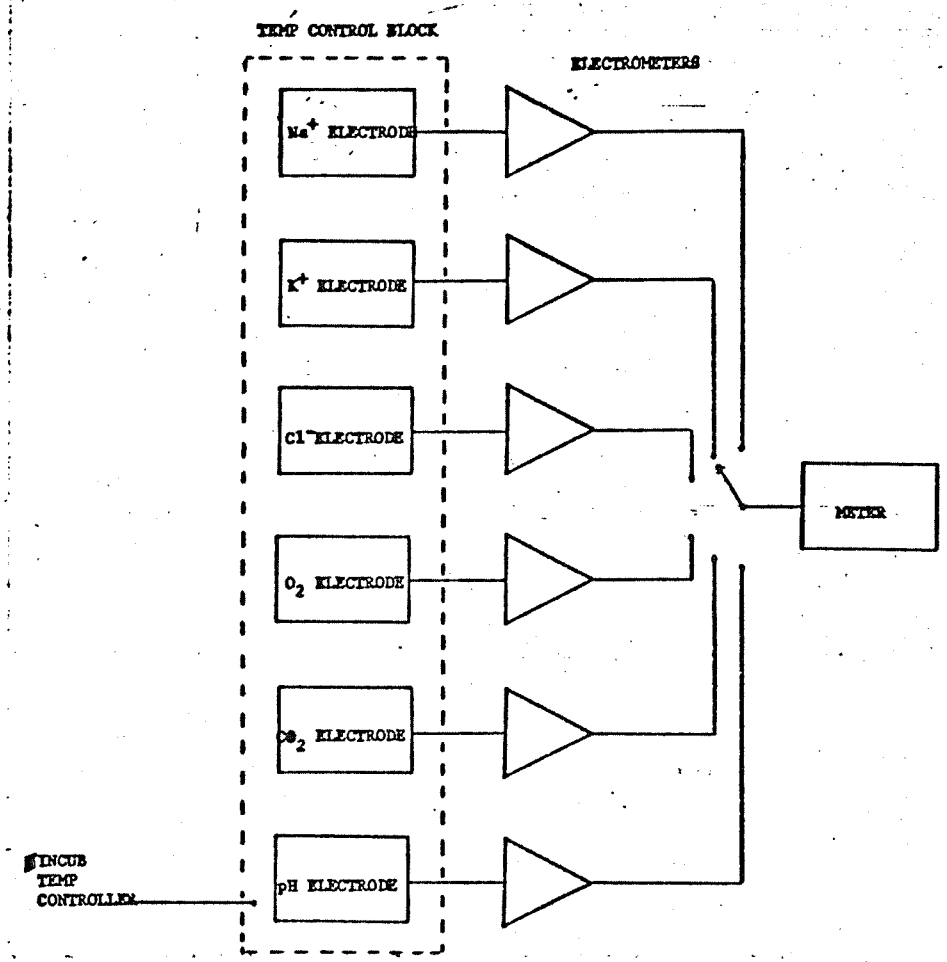
4.2.1.2 Hematocrit Subsystem. - The electronic hematocrit is a device for determining the relative concentration of red blood cells in blood by means of resistance measurements. Blood is aspirated into a sample cell which forms one arm of the bridge circuit, the other arm consisting of a thermistor-resistor combination for temperature compensation. This bridge circuit is driven



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 6. FEB-BPAS INSTRUMENT SYSTEM	
CHK		APPD		CODE IDENT NO. 1[illegible]	DOCUMENT NO. III-I-18 / REV
SUPV		APPD		SIZE B / SH / OF	
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.		

Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 7. ELECTRODE SUBSYSTEM	
CHK		APPD		CODE IDENT NO. 1[illegible]	DOCUMENT NO. III-I-19 / REV
SUPV		APPD			
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B / SH OF	

Form LMSC 26208

by a 10,000 KC oscillator. The output of the bridge circuit is amplified, DC voltage to the amplifier being controlled at 6.5 volts ± 5% by a zener diode. The signal from the amplifier will be passed through the switch into the digital voltmeter.

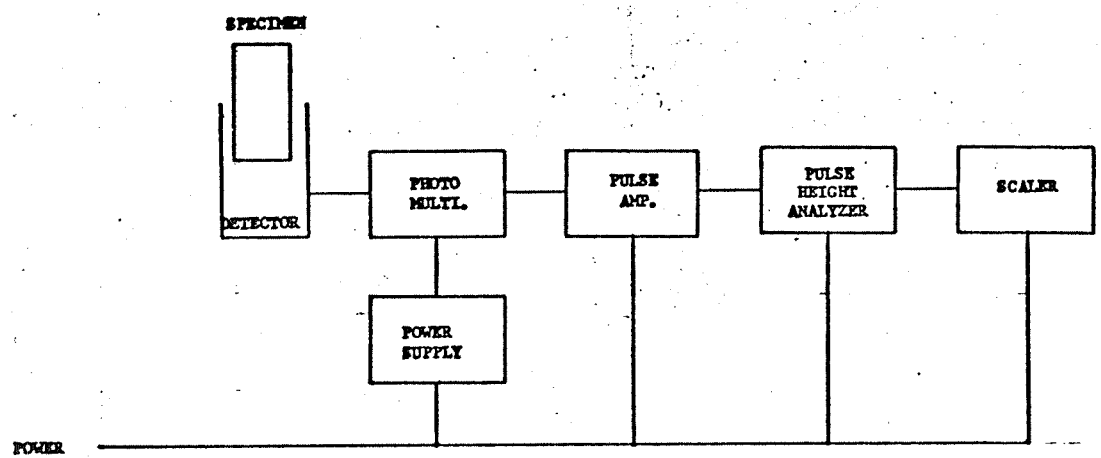
4.2.1.3 Isotope Counter. - The Abbott Model 101 counter will be used. Fig. 8 shows the specimen being introduced into the detector. The counter has a high speed scaler to accumulate output pulses of the pulse height analyzer during the counting period. Total count will be indicated on a display at the BPA Station.

4.2.1.4 Electronic Hematocrit. - The YSI electronic hematocrit device will be used. The electronic circuit shown in Fig. 9 will incorporate a 10,000 cycle oscillator which drives a bridge circuit. One arm of the bridge circuit will be the sample cell and another arm the thermistor-resistor combination for temperaturn compensation. The output of the bridge circuit will be amplified and displayed on a microammeter at the BPA Station.

4.2.1.5 Colorimetry Subsystem. - Those tests involving chemical reactions will be analyzed by colorimetry. The colorimeter is illustrated in Fig. 10. In this system, light from a tungsten bulb is passed through a continuously adjustable filter wedge, which allows selection of wavelengths between 400 and 650 nm. Light at the proper wavelength is then passed through the sample cell, containing the colored reaction product, and the intensity of the light passing through the sample is measured by a photodetector. The output of the photodetectors amplified and then sent through the main switch into the digital voltmeter.

The colorimetry reaction subsystem is illustrated in Fig. 11. The reaction vessel will be evaluated to eliminate any traces of air which might interfere with subsequent optical measurements. The volume of the chamber will be accurately known and will serve as the specimen chamber. By changing a valve position, the evacuated chamber will be opened to the specimen which will completely fill the evacuated space. Reagents will be added, the number depending upon the specific test, and the reaction will be allowed to take place. The colored end product will then be read in the reaction vessel, thus eliminating any need for specimen transfer. This technique will allow total containment of specimen, reagents, and reaction products.

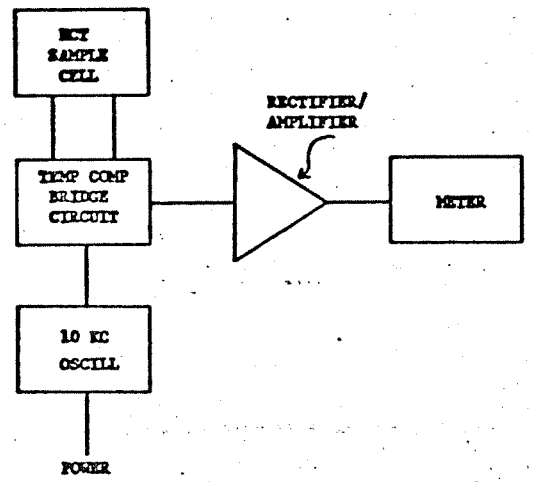
4.3.1.6 Microscopy Subsystem. - Blood cells must be stained as illustracted in Fig. 12 in order to defferentiate among the various white blood cells and to permit the recognition of reticulocytes. Whole blood, either peripheral or venous, can be used for these tests. For the differential, a drop of blood will be placed on a slide and a smear prepared. For the reticulocyte preparation, a drop of blood will be drawn into a pipet and mixed with the supra-vital stain and then a smear prepared. These slides will then be placed into a slide stainer. The slide stainer is a rectangular chamber into which is machined a concavity. The slide, placed on top of the concavity, forms an air and liquid tight chamber. At one end of the chamber is attached a vacuum source and the other a connection for stains and washes. In operation, the camber is evacuated to remove all traces of air, a valve to the vacuum source turned off, and the valve to the stain or wash solution opened. The stain or wash solution then completely fills the evacuated chamber. The used stains and washes pass into the liquid disposal unit. The stained slides will be air dried and the cells enumerated microcsopically.



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 19. RADIOISOTOPE COUNTER	
CHK		APPD		CODE IDENT NO.	DOCUMENT NO. III-I-21 — REV
SUPV		APPD			
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B SH OF	

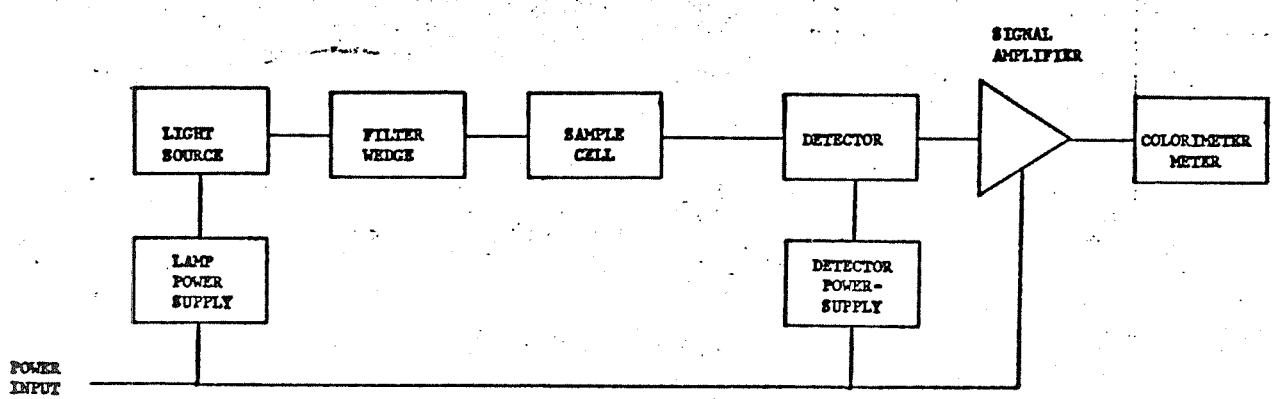
Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 9. ELECTRONIC HEMATOCRIT	
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-I-22 / REV
SUPV		APPD			
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B / SH / OF	

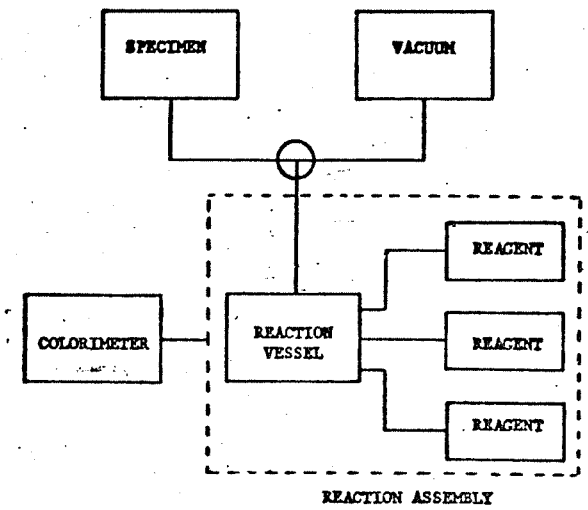
Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 10. COLORIMETER		
CHK		APPD		CODE IDENT NO. 17C7	DOCUMENT NO.	REV
SUPV		APPD				
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B / SH / OF	III-X-23	

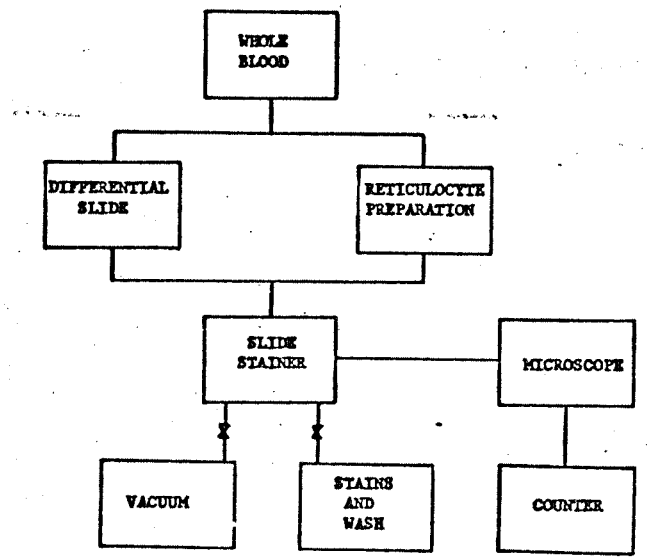
Form LMSC 26208



SCHEMATIC BLOCK DIAGRAM

ORIGR DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA		TITLE FIGURE 11. COLORIMETRY REACTION SUBSYSTEM	
CHK	APPD			CODE IDENT NO. 2[illegible]	DOCUMENT NO. III-I-24 / REV
SUPV	APPD			SIZE B / SH OF	
SYS ENGR	SPO/GSETD	CEI/FD NO	CONTR NO.		

Form LMSC 26208



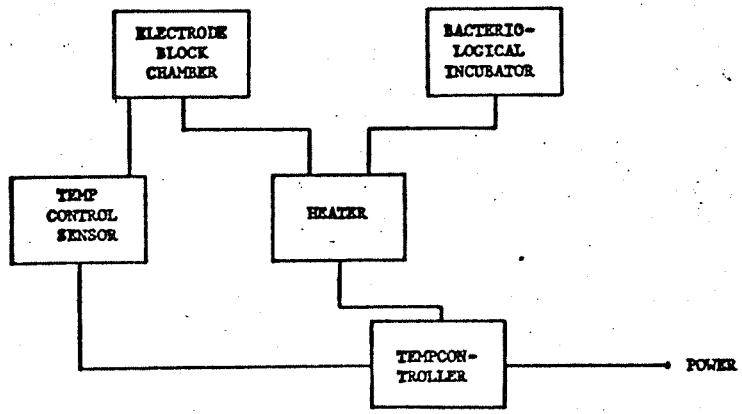
SCHEMATIC BLOCK DIAGRAM

ORIGR DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 12. STAINING SUBSYSTEM	
CHK	APPD		CODE IDENT NO. [illegible]	DOCUMENT NO. III-I-25 5 REV
SUPV	APPD			
SYS ENGR	SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B SH OF	

Form LMSC 26208

The number of various types of cells will be enumerated on a counter.

4.2.1.7 Incubator Subsystem. - The incubator subsystem serves two purposes: (1) to serve as a heat source for the electrode blocks and (2) as an incubator for the culture of micro-organisms. This subsystem is illustrated in Fig. 13. Both the incubator and the heating chamber for the block will be operated from a single source of heat. However, since the temperature control is much more critical for the electrodes than for the culture of micro-organisms, the thermistor will be located in the electrode chamber. The power source of the heater will be regulated by a temperature controller with a feedback from the thermistor.



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 13. INCUBATOR SUBSYSTEM		
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-I-2	REV
SUPV		APPD				
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B / SH / OF		

Form LMSC 26208

SECTION III-J

IMBLMS FUNCTIONAL BREADBOARD (FBB) SYSTEM PERFORMANCE/DESIGN REQUIREMENTS

DATA MANAGEMENT SUBSYSTEM

DATA MANAGEMENT

1.0 INTRODUCTION
- 1.1 Scope
- 1.2 Definition

2.0 APPLICABLE DOCUMENTS

3.0 TECHNICAL REQUIREMENTS

- 3.1 Performance
  - 3.1.1 Functional
    - 3.1.1.1 Overall System
    - 3.1.1.2 Inputs
    - 3.1.1.3 Accuracy
    - 3.1.1.4 Recording
    - 3.1.1.5 Display
    - 3.1.1.6 Processing
    - 3.1.1.7 Backup Modes
  - 3.1.2 Operability
    - 3.1.2.1 Reliability
    - 3.1.2.2 Maintainability
    - 3.1.2.3 Useful Life
    - 3.1.2.4 Natural Environment
    - 3.1.2.5 Transportability
    - 3.1.2.6 Human Engineering
    - 3.1.2.7 Safety
- 3.2 Interface Requirements
  - 3.2.1 Experiment Equipment/Measurement Interface
    - 3.2.1.1 Dynamic Physiological Monitor
    - 3.2.1.2 Biochemical Preparation and Analysis (BPA) Station
    - 3.2.1.3 Ergometer
    - 3.2.1.4 LBNP
    - 3.2.1.5 Repiratory
    - 3.2.1.6 Exer-Genie
    - 3.2.1.7 Mass Measurement Devices
    - 3.2.1.8 Pressure Transducers for Peripheral Venous Pressure (Director Indirect Technique)
    - 3.2.1.9 Behavioral Measurement Subsystem
  - 3.2.2 Peripheral Equipment (Deliverable and Non-Deliverable) Interfaces
    - 3.2.2.1 Magnetic Tape Analog Recorder
    - 3.2.2.2 Video Recorder
    - 3.2.2.3 Computer and Digital Recorder
    - 3.2.2.4 Pen Recorder
    - 3.2.2.5 Calibration Equipment

3.2.3 Operator Interface
3.2.3.1 Processor Keyboard
3.2.3.2 Numerical Data Entry Switches
3.2.3.3 Memo Recorder
3.2.3.4 Displays
3.2.3.5 Miscellaneous
3.3 Design and Construction
3.3.1 Subsystem Elements
3.3.1.1 Switching Matrix
3.3.1.2 Mission Timer
3.3.1.3 Processor Keyboard and Display
3.3.1.3.1 Keyboard
3.3.1.3.2 Keyboard Display
3.3.1.4 Numerical Data Entry Switches
3.3.1.5 Strip Printer
3.3.1.6 Four-Channel CRT
3.3.1.7 Video Equipment
3.3.1.8 Digital Data Display
3.3.1.9 Computer and Digital Recorders
3.3.1.10 Analog Tape Recorder
3.3.1.11 Pen Recorders
3.3.1.12 Software
3.3.1.13 Multiplexer/AD and D/A Converter
3.3.1.14 Decoder and Encoder
3.3.1.15 Power Supplies
3.3.1.16 Calibration Equipment

4.0 DESCRIPTIVE DEFINITION AND BLOCK DIAGRAMS

APPENDIX - MEASUREMENT DISPLAY REQUIREMENTS

1.0 INTRODUCTION

1.1 Scope

This portion of the FBB documentation establishes the overall data handling capability and performance requirements for that part of the IMBLMS FBB dedicated to data management.

These requirements are, in essence, an expansion and detailing of the broader guidelines presented in the FBB System Document.

1.2 Definition

The IMBLMS FBB Data Management Subsystem (DMS) will be directed towards fulfilling several major design and performance goals. Among these goals are; simulation of data handling to be performed with the flight IMBLMS; sizing of the computer and data storage required for the flight IMBLMS; ease of operation through automatic signal routing and data processing; display evaluation relative to flight IMBLMS usage; and equipment utilization which can be duplicated with space-qualified equipment.

The FBB Data Management Subsystem is illustrated in block diagram form (Figure 1), to depict its conceptual boundries. Although the system will accept information from, and deliver signals to, various measurement dedicated meters, etc., the dedicated meters themselves will not be considered part of the DMS, only the capability for accepting and routing the data to these devices. All general purpose and universal type display and data handling functions will be considered part of the system.

In general, the DMS will receive incoming measurement data, in either an analog or digital form, through its switching matrix and/or its multiplexer. The switching matrix, under either manual or computer control, will route the analog information to one, or all, of several locations; including a four-channel variable persistence oscilloscope, an analog magnetic tape recorder and parallel pen recorder, and/or the input to the multiplexer. The multiplexer will sample incoming analog signals, and, through the use of an analog-to-digital converter, convert these signals into a digital format for combination with other incoming digital data and ultimate computer processing, plus digital recording. The computer will have the capability of converting received, or analyzed data into measurement terms and displaying that data on alphanumeric readouts and on a strip printer. The computer will also have the capability for converting digital data back into an analog form for display on the previously discussed analog display devices, plus certain analog meter readouts that require data derivation prior to display. DMS will also have the capability for accepting visual data, from either a microscope or subject observation, and displaying or recording that data for later display. The handling of visual data is accomplished through the use of an integrated video system. A keyboard will be provided to permit operator communication with the DMS and computer and a special panel will use "digit-dial"

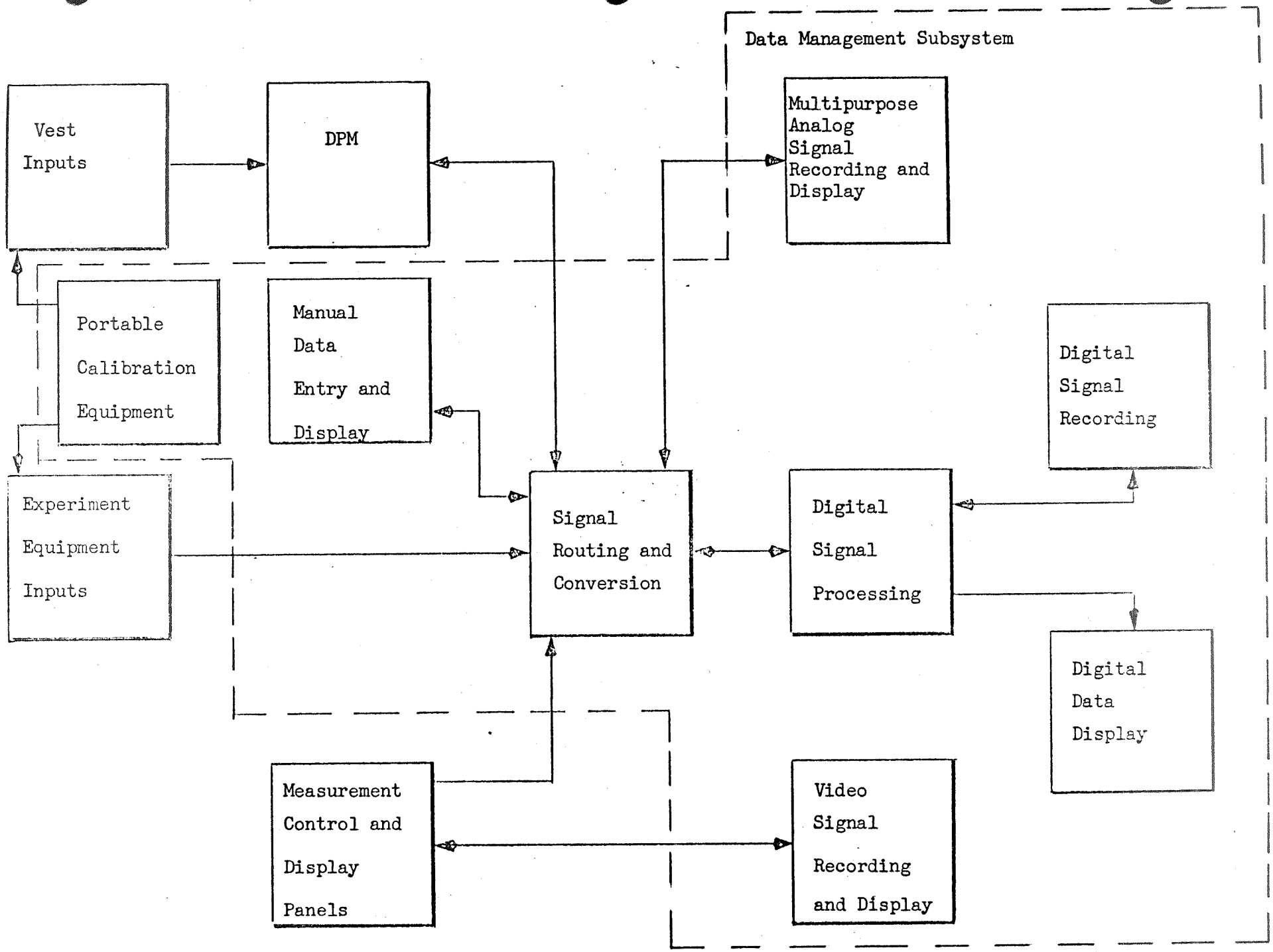


Fig. 1 Data Management Conceptual Boundries and Information Flow

switches to facilitate the entry of biochemical, clinical, and other data of this nature into the system. Appendix A indicates the various Cardiovascular and Pulmonary display and recording requirements that must be fulfilled by the DMS.

2.0 APPLICABLE DOCUMENTS

Section III-A FBB System Requirements document contains all applicable documents.

3.0 TECHNICAL REQUIREMENTS

3.1 Performance

3.1.1 Functional. - The following subheadings have been created to provide a total functional view of the various requirements that must be met and performed by the DMS. The "Overall System" heading provides a gross view of the DMS requirements, followed by "Inputs", to indicate the measurement signals that will be received by the DMS. The next heading, "Accuracy", describes the accuracy goals established for the DMS in handling the incoming data after which "Recording" requirements, "Display" requirements and "Processing" requirements are presented. The last subheading, "Backup Modes", describes alternate methods of functionally handling data that would permit reduced, but continuous, subsystem operation in the case of certain malfunctions.

3.1.1.1 Overall System. - The DMBLMS FBB will provide, in addition to dedicated display equipment, a multipurpose Data Management Subsystem capable of both analog and digital display of measurements, analog and digital recording of measurement data, and derivation of measurement data via automatic computation and analysis.

3.1.1.2 Inputs. - Physiological signals being obtained from a subject under test, and/or data originating in special purpose equipment used during these tests shall input to the system through a switching matrix. Physiological data obtained from a subject shall be initially routed through a monitor for immediate display, gain equalization, and additional signal conditioning or computation. The monitor is not considered part of the DMS. Outputs from the monitor, as well as direct outputs from the other special purpose measurements, will be accepted by the DMS for appropriate handling. Visual input data will be obtained from both a microscope and astronaut observation for display and recording. That portion of the Data Management Subsystem designated for the recording and display of visual data will perform independently of other elements of the subsystem, and directly under an operator's control.

The DMS will be capable of accepting single value biochemical determinations, and various identifying data at the beginning of any physiological or behavioral test. This data, as it is being entered, will be encoded for acceptance by the recording and computational portion of the subsystem. Audio signals, as well as previously discussed physiological analog data, will be accepted by the subsystem for both permanent and temporary recording. (see 3.1.1.4 for further discussion)

3.1.1.3 Accuracy. - Because of the varying and sometimes unknown accuracies of the physiological data transducers and associated special test equipment, the Data Management Subsystem will be required to maintain, within its own conceptual boundries, the following accuracies:

- 0 0.5 percent for measurements sampled, converted to, and displayed in, a digital format.
- 0 2.0 percent for measurements accepted, displayed or recorded for playback, in an analog format.

3.1.1.4 Recording. - The DMS will provide the capability for recording all data; with later playback for operator observation, using display capabilities described in paragraph 3.1.1.5, Display. Playback of digital data, in its originating analog format, will be provided on a somewhat restrictive basis to minimize subsystem costs. Significant derived data, particularly in the pulmonary area, and data channels selected to evaluate the overall subsystems operation by comparison to original analog waveforms will constitute the bulk of information that will be available through digital-to-analog conversion.

Audio data recording will be performed in two modes. One mode will involve the simultaneous recording of audio comments with related analog measurement data; primarily for future correlated playback and evaluation. The other mode will include short "note-taking", scratch-pad type of audio-memo recording for early playback and action. The latter mode of memo-recording will be of particular use during single value determinations at a Biochemical Preparation and Analysis (BPA) station; with later playback and entry of that data through the subsystems numerical entry capability. An audio intercommunication capability between operator and subject will be provided along with the capability for recording audio comments. The analog data/audio signal recording capability will be under direct operator control so that all intercommunication conversation, particularly during a non-test period, will not necessarily be recorded.

3.1.1.5 Display. - The DMS will require several types of multi-usage data display presentations for operator observation. Included in these techniques will be at least four simultaneous channels of real-time transitory analog waveform display, including effective three dimensional presentations, alphanumeric readout to provide identified readout of data converted to measured values, readout of any manually inputed signals. (see 3.2.3 Operator Interface), printed (hard copy) of post-test tabulated measurement data, visual data monitoring, and display recordings of input or previously recorded analog data.

The major display/recording capability will be provided by 2 eight-channel non-deliverable peripheral recorders, however, the subsystem will provide at least 2 channels of display/recording capability integral with the delivered equipment.

3.1.1.6 Processing. - The DMS will have the capability to provide semi-automatic operation of the FBB system, measurement analysis and evaluation through stored reference information and arithmetic computations, including conversion of input data to engineering/medical terms for read-out and printed copy. Due to the unknown nature of processing capabilities in any future space-craft that might house the flight DMBLMS, a non-deliverable computer system will function as, and simulate,

the potential flight unit. Information gathered from this simulated processor will be invaluable in performing trade-off studies relative to any existing processors, or projected development.

3.1.1.7 Backup Modes. - The DMS will have sufficient logic and internal electronics to permit manual operation of its input analog signal routing. (see paragraph 3.2.3.2). This function will be possible with, or without, automatic processing functions. The subsystem will be capable, under the same circumstances, to record and playback any analog input signals which are not dependent on automatic processing.

3.1.2 Operability. - The follow-on subheadings, where required, contain additional DMS operability requirements in the areas of "Reliability", Maintainability", "Useful Life", "Natural Environment", "Transportability", "Human Engineering", and "Safety".

3.1.2.1 Reliability. - Section III - A FBB System Requirements document contains all applicable statements.

3.1.2.2 Maintainability. - The DMS, in addition to statements in Section III-A FBB System Requirements, will strive to provide rear access to all electronic circuit boards and plug-in integrated circuits for both on-line checkout and on or off-line maintenance. Wherever possible, operating panels will interconnect with the DMS via easily disengaged connectors. Rapid disconnect of an entire input/output panel will aid in expediting bench testing of that unit and/or replacement with an equal, or similar, unit.

Processor and subsystem self-check programs will be written to aid in determining malfunctions, and subsequently minimize down-time required during repairs.

3.1.2.3 Useful Life. - Section III -A FBB System Requirements document contains all applicable statements.

3.1.2.4 Natural Environment. - Section III -A FBB System Requirements document contains all applicable statements.

3.1.2.5 Transportability. - With the exception of the peripheral (non-deliverable) digital computer system with digital recorders, the two 8-pen recorders, and the Analog Tape Recorder, the balance of the DMS will be designed to the transportability requirements of the FBB system contained in Section III-A.

3.1.2.6 Human Engineering. - Within the design constraints of currently available equipment, the Data Management Subsystem will maximize its uses of Human Factors engineering personnel and standards. MIL Standard 1472 will be used for system display guidelines. Deviations, if any, will be taken under advisement and appropriate (short) trade-studies performed.

3.1.2.7 Safety. - Section III-A FBB System Requirements document contains all applicable general requirements, with the exception that all chassis

using A.C. power will be interconnected and grounded to the A.C. power ground (green wire) at a single point.

3.2 Interface Requirements

3.2.1 Experimental Equipment/Measurement Interface. - This section contains a description of the various functional and electrical interfaces presented to the DMS by both Measurement and Experiment Equipment.

3.2.1.1 Dynamic Physiological Monitor. - The DMS will present an electrical interface to the DPM containing the following information:

- Alarm indicator activate voltages (4 circuits)
- Analog recorder status
- Audio signals from/to a subject
- A.C. power (115 V. 60Hz)
- D.C. power (28 V.D.C.)
- Harness/vest signals (fixed "in-console" mode of operation)

The DPM will present an interface to the DMS containing the following information:

- Analog recorder start/stop, and other controls
- Direct and derived data from each vest/harness input, regardless of fixed or portable mode of operation
- Calibrate data routed via vest/harness signal conditioners.

3.2.1.2 Biochemical Preparation and Analysis (BPA) Station. - There will be no electrical/electronic interface connections with the initial BPA configuration. The BPA console will have an electrical input/output connector which is designated for any future interconnection with the DMS. All BPA determinations will be verbally recorded, or if desired, manually recorded for later entry into the DMS. The memo recording capability previously discussed as integral with the DMS, will provide the only interface (verbal) with the BPA.

3.2.1.3 Ergometer. - Measurements involving the use of an ergometer will necessitate the input of ergometer status to the PBDM. Ergometer status information will include power levels and continuous indication of RPM levels.

Outout of the ergometer's RPM tachometer and power converter multiplier will be presented to the DMS for recording, display and sampling subsequent to computation of work-force profiles for the subject under test.

3.2.1.4 LBNP. - Measurements involving the use of a Lower Body Negative Pressure device will provide the DMS with an analog signal directly proportional to the pressure within the device. The DMS must be capable of integrating these pressure values with physiological data being simultaneously obtained from a subject. Physiological data will be obtained via a monitoring harness input to the DPM and from leg plethysmographs. Outputs from the plethysmographs will be in the 0-5 volt range (using ultrasonic and/or mercury strain gage

techniques) for acceptance by the DMS, and conversion to a percent volume change value. This percent change will be used to operate appropriate meters on the Vascular Dynamics Panel.

3.2.1.5 Respiratory. - The DMS will receive information from a group of equipment used to establish certain respiratory parameters on a subject. Included in these parameters are Flow, Volume, Gas Temperature, Percent CO, O_2, N_2, etc. The respiratory data will be available as electrical signals which, in some cases, will require conditioning to a 0-5 volt D.C. level for further processing. The DMS will provide a voltage pulse, for relay operation, based on monitoring the flow rate for specific rate crossover. The pulse will be initiated when the rate exceeds or drops below the monitor level.

3.2.1.6 Exer-Genie. - As part of the muscle strength, muscle size, measurements, an Exer-Genie (having a manually adjustable load) will be used in conjunction with a load-cell (having a 0-5 volt D.C. adjustable output) to obtain data for a force vs. time plot on each subject, and digital readout of maximum forces from the DMS. To provide complete measurement data to the DMS, for the required force vs. time plot, it will be necessary to manually enter the load settings and tape measured muscle sizes into the DMS. (see 3.2.3.2 for further details)

3.2.1.7 Mass Measurement Devices. - Both body mass measurements and specimen mass measurements will be performed with equipment that has the capability to measure a period between 3 to 5 cycles respectively, of free oscillations of the object being weighed while attached to a special low-friction linear spring device. The periods will be timed by the DMS receiving both a start and stop pulse from the equipment, and timing the increment in between. The DMS will perform computation of the mass weight. The resultant weight, with identification will be digitally recorded, available for digital readout, and printout.

3.2.1.8 Pressure Transducers for Peripheral Venous Pressure (Direct or Indirect Technique). - During the "Indirect Technique" of peripheral venous pressure, the DMS will accept inputs from two strain gage driver amplifiers, over a 0-5 volt range. Each measurement will take approximately one minute to perform, with the DMS digitally recording the data, providing an average value of the plethysmograph traces (using negative to zero slope change) peripheral venous blood pressure after three complete one-minute cycles. Average values will be presented for readout and printout. Real time data obtained during these measurements will also be recorded on an analog device, displayed on a display/recorder, and displayed on a transitory analog wave for device for operator observation. Measurement and subject identification, plus calibration data, will be manually entered into the DMS.

3.2.1.9 Behavioral Measurement Subsystem. - The behavioral measurement subsystem includes numerous items of equipment that will interface with the Data Management Subsystem. The DMS will provide means for; setting up a particular test element; controlling the nature and timing of stimulus presentations and procedural steps (as required by individual tests); recording,

computing, and presenting test results; and identifying test, time, and subject.

Behavioral Equipment involved will include:

- O A Vision Testing Unit
- O An Audiometer Unit
- O A Critical Tracking Task Unit
- O A Performance Measurement Unit (Including Test Control Information)

Other DMS capabilities, not specifically identified as part of the Behavioral Subsystem, but serving as one of its measurement interfaces, includes:

- O TV Camera, Monitor Screen, and Video Recorder
- O Numerical Data Entry Switches
- O Processor Keyboard
- O Audio Recorder

3.2.2 Peripheral Equipment (Deliverable and Non-Deliverable) Interfaces. - In order to be responsive to the various medical requirements for displaying and processing data, it becomes mandatory for the FBB Data Management Subsystem to provide certain functional equipment that is not integral to a console housing the majority of measurement and processing equipment. It is intended that these capabilities such as will be briefly described, hereafter, will either be integral with the flight IMBLMS or exist within the spacecraft on which the IMBLMS is placed; with the exception of pen recorders. These recorders are included; primarily, to aid in evaluation of the other more flight oriented methods of data gathering and presentation.

3.2.2.1 Magnetic Tape Analog Recorder. - It is required to provide a capability for recording up to 12 simultaneous sources of analog data, 1 source of audio data, and timing information to aid in locating specific measurements during playback. A fourteen channel instrumentation type recorder, will be required to meet this need and also to maintain the overall subsystem accuracy requirement of 2 percent for analog information. Since this recorder will be too large for console integration, a remote control panel (either console mounted or, preferably, on the lower portion of the DMS) will be required for its operation. The start-stop switch for this recorder will have sufficient contacts to provide an indication of its position to the DMS computer and digital recorders (see 3.2.2.3) Data paths to and from the recorder will be assigned by coded information manually and/or automatically generated).

3.2.2.2 Video Recorder. - A video recorder is required to record information from a TV/Microscope setup, or from direct observation of a subject during various work-task assignments, etc. Since the recorder is remote to the basic PBDM IMBLMS console, an operating panel integral with the console will be required. The entire video system (i.e., camera, operating panel, monitor screen and tape recorder) is essentially independent of the balance of the DMS, with the exception of audio identifying data. Identification of a video image is possible through the use of direct, or microscopic, observation of identifying information or by recording an audio track along with the visual data. The later method will be accomplished by interconnnecting the video recorders audio

input/output channels with the DMS audio system.

3.2.2.3 Computer and Digital Recorder. - In the flight IMBLMS, it is visualized that a digital data recorder, combined with an analog recording capability (primarily for audio information), will be used to meet overall data recording requirements; it is also a requirement to perform certain on-orbit calculations and program control, of sufficient complexity to warrant the usage of a digital computer. Since the computer cannot be adequately identified at this time (i.e., it might be an existing navigation computer integrated into IMBLMS, it might be an on-board computer that is timed shared with IMBLMS, or it might be a new design tailored to IMBLMS requirements) it becomes a requirement to provide sufficient computational capability to meet the growing FBB requirements, provide breadboard flexibility and future growth, and to define the ultimate flight IMBLMS computing needs. This computer, by the virtue of having a need for its own digital (Program) storage recorders, will also use its recorders to simulate the digital data recording requirements. Digital I/O registers and appropriate control lines will be provided in the basic DMS to interface with the computer intended for use at LMSC and, if an NASA MSC computer is identified early in the program, similar electronic interface will be provided for the NASA computer.

3.2.2.4 Pen Recorder. - Although not in the LMSC flight IMBLMS design, an interface will be required to route incoming analog data(for display/recording) to one or two external eight-channel analog data pen recorders for data comparison and evaluation. Since the recorders planned for use at LMSC are not deliverable, it is intended to also route any two channels of incoming analog data to a two-channel strip chart recorder supplied with the respiratory equipment. The latter pen recording capability is also not part of the flight concept but, because of its availability, will be provided with the delivered FBB for immediate use by NASA.

3.2.2.5 Calibration Equipment. - The various biomedical data gathering equipment, in addition to the overall DMS signal processing capabilities, will require the use of precise calibration signals entered into the DMS pre and post-test. These signals, in general, will be inserted into the subsystem at the signal conditioner inputs. To facilitate this calibration input requirement, the calibration unit will be designed as a piece of portable equipment, preferably battery operated for maximum mobility. The calibration unit will have the capability of inserting both D.C. pulses and sine wave information. Accuracies of these signals will be on the order of 0.2%.

3.2.3 Operator Interface. - In addition to some of the specialized, or measurement dedicated displays and controls, there exists a requirement for certain displays and controls to interface an operator with the DMS. These capabilities will include (1) a means to manually enter numerical data (2) a means to communicate with an integrated processor (3) Alphanumeric Displays, manual entry status displays, video monitor, and analog wave form display, (4) Analog and Video recording equipment controls and status displays.

3.2.3.1 Processor Keyboard. - An operator keyboard, modeled after the Apollo navigation computer keyboard to minimize operator familiarization and

training, is required to communicate with the computer. These communications will include program modification, such as monitoring limit changes, initiation of a specific test group or sequence, digital and analog display changes, and direct communication with the DMS in a backup mode of operation, that does not require on-line processing. See paragraph 3.2.3.3 for the digital display requirements that complement the operation of the keyboard.

3.2.3.2 Numerical Data Entry Switches. - A special group of digit-dial switches have been assigned the function of manually entering numerical data into the DMS for recording, computation, printout, etc. This function facilitates the entry of data obtained elsewhere, such as clinical data or information obtained at the BPA console, besides providing easy entry of astronaut identification, test number, and test time prior to any measurement. Since the same data entry function could be achieved at the processor keyboard, but with somewhat less ease, the FBB DMS will evaluate each approach.

3.2.3.3 Memo Recorder. - To aid an FBB operator in efficiently handling data, the DMS must provide the capability for an operator to verbally log data that can be played back at some later point in time. A portable audio recorder will be provided to fulfill this need. The recorder will permit up to one hour of verbal data recording which can be played back, at an operator's discretion, for evaluation and/or entry into the DMS via the numerical data entry switches.

3.2.3.4 Displays. - Various displays are required to interface with an operator to present the data accepted by the DMS,the results of computed data, the keyboard and computer status, the data being entered into the computer, and the operational status of peripheral equipment. These displays will take several different forms, such as: Five 8-position alphanumeric readouts with the three most significant positions having a 24 alphabetical character capability for measurement identification, the fourth position will have a 0-9 and decimal point capability plus 14 selected alphabetical readouts for identifications requiring four letters, while the remaining 4 positions will have a 0-9 and decimal point capability; a four-channel oscilloscope for waveform presentation; a 64-character alphanumeric strip pointer for "hard copy" data presentation; keyboard and computer status lights to indicate computer locations and programs that have been addressed by keyboard activation and various DMS status lights to indicate computer activity and operating modes; status lights on remote operating panels for the video recorder and analog magnetic tape recorder; a video monitor screen for real-time presentations or playback of previously recorded video data; 18 channels of pen recorder display (2 channels at the console) and 16 channels on remote equipment; and a mission timer display to display either test-time, or real-time.

3.2.3.5 Miscellaneous. - In addition to an operator interface with the previously described displays and operating panels, there also exists a requirement for the operator to have remote control (at the console) of; an analog tape recorder and video tape recorder; PBDM console power; oscilloscope channel identification, wherein operation of the control will temporarily halt the digital display of data on the first 4 alpha-digtal readouts and substitute alpha

data identifying which four data channels are currently being displayed on the four-channel oscilloscope; various measurement discrete controls, not necessarily part of the DMS, and, in the case of the behavioral performance panel, controls to start and stop a particular test sequence (a function normally assigned to the processor keyboard) plus computer/test ready status data displays.

3.3 Design and Construction

This section is to present more detailed information relative to the previously described requirements for the design and construction of the various elements comprising the Data Management Subsystem.

3.3.1 Subsystem Elements. - The following subheadings describe those elements, which, when interconnected, provide the capabilities and meet the requirements for the DMS outlined in previous paragraphs. The "Switching Matrix" routes incoming measurement data to various display and recording devices; the "Mission Timer" provides either mission or real-time display and clock signals to other equipment for system timing; the "Processor Keyboard and Display" provides operator communication with the system computer; the "Numerical Data Entry Switches" facilitate entry of numerical type data obtained at the BPA, etc.; the "Strip Printer" provides hard-copy of post-test data; the "Four-Channel CRT" provides visual display of analog measurement data; the "Video Equipment" provides data handling for visual information; the "Digital Data Display" provides readout of measurement data after digital processing; the "Computer and Digital Recorders" provide necessary data derivation, computation, recording, and overall automatic control; the "Analog Tape Recorder" provides a permanent record of incoming analog signals; the "Pen Recorders" provide both a real-time display and permanent record of incoming, or replayed, analog data; "Software" provides the requirements for the computer programming; "Multiplexer A/D and D/A Converters" describe the requirements for equipment to sample analog signals and convert them into a digital format for computer usage, plus converting digital data back into analog data for display on the oscilloscope or pen-recorders; "Decoder Encoder" describes equipment requirements within the DMS design to (1) accept discrete inputs and encode them for the computer or (2) convert (decode) digital signals from the computer for discrete outputs - two examples of these functions are, respectively, encoding of behavioral keyboard responses and decoding of alarm signals for the DPM; "Power Supplies" describe the general power supply requirements for the DMS; and "Calibration Equipment" describes the detailed requirements for a calibration unit.

3.3.1.1 Switching Matrix. - The following are basic requirements of the switching matrix: Incoming data lines, which may have any of the signals described in paragraphs 3.2.1 or in some cases a combination, must be routed first through 12/Record/Re-run switches to the differential inputs of 12 channels of a 16-channel pen recorder. As twisted-pair lines will be used for noise reduction, 12 differential solid state switches are required. This same set of switches must also be used to route the magnetic-tape recorder playback output to the pen recorder (16 channel) during a Re-run mode. These 12 solid state switches are required to be 6 position differential switches to accommodate all the various inputs presented in Appendix-A, and to provide a capability for future expansion.

Due to the need to maintain balanced lines, any amplifier following a single ended magnetic tape playback output will have a differential output as a drive source to the differential Record/Rerun solid-state switches. Post amplifiers on each of the 12 channels of the pen recorder are used to drive 12 channels of the magnetic tape recorder, in the Record mode, to provide a balanced high impedance input. Referring to Fig. 2, it can be seen that the switching matrix must also provide appropriate switching to route data inputs, and rerun signals from the magnetic tape recorder to the following inputs.

- The 4-channel variable persistence oscilloscope
- The 2-channel pen recorder
- Channels 13 to 16 of the 16-channel pen recorder

In addition, the output of four digital to analog converters are required to route data to channels 1, 2, 3 and 4 of Z axis of the oscilloscope and to other items in parallel with these channels, including certain discrete analog meter readouts. One additional requirement is that timing track information, which is recorded on channel 13 of the magnetic tape recorder must be routed to channel 4 of the oscilloscope during rerun. Four sets of 15 position differential solid state switches will be provided to accomplish this. Twelve of the inputs are in parallel and obtain their inputs from the first 12 channels of the pen recorder (16 channel) input. The 13th input of the switch sets receive signals from the D/A converters and the 14th input of the 4th set receives data from the timing track of the tape recorder. The remaining unused inputs provide for future expansion. This requirement for four sets of switches permits complete flexibility, so that any of the 4-channels of the oscilloscope and items in parallel with it may be switched to any of the 12 input lines, thus accomplishing all CRT options required in Appendix A. Again, in order to maintain a balanced system, isolating 1:1 differential input differential output amplifiers are required at the oscilloscope inputs to channels 1 to 4. As one side of the oscilloscope input is grounded to the frame, the differential output prevents a ground loop problem within the system.

Solid state switches of the MOS FET type will be required to maintain a high impedance open condition. The switches, for maintenance reasons, will be mounted on a mother board and be driven with I/C digital circuits that will be common to other digital logic in the system.

3.3.1.2 Mission Timer.

General. - The mission timer will be located on the PBDM console front and will be used to visually ascertain mission time. Its electronics will also provide logic levels that may be sampled by the computer for time calculations.

Logic. - The mission timer logic circuitry will count down a crystal oscillator to provide BCD output to the computer, when sampled, in two modes. One mode will read out mission time in hours, minutes, and seconds up to 23 hours, 59 minutes, 59 seconds in BCD format and then repeat. Upon interrogation, the

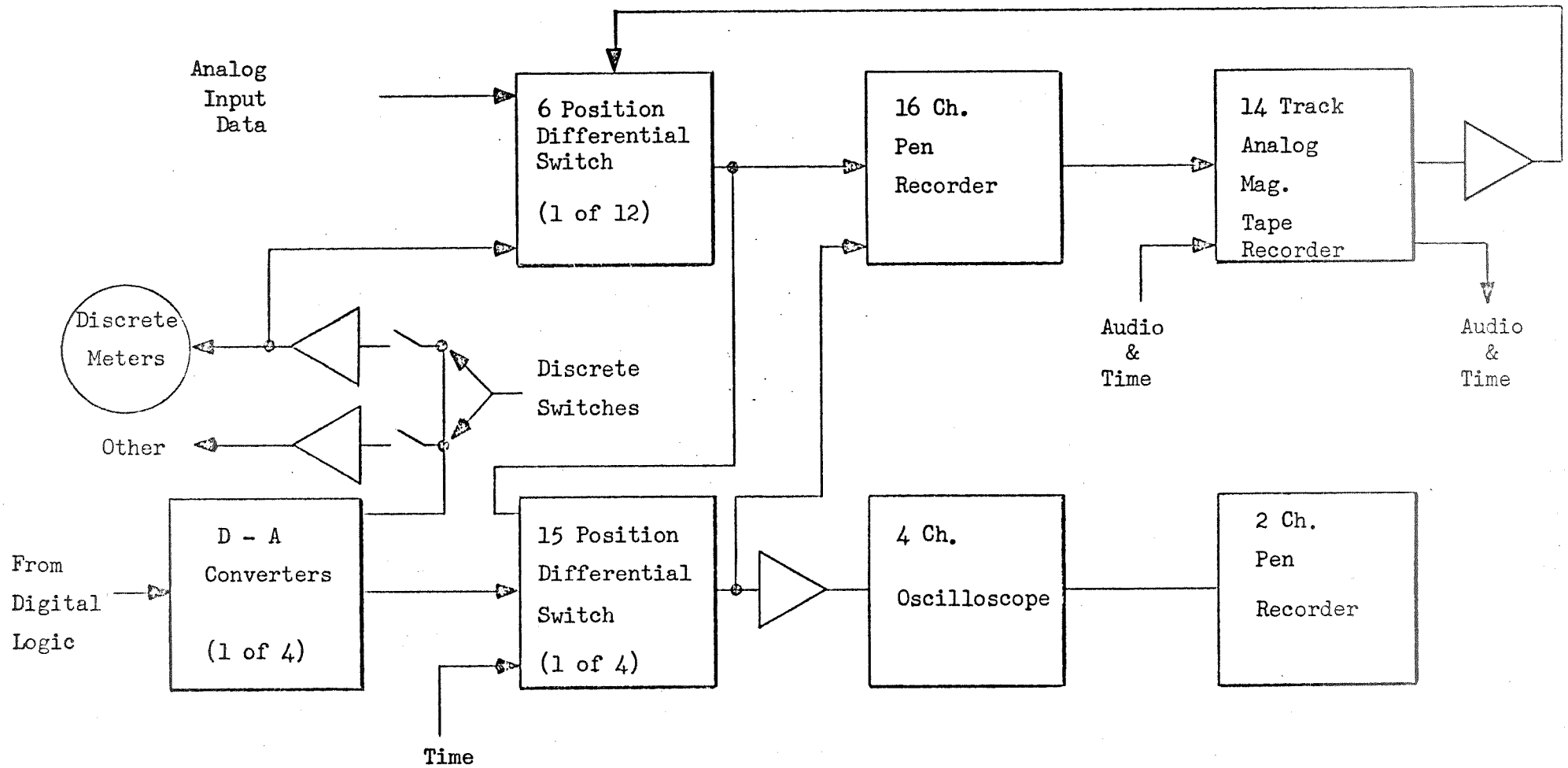


Fig. 2 Typical Diagram of DMS Analog Switching

time will be transferred to a 22-bit portion of a 24-bit register. In the second mode, the timer will read out in unit minutes, tens of seconds, unit seconds, tenths of seconds, hundredths of seconds, milliseconds, tenths of milliseconds and hundredths of milliseconds. Upon interrogation, the time will be transferred to BCD format to a 32-bit register. The 32-bit register will be used to provide timing data to the system computer.

Display. - The visual display will continuously read out hours, minutes, and seconds up to 23 hours, 59 minutes, and 59 seconds, and then repeat, regardless of the mode used for the computer input.

Controls. - Front panel controls will be required to clear the mission timer registers and reset them to zero. A Hold-Run control will be required to cause the timer internal clock to be disabled or enabled. Additional controls on the front panel will be required to advance seconds, minutes, or hours to allow pre-setting time to some specified value, such as real-time.

Accuracy. - The crystal oscillator frequency source will have a long-time accuracy of $\pm$ .01%.

Maintainability. - Circuit logic for the Mission Timer will use dual in-line packaging and will be mounted on a mother board facilitating removal of the individual dual in-line packages for replacement, if necessary. The crystal will also be mounted on a pin-type plug-in board which will mount on the mother board.

3.3.1.3 Processor Keyboard and Display.

Keyboard. - The processor keyboard will be similar in design to the Apollo keyboard (Fig. 3). Verb and noun keys will enable their respective registers. Each register will then sequentially receive two BCD numbers from the keyboard. These BCD numbers can either be encoded mechanically by keyboard switch contacts, or by a logic circuit encoder, depending on final keyboard switch selection. The ENTR button (can be a single contact closure) will transfer the respective Verb and Noun register data to the computer. A PROGRAM display will show the last entered NOUN number when the computer is ready. A storage register for the Program number must be provided. A total of 24 storage flip-flops will be required for the 6 numerals displayed.

The CLR button (can be a single-contact closure) will clear all PBDM registers, except the Mission Timer.

Keyboard Display. - The keyboard display will consist of two types of displays. See Fig. 4. The VERB NOUN and PROGRAM displays will be incandescent lamp types, using numerals only. Character height will be 3/8 inch. A total of six 16-pin dual in-line decoders will be required for the 6 numeric displays. These will be mounted on a DMS mother board with other subsystem logic circuits.

The status lights will be back-illuminated incandescent lamp displays, with 2 lamps per display for reliability. There are 3 spare displays for future

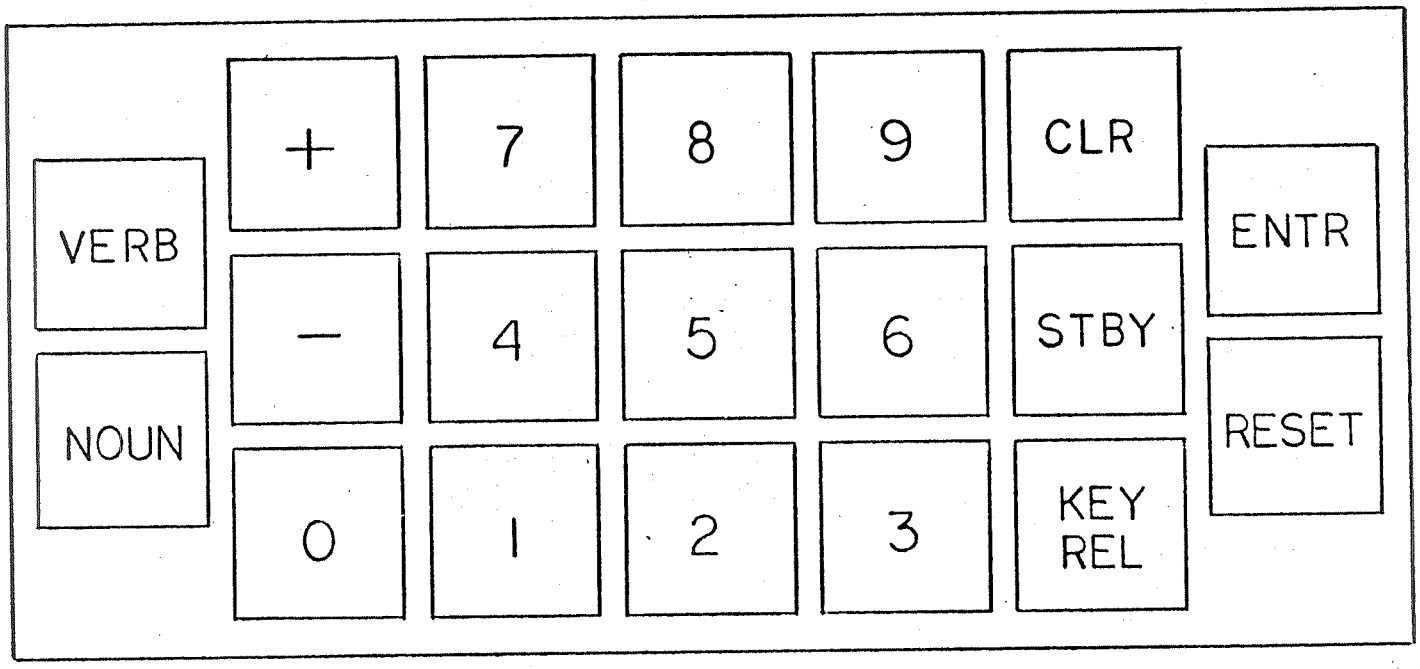


Fig. 3 Processor Keyboard Model

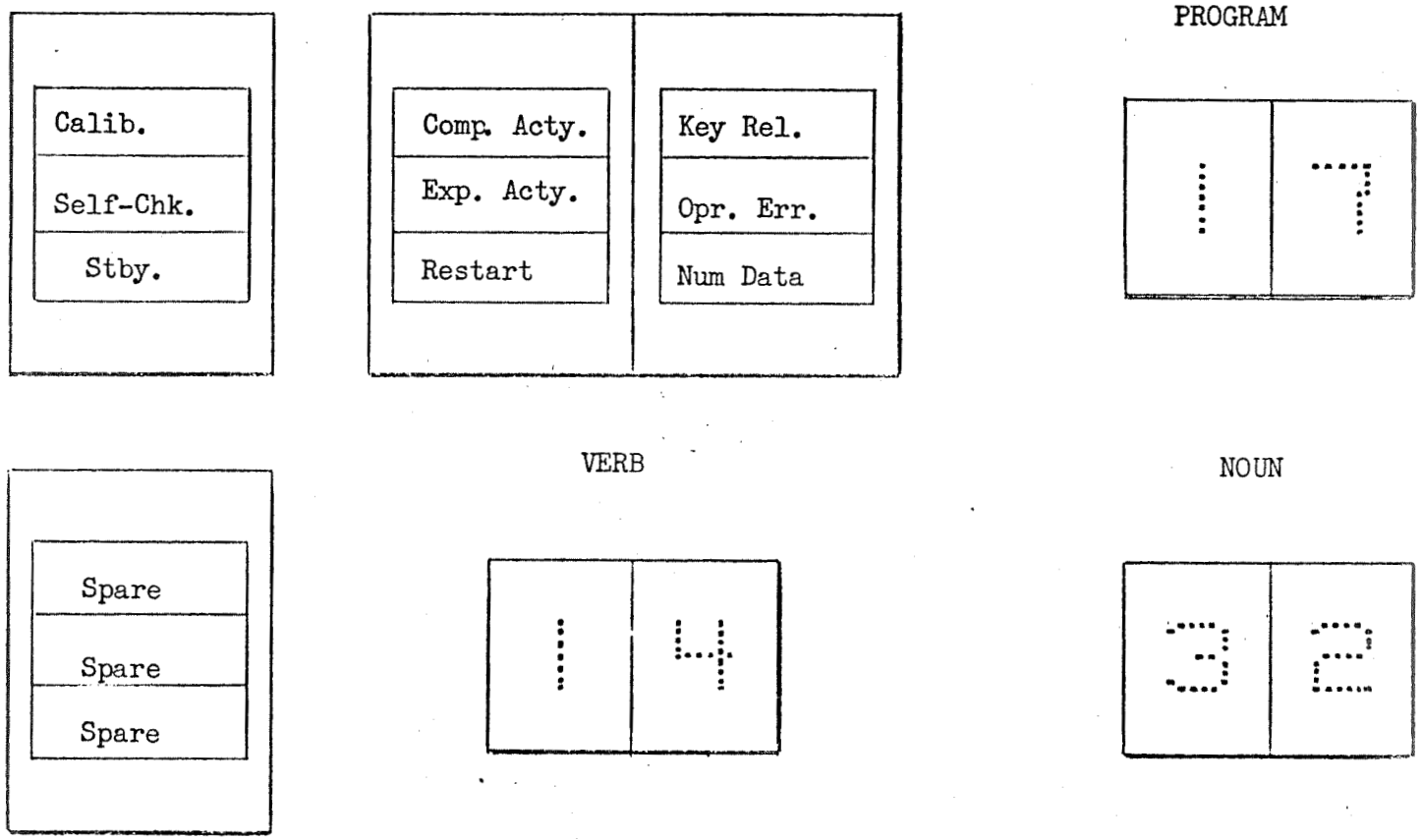


Fig. 4 Processor and Keyboard Displays

expansion and/or modified functions. "CALIB" will be illuminated when the computer is in the calibrate mode. "SELF-CHK" is illuminated when the computer is in self-check mode. STBY is illuminated after STBY button has been pushed on the keyboard the first time and indicates a ready or idle mode, "COMP ACTY" is illuminated when the computer is in operation doing calculations, storing programs, etc.; "EXP ACTY" is illuminated when experimental measurements are being made. "RESTART" is illuminated any time a program error occurs and the program must be reloaded, or restarted, by means of the keyboard. "KEY REL" is illuminated during the time that the #3, #4, and #5 Digital Data displays are being used by the keyboard to enter numerical data into them and, subsequently, the computer. It will remain illuminated until the KEY REL button on the keyboard is depressed returning the use of the Digital Data displays to their normal function of data readout. "OPR ERR" illuminates when an error occurs in the computer operation or keyboard usage. The "NUM DATA" display is illuminated when the computer is in a mode to receive data from the thumbwheel numerical data entry switches. The program to initiate this mode is entered into the processor keyboard prior to use of the numerical data entry switches.

3.3.1.4 Numerical Data Entry Switches. - The numerical data entry function will require 17 thumbwheel ("digit-dial") switches, an Enter button, a Print button, a Clear button, a Record Button and a Data Accepted Display. The thumbwheels will have 10 positions (for numerals 0 through 9) and outputs in a BCD format. Each switch will have four output terminals, numbered 1, 2, 4, and 8, and two separate levels, ground and +5 VDC. The latter two terminals are never shorted together, either directly or through the output terminals. The output terminals will be at either +5 VDC or ground; there will be no non-active or "floating" positions. Fig. 5 illustrates the required output coding, and the functional assignment of each thumbwheel.

The balance of the controls initiate the following functional operations:

- "ENTER". This button notifies the computer that data displayed on all the thumbwheels can be entered into the computer program.
- "PRINT" this button notifies the computer or printer directly, to provide a sequential hard-copy printout (with appropriate spacing) of the numerals indicated on the thumbwheels.
- "CLEAR". This button notifies the computer to ignore, and clear its input register of the last line of data entered therein.
- "RECORD". This button notifies the computer that the data obtained from the ENTER signal is valid, and can be recorded or operated on.
- "DATA ACCEPTED". This display notifies an operator that the data received as a result of an ENTER function, or a RECORD function has been received by the computer. The display should remain illuminated approximately 1/2 second to signify acceptance.

3.3.1.5 Strip Printer. - A single-column strip printer will be required to provide print-out of a 64-character font-numerals 0-9, alphabet A-Z, punctuation marks, a space, and various signs and symbols. The printer will print at an average of 20 characters per second with the printout appearing

DIAL POSITION	Output Terminals			
	1	2	3	4
0	GND	GND	GND	GND
1	+5	GND	GND	GND
2	GND	+5	GND	GND
3	+5	+5	GND	GND
4	GND	GND	+5	GND
5	+5	GND	+5	GND
6	GND	+5	+5	GND
7	+5	+5	+5	GND
8	GND	GND	GND	+5
9	+5	GND	GND	+5

SWITCH OUTOUT CODING

THUMBWHEEL	FUNCTION	
1	ASTRO IDENT	TENS
2	" "	UNITS
3	DAY	HUNDREDS
4	DAY	TENS
5	DAY	UNITS
6	TEST TIME	TENS OF HOURS
7	TEST TIME	UNIT HOURS
8	TEST TIME	TENS - MINUTES
9	TEST TIME	UNIT - MINUTES
10	ORG SYS	UNITS
11	TEST NO.	TENS
12	TEST NO.	UNITS
13	TEST VALUE	TENS THOUSANDS
14	TEST VALUE	THOUSANDS
15	TEST VALUE	HUNDREDS
16	TEST VALUE	TENS
17	TEST VALUE	UNITS

FUNCTIONAL ASSIGNMENT

FIG. 5

serially along a 1/2"-wide impact-printing paper tape. The character spacing will be 10 characters per inch; letters of the alphabet will be capitals, 0.100" high x 0.065" wide. The readout will be with the characters vertical axis perpendicular to the longitudinal axis of the paper strip. The paper roll stock will be at least 200' long. Input to the printer will be accomplished with a 6-bit truncated ASCII code, and a print command. The printer will provide two output signals, one which indicates that the printer is printing, and one which indicates that the printout is completed.

Power Requirements

- 105-125 VAC single phase, 0.2A, 60Hz
- 15 VDC ± 10% regulation, 0.1A
- 26 VDC ± 1% regulation, 0.65A average

Mechanical - The printer will be mounted on the front of the PBIM console, such that the printout may be easily read. The printer will meet standard commercial specifications but will be fairly small size, approximately 3/16 of a cu. ft., and weigh approximately 11 lbs.

3.3.1.6 Four-Channel CRT. - A four-channel oscilloscope, with a variable persistence screen, is required to present the various simultaneous analog waveforms specified in Appendix A, "Measurement Display Requirements".

The oscilloscope will have individual step and vernier gain controls for each input channel, with an input selection of DC, AC, or GND. The GND position will disconnect the input signal and ground the amplifier for reference. Each channel will have a position adjustment control and a channel identity push-button that causes the selected channel to displace its trace by approximately 0.5 divisions. Input impedance to each channel will be approximately 1 megohm shunted by 25 pF. Versatility in modes of operation and triggering modes (with off channels being skipped) will be required. Each channel will have a wide-band width input capability (0-50 MHz when DC coupled, 10 Hz to 50 MHz when AC coupled) and a maximum input amplitude capability in excess of ± 150 V.

The CRT will have a variable persistence capability of from less than 0.2 seconds to more than one minute. It will have a Store mode which will permit traces to be stored for up to one hour and an Erase control to clear the trace. The CRT will be capable of z axis modulation to facilitate 3-dimensional presentations. The CRT will have a sweep magnifier of X1, X5 and X10, plus sweep control (step and veriner) to provide a range from 0.1 s/div. to 50 ms/div. The CRT will have an internal calibrate signal of approximately 10 v pk-pk, in the form of a 1KHz square wave. The entire oscilloscope element with appropriate plug-ins, will be designed for rack mounting, and will function within input power source of 115 volts ± 10% over a frequency of 50 to 400 Hz. It will use less than 115 watts of power from a normal line source, when convection cooled.

3.3.1.7 Video Equipment. -

Definition. - The FBB DMS video/microscope equipment is required

to fulfill specific purposes in 2 discrete areas. Its primary purpose is to view, and record, biological specimen samples and its secondary usage is in the behavioral area; for time and motion tests and studies. The equipment, as illustrated in Fig. 6, will be comprised of the following items: a small 525 line TV camera, a video tape recorder (VTR) with remote control capability, a 5-inch screen TV monitor, and a small microscope.

Measurements. - Measurement requirements include following categories:

- Hematological Measurements
  Red blood cell count and morphology
  White blood cell differential count and morphology

- Urine Sediment

- Microbiology
  Body microflora cultures
  Environmental cultures

- Wet size, color, and consistency of feces

- Behavioral Testing
  Complex Patterns
  Time and Motion Studies

Sensing. - Two input sensing devices will be required; a microscope and a TV camera. The microscope will be a small, hand-held, portable unit, which may be removed from the PBDM console to change slides, observe the slide context, select field(s) of view, and initially focus the microscope before placing it under the camera to display specimen slide information at 100X magnification. The TV camera, in addition to sensing images from the microscope, will be capable of being moved to an external position above the top of the console so that it may be used to image and record movements of test subjects for time and motion studies, etc.

Recording. - A video tape recorder (VTR) will be required to interface with the TV camera for recording of specimen information, and time and motion studies. This recorder will be capable of one hour of continuous video recording, and will contain a stop-motion capability for frame-by-frame analysis of the recorded information. The VTR will also accept audio signals to permit visual image identification. Audio interface will be made with the PBDM audio equipment.

Display. - A 5" TV monitor will be required to display information from the TV camera and VTR. The monitor will be primarily used to establish the photographic quality (resolution, contrast, and context) of the specimen sample slides, prior to recording them on the VTR. It will also be used for establishing photographic quality of the subject before recording time and motion information.

Interface

Camera - VTR - Monitor Interface. - A remote control panel will be required for

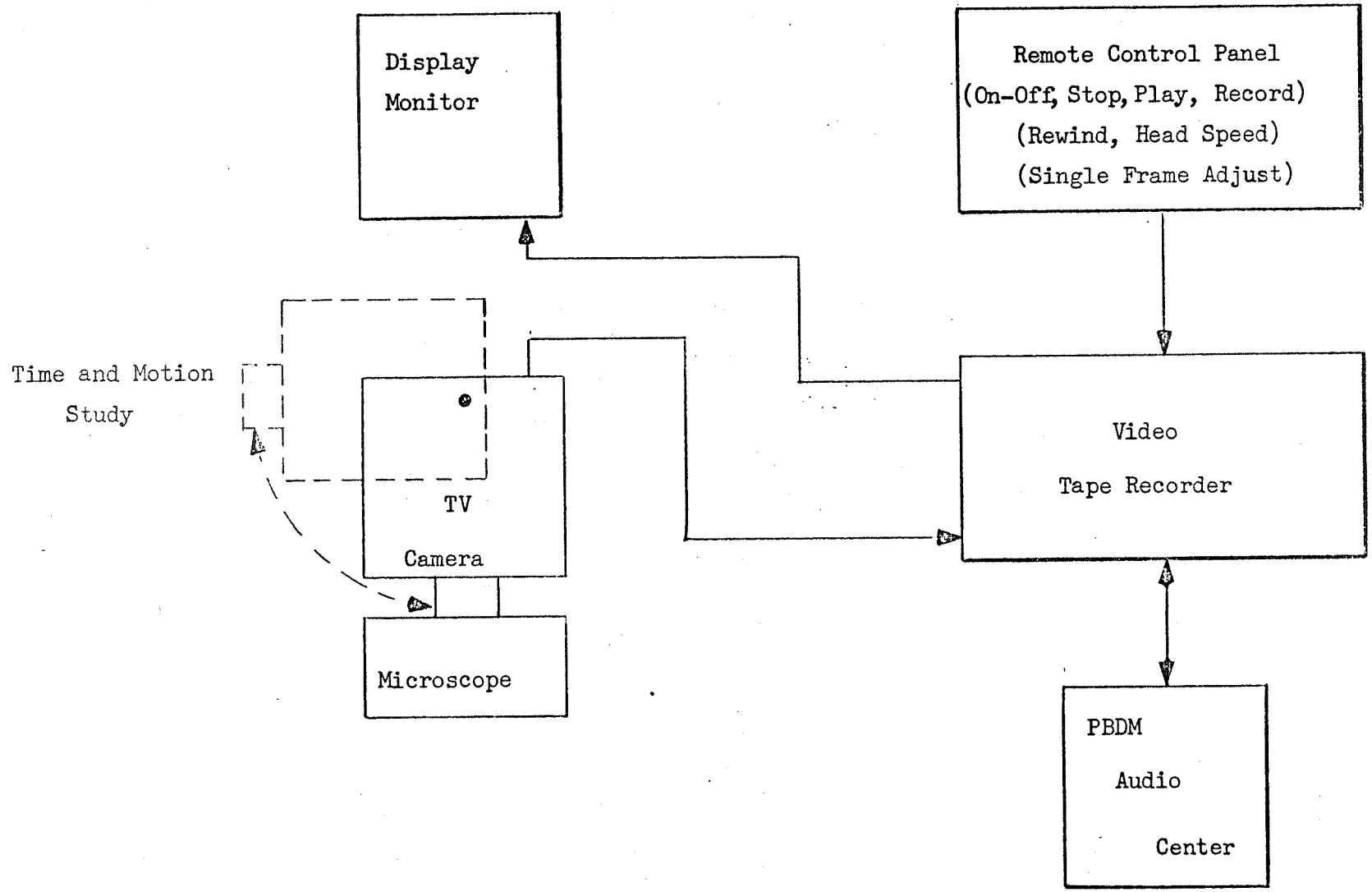


Fig. 6 Video System Block Diagram

installation in the PBDM, and will contain switches to activate the following VTR functions: "On-Off", "Record", "Play", "Stop", "Rewind", and "Head Speed". The "Head Speed" function is used for single-framing purposes, wherein the tape is stopped, but the helical scan VTR rotating head is kept up to speed to read and display only a single frame of view out of the normal 30-frames per second. This function will be used for time and motion analysis and to enable instantaneous recording, rather than waiting 5 to 10 seconds for the head to come up to speed before recording as normally occurs when only the "Record" switch is activated. A plug-in cable will be required for interconnection between the various control activation points on the VTR and the 6 switches on the remote control panel.

Camera - Microscope Interface. - The interface between the TV camera and microscope is critical because of the optical spacing and alignment that must be maintained between the 2 instruments. This positioning will be determined by an empirical evaluation of the optical relationship between the 4 x field lens of the microscope and the one-inch lens of the camera. The configurational design of the FBB console will be such that realignment of the 2 instruments, after using them independently, will automatically be accomplished when they are locked into their operating position.

Component Mounting

Camera - Microscope. - A 5" x 1½" x 4¼" (WDH) microscope and a 5-5/8" x 10-7/16" x 4-1/4" TV camera will be mounted inside one of the lower bays of the FBB. They will be affixed to a telescoping fixture so that they may be pulled up from the bay and then replaced (out of the way) when not in use. The microscope will be capable of easily being removed from its mounting bracket for manual accessibility. Replacement will cause an automatic interface with the camera through the configuration of the mounting fixture. The camera, in addition to interfacing with the microscope will be capable of extension up and above the top of the FBB console. It can then be locked in place and panned and tilted by the console operator to observe and follow subject movements for time and motion study.

Video Tape Recorder (VTR) and Remove Control Panel. - A 18-1/8" x 11-7/8" x 15-3/4" VTR will be remotely located with a cable connection to its control panel. The six operating functions will be activated by push button switches on the panel which will be in a position adjacent to the 5" monitor. The VTR will be located so that the tape reels and record heads are easily accessible to facilitate changing tapes and cleaning heads.

Monitor. - A 7-5/8" x 7-1/4" x 4-1/4" monitor will be mounted in the FBB console so that the operator may easily view the displayed information; while performing his other functions. He will have access to the remote control panel, while viewing the monitor, to establish image quality prior to recording.

Electrical

Camera. - The TV camera will operate on 117 v AC and consume no more than 12 watts of power.

Microscope . - The microscope will require 6.3v DC and no more than 2 watts of power.

Video Tape Recorder. - The VTR will operate on 117vAC and consume no more than 80 watts.

Monitor. - The 5" monitor will operate on 117v AC and consume no more than 125 watts of power.

3.3.1.8 Digital Data Display. -

Mechanical. - Incandescent lamp projection type readout will be used for this display. Fig. 7 shows general organization of the Digital Data display. All displays in Columns 1 through 8 will be 24 character types with character heights of 3/4 inch. Columns 5 through 8 will contain only numerals 0 through 9, plus a decimal point. The decimal point may be displayed simultaneously with the numeral, and to its left. Column 4 will contain numerals 0 through 9, plus decimal point, plus 13 other special and alpha characters. Columns 1 through 3 will contain a selected combination of up to 24 alphanumerics in accordance with the display requirements in Appendix A. A space is indicated between columns 3 and 4 as, in most cases, columns 1 to 3 will describe the majority of identifying information (for example HR, RR, CO_2, etc.,) followed by the numerical data in columns 4 through 8.

Decoders to operate and drive the Digital Data display will be 16-pin dual in-line plug-in packaged, and will be mounted in a mother board, along with other digital circuitry. Plug-in units will provide easy replacement, if necessary. The display will be mounted as a unit, and wired with one or more cables, as required. Cable(s) will have plug(s) which will plug into the rear panel of the mother board assembly.

Electrical. - Each display in columns 1 through 4 (Fig. 7) will require a decoder capable of decoding a 5-bit input to 1 of 24 outputs. For this purpose, 3 identical 10-bit decoders will be used, plus two 2 input OR circuits. For columns 5 through 8, a single 4-bit input to 1 out of 10 output decoder will be used, plus a single driver circuit for the decimal point.

A 5-volt source (common to all logic circuitry) will be used for the decoders, and a separate 5-volt source will be used for the lamps. Approximately 3 amps will be required for lamp power.

Each display element in columns 1 through 4 (Fig. 7) (total of 20) will require 5 flip-flops per display element for storage. Each display element in columns 5 through 8 (total of 20 will require 4 flip-flops per element for storage. A total of 180 flip-flops are, therefore, required for the entire Digital Data Display storage requirement. Using 16 pin dual in-line packaging with 4 flip-flops per package, will require a minimum of 45 modules.

3.3.1.9 Computer and Digital Recorders. - As previously mentioned in paragraphs 3.1.1.6 "Processing" functions, and 3.2.2.3 "Computer and Digital Recorder" interface, the computer and digital recorder will simulate flight-type

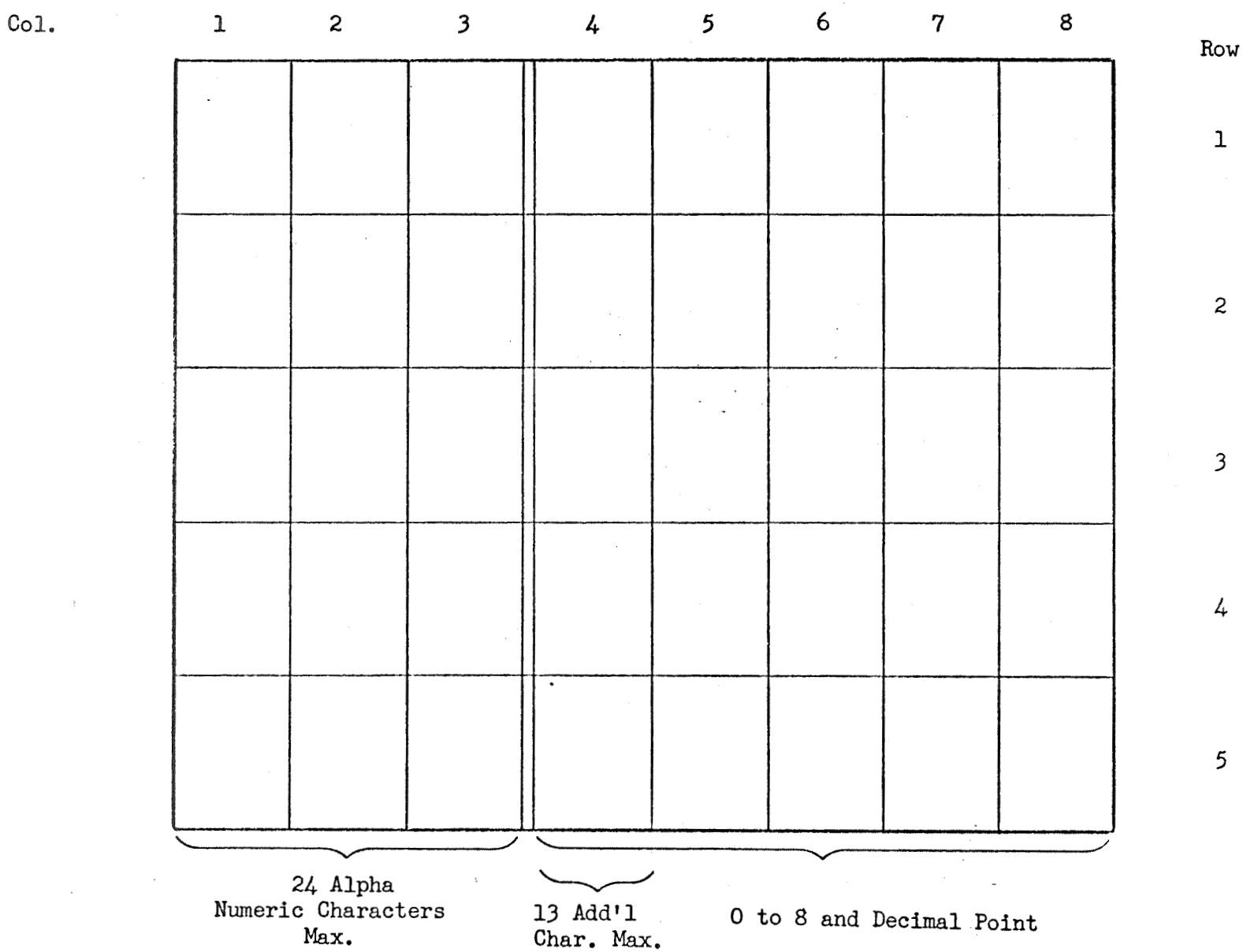


Fig. 7 Digital Data Display Layout

equipment, and techniques, and will be physically removed from the FBB consoles. Interconnecting cables between the computer and the PBDM station will provide the necessary electrical interface. Communication with the computer will be accomplished through the computers' local controls, paper tape reader, and teletype unit; and the DMS processor keyboard and digital logic. Since a different computer may be used by NASA MSC, a separate digital logic interface will be provided for that unit. Complete checkout of this secondary interface will not be accomplished until after the FBB is installed at the MSC.

The digital computer will have a minimum word length of 16 bits, 8,192 words of memory, a minimum cycle time of 1.75 sec., a hardware multiply and divide to speed computations, 14 interrupts and 16 sense switches. The computer will be provided with a digital input/output capability to provide direct communication between the computer and numerous external devices.

The computer, with its peripheral teletype station and high-speed tape reader, will interface with two external digital magnetic tape recorders. Formatting of data for storage on the tape recorders and subsequent removal, will be performed by the computers program (see 3.3.1.12 "Software" for a further discussion). The magnetic tape recorders will contain 7 tracks and will record at 45 ips. It will be possible to record digital information at varying densities of 200, 556, and 800 bpi. Functionally, one tape recorder will be used to store operating programs, while the other recorder will be used to store data.

3.3.1.10 Analog Tape Recorder. - A 14-channel analog tape recorder (instrumentation type) will be used to simulate flight EMBLMS data recording requirements and is a non-deliverable item. The recorder, will have twelve FM record/reproduce channels and two direct record/reproduce channels with the following detailed commercial characteristics.

Direct Record/Reproduce System

o Input Sensitivity	0.15 volts to 10 volts rms
o Nominal Input Level	1 volt rms.
o Input Impedance	20,000 ohms unbalanced to ground 100 cps to 250,000 cps ± 3 db at 60 ips lower speeds have proportional frequency response from 50 cps up.
o Harmonic Distortion	1 percent 3rd harmonic distortion at 1000 cps recorded at 60 ips
o Signal-to-Noise Ratio	24 db at 60 ips 24 db at 30 ips 24 db at 15 ips 24 db at 7-1/2 ips 24 db at 3-3/4 ips 24 db at 1-7/8 ips
o Output Level	1 volt rms into 600 ohms
o Output Impedance	Approximately 100 ohms in series with 40 microfarads.

FM Record/Reproduce System

- o Input Sensitivity ± 0.6 to 10 volts rms for 40 percent deviation
- o Nominal Input Level ±1.4 volts peak
- o Input Impedance 10,000 ohms

o Tape Speed	Center Frequency	Response (F)	Signal/Noise Ratio
60	108.0 kc	DC - 20 kc	46
30	54.0 kc	DC - 10 kc	46
15	27.0 kc	DC - 5.0 kc	46
7-1/2	13.5 kc	DC - 2.5 kc	40
3-3/4	6.75 kc	DC - 1.25 kc	38
1-7/8	3.375 kc	DC - 625 cps	35

- o DC Drift Less than 1 percent peak to peak deviation when temperature is controlled within ± 10°F in the temperature range of from 40°F to 125°F.
- o DC Linearity Within 1 percent of zero centered straight line at peak to peak deviation (30 to 60 ips). 0.5 percent at lower speeds.
- o Distortion Less than 1.5 percent over specific bandpass.
- o Output Level 1 volt rms into 1,000 ohms (± 40% peak deviation)
- o Output Filter Adjustable for flat frequency response or best linear phase.
- o Rise Time Flat phase 22 microseconds
- o Overshoot Flat phase, less than 2 percent
- o Rise Time Flat amplitude 16 microseconds
- o Overshoot Flat amplitude, approximately 6 percent

The analog tape recorder will be mounted in its own 70" high rack. A remote control panel will be provided on the PBDM console to facilitate operator use, and more closely simulate operational configurations.

3.3.1.11 Pen Recorders. -

16 Channel Pen Recorder. - A 16-channel pen recorder (actually two 8-channel units) will record 0-5V analog signals, DC to 100 cps, on two separate 15" wide paper strips. Inputs to the recorder amplifiers will be differential with an impedance greater than 10^6 ohms. The output of the recorders preamplifiers will be used as inputs to the analog magnetic tape recorder (see 3.3.1.10). The recording equipment will be contained in two separate racks and will not be delivered with the FBB.

2-channel Pen Recorder. - A 2-channel pen recorder will be located on the PBDM

console panel and will be delivered with the FBB assembly. This unit will record 0-5 volt analog signals, DC to 100 CPS. Inputs will be differential, with an impedance greater than 10^6 ohms.

3.3.1.12 Software. - Deliverable software will be developed for the Lockheed computer. Where possible, routines will be written in basic Fortran IV, taking into account known differences between the LMSC computer and the NASA MSC computers Fortran IV. Documentation will consist of operating instructions, program listings, flow diagrams, and data format information in sufficient detail to assist implementing the software on the NASA computer. It is planned for the following routines to be written (additional routines may be identified later as requirements are more fully defined).

Executive Routine. - A core-resident executive routine will be entered on an interrupt from the DMS Processor Keyboard. The executive will interpret keyboard inputs, load required programs from magnetic tape, process interrupts, and handle all timing requirements.

General Purpose Routines. - The following general purpose routines and drivers will be furnished:

- Computer self-test and diagnostics
- IMBLMS FBB console test and diagnostics
- Analog calibration routines to derive required calibration information from the various harnesses and sensors.
- Alphanumeric printer driver
- Digital display driver, with options
- Analog matrix switch driver, with options
- Analog to Digital input and multiplexer control
- Digital to Analog Output
- Data recording on magnetic tape
- Data conversion to engineering/medical units
- Limit checking
- Data Compression Algorithms

Behavioral Programs. - Programs will be written to control, score, and record results of the following Behavioral Tasks:

- Pattern Perception
- Arithmetic
- Probability Monitoring
- Tracking
- Audiometer Testing
- Vision Testing
- Rate of Gain of Information
- Discrete Signal Monitoring
- Auditory Monitoring
- Mediational Processes
- Psychomotor Testing to include the following tests:

Arm-hand steadiness
Wrist-finger speed
Response Orientation
Speed of Arm Movement
Multi-limb Coordination
Static Strength
Dynamic Strength

Physiological Programs. - All physiological data received in either analog or digital form will be made available to the computer. Routines will be available to convert data to the appropriate engineering units, record it on digital magnetic tape, and display requested measures on digital displays or the alpha-numeric printer. Data will be checked against tolerance limits and alarms activated if the limits are exceeded. Calculations of physiological parameters such as average heart rate, estimated cardiac output, lung volumes, average respiratory rates, etc., will be made and, if required, displayed on various devices.

3.3.1.13 Multiplexer, A to D Converter and D to A Converters.

Electrical. - A multiplexer and A to D converter will be provided to meet the following requirements:

- 32 channel multiplexer A to D Converter (expandable to 128 channels)
- Max Sampling Rate - 20,000 samples/second
- Overall System Accuracy - ± 1/2 LSB + 0.05% of Full Scale
- Operating Temperature - +10°C to +50°C
- Channel to Channel Crosstalk - ± 0.01% of Full Scale
- Long-Term Stability - ± 5 MV max.
- Random and Sequential Channel Selection
- Analog Inputs

  Type of Input - differential
  Full Scale Input - ± 5 VDC
  Per Channel Input Impedance - greater than 10^6ohms
  Source Impedance - 0 to 1000 ohms

- Digital Inputs - TTL Compatible

  Logical "L", +4.0 ± 1.0 VDC
  Logical "0", +0.2 ± 0.2 VDC

- Digital Outputs - TTL Compatibles

  10 bits of parallel binary data
  Logical "L", +4.0 ± 1.0 VDC
  Logical "0", + .2 ± 0.2 VDC

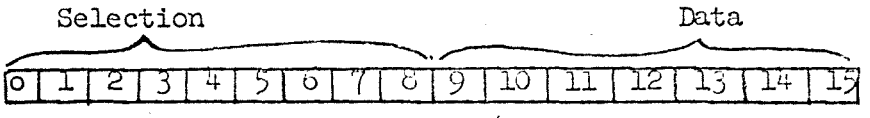
Mechanical. - The multiplexer/A-D converter will be mounted in the rear of the PBDM console and be interconnected with the other electronics motherboards. The multiplexer/A-D equipment will comply with commercial specifications.

D-A Converters. - There will be four 8-bit D-A converters. Inputs to the D-A will be parallel 8-bit binary words from T^2L flip-flops. Their analog output will range from 0 to +5 VDC with an overall accuracy of ± 1% of full scale. The output will be able to drive a load of 5K ohms. The D-A converters will be mounted in the rear of the PBDM console on the DMS motherboards.

3.3.1.14 Decoder and Encoder.

Decoder. - In order that the computer may select and transmit data to the various pieces of equipment comprising the Data Management Subsystem, an 8-bit portion of the 16-bit computer word will be used. The 8 high order bits will be used to select an item, and up to 8 low order bits will be used as data bits to the selected item, i.e., bits 8 to 15 of the computer word.

O DATA WORD



Following is a list of items that will be selected by bits 0 to 7 and data bits 9-15 associated with them:

	No. of Addresses Bits 0-7	Data Bits 8-15
O Analog Switch	5 (Approx.)	4
O Data Displays	53	5
O Decimal Points	5	3
O Multiplexer Control	6	6 (Approx.)
O D/A Converters	6	8
O Printer	1	6
O Behavioral Matrix	6	6
O Behavioral Lights	3	7
O Following Discretes		1

a. 30 lights (approx.)
b. 4 alarms
c. 10-vision tester (approx.)
d. 3 audiometer
e. 3-critical task tester
f. 2-mission timer

Encoder. - The following items will be encoded to one or more 16-bit computer words for entry to the computer:

	No. of Switches or Monitor Responses
O Vision Tester Responses	14 approx.
O Behavioral Panel Switches	15
O Behavioral Thumbwheel Data Switches	4 (with BCD Outputs)
O Numerical Data Entry Thumbwheel Switches (5 words will be required to enter all data)	17 (with BDC Outputs)
O Analog tape recorder run-stop switch	1
O Reset for Alarm on DHM Panel	1
O CRT Channel Identification Switch	1
O Processor Keyboard	1

3.3.1.15 Power Supplies. - Separate DC power supplies will be used to provide DC power to the Data Management Subsystem. All DC power returns will be connected to a common ground bus in the console, and will be connected to the console frame at one point. The power supplies will be "off the shelf" commercial units. All power input to the supplies and other commercial equipment will be 105-125V AC 60 Hz.

3.3.1.16 Calibration Equipment

Mechanical. - A calibration unit will be provided that can be easily transported to a subject for insertion of calibration signals into signal conditioners contained in the subjects' harness/rest. As with other commercial equipment, the unit will require an A.C. power outlet with 115 V.A.C. 60 Hz for its operation.

Signal Charateristics. - The calibration unit will provide the following output signal variations and characteristics:

- O Freq. Range: 001 Hz to 100KHz @ 0.1%
- O Amplitude Accuracy: $\pm$ 0.25%
- O Voltage Range: 100 μv - 5v
- O Output Wave Shape: Sine, Square and variable width pulse

4.0 DESCRIPTIVE DEFINITIONS AND BLOCK DIAGRAMS

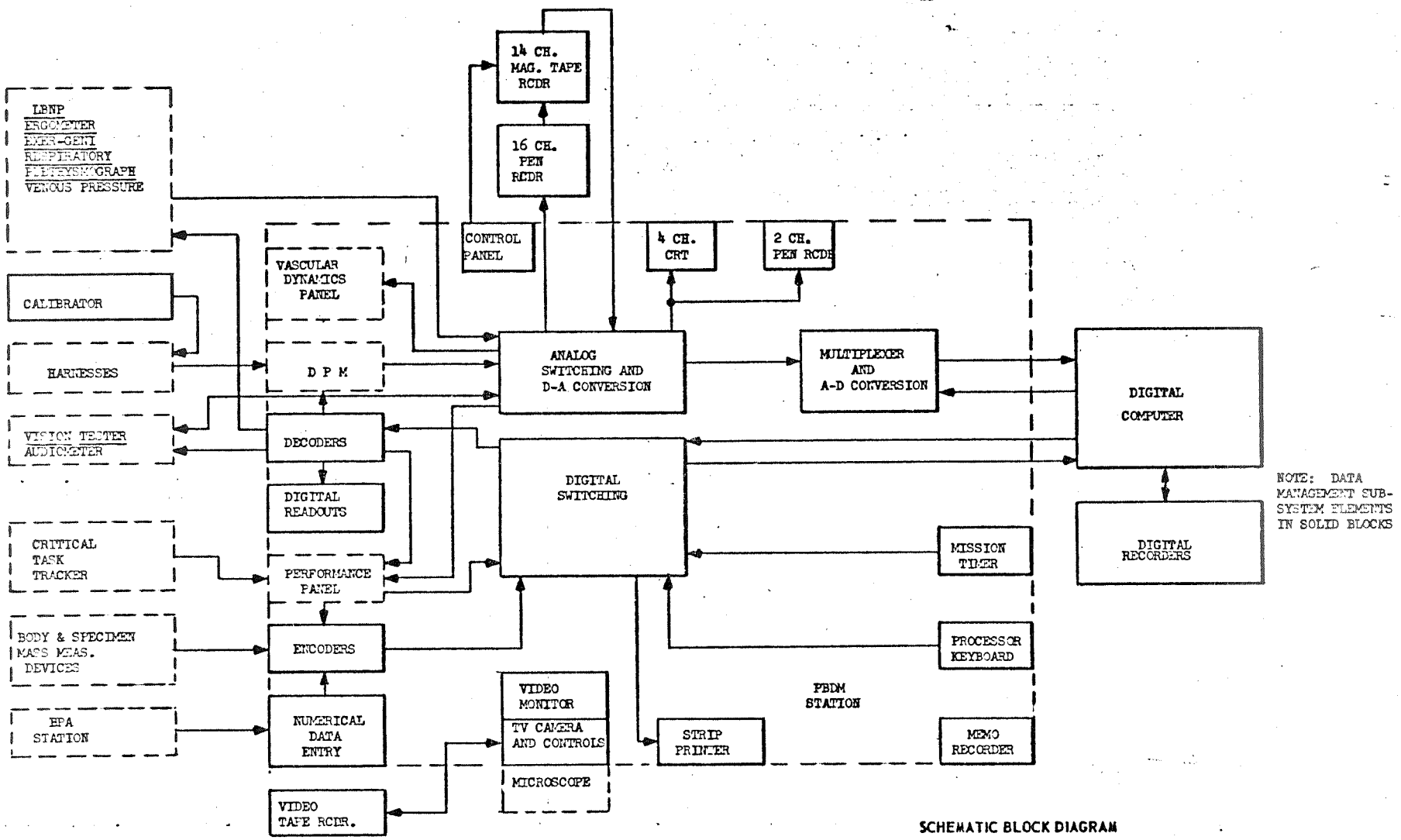
4.1 Conceptual Design

4.1.1 Design Objective.- The IMBLMS FBB Data Management Subsystem will be designed to fulfill several major design and performance goals. Among these goals are; ease of astronaut/physician operation through automatic signal handling and "on-board" processing; simulation of data handling to be performed with the flight IMBLMS; sizing of the computer and data storage required for the flight IMBLMS; display evaluation relative to flight use; and equipment capabilities that can be duplicated with, or designed into, space-qualified equipment.

4.1.2 Design Concept.- To meet the objective of automatic signal handling, the DMS will input analog data through a solid-state switching matrix which can be automatically, or manually, programmed to route the data to the various display and recording equipment required for the measurement in progress. Simultaneously, with accepting and rerouting analog signals, the DMS will be sampling the analog information and converting it into a digital format. Once in a digital form, a digital computer will obtain derived information which can be displayed and/or recorded, along with the digitally converted parameters that were used for the derivation. The digital computer will also serve to provide the required overall automatic features of the DMS. Analog data will be displayed on a variable persistence four channel oscilloscope and pen recorders which, although not conceived of being adaptable to flight use, will aid in evaluating overall FBB operation. Analog data will be recorded on a 14 track analog magnetic tape recorder, with two of its tracks exclusively dedicated to respectively, audio signals and time coded signals. The data converted into a digital format will be displayed on five digital readouts having sufficient alphabetical capability to precede measurement values with identifying abbreviations. A strip printer will be used to provide post-test "hard-copy" of measurement results. A video system, including camera, tape recorder, video monitor and remote control panel, will be used to preserve visual data from both a microscope and subject observation. To round out the system a memo-recorder will be provided to permit an operator to make verbal notes, particularly during a clinical evaluation or biochemical determination, and at a later point in time he can replay his notes for entry into the DMS via Numerical Data Entry switches. The following paragraphs present discussions of the various block diagrams that have been prepared to show the interrelationship between the elements of the DMS and its interface with measurement equipments.

4.1.3 Data Management Subsystem.- Figure 8 presents the various elements comprising the DMS, along with an indication of those elements that are physically located within the PBDM station, and those elements which are remote from the station. The digital computer, digital recorders, 14 channel analog magnetic tape recorder, and 16 channel pen recorders are non-deliverable Lockheed equipment which will be used to, operate the FBB, aid in sizing a computer for flight IMBLMS, and assist in overall measurement evaluation. An electrical interface will be provided for a NASA owned computer to function with the breadboard.

4.1.3.1 Analog Switching and D-A Conversion.- This portion of the DMS provides automatic routing of incoming analog data to a 4 channel oscilloscope (CRT), a 2 channel Pen Recorder, a 16 channel Pen Recorder, a Magnetic Tape Recorder, and a Multiplexer/A-D Converter. The switching is under automatic control of the computer, or manual (backup mode) control from the Processor Keyboard. Included in the switching is digital to analog conversion equipment which will permit the computer to provide



SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 8. DATA MANAGEMENT SUBSYSTEM (DMS)	
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO. III-J-33
SUPV		APPD		SIZE B SH OF	REV
SYS ENGR		SPO/GSETD	CEI/FD NO / CONTR NO.		

Form LMSC 26208

information to the various analog display and recording devices, in addition to driving discrete analog meters on various measurement panels, for the purpose of displaying derived data.

4.1.3.2 Digital Switching.- Digital switching is provided for computer-interface, acceptance of digital and/or discrete data from various measurement equipments, and outputing digital or discrete signals to measurement and display equipment.

4.1.3.3 Decoders.- Decoders are designed to accept digital information from the computer and decode the digital words into discrete outputs for operating relays, driving multilamp displays, etc.

4.1.3.4 Digital Readout.- Digital readouts are provided to display measurement results in a digital form, and digital word data when an operator choses to communicate with the computers program.

4.1.3.5 Encoders.- Encoders perform the function of converting external switch closures into computer words that will identify which switch was operated.

4.1.3.6 Numerical Data Entry.- This is a group of switches which facilitate an operators entering numerical data (clinical observations, biochemical derivations, etc.) into the DMS for recording, further analysis, or other operations.

4.1.3.7 Video Monitor, TV Camera and Controls, Video Tape Recorder.- This equipment is provided for handling and recording visual data, either obtained from a microscope or subject observation. A remote control panel in the PBDM will be provided to operate the VTR.

4.1.3.8 Strip Printer.- The strip printer is primarily used to provide post-test printed measurement results. It will function in conjunction with the computer to provide suitable formatting and alphabetical identification of printed data.

4.1.3.9 Memo Recorder.- This is a portable audio recorder which will permit up to 1 hour of verbal notes to be recorded and played back for later analysis.

4.1.3.10 Processor Keyboard.- This keyboard, in conjunction with appropriate keyboard and computer status displays, will permit an operator to communicate with the DMS. Measurement routines, calibration set-ups, program modification, signal rerouting, and other similar functions will be accomplished via this keyboard.

4.1.3.11 Mission Timer.- The mission timer will display, as required, mission or real-time. It will also provide clock signals to the overall system for the purposes of time tagging data, establishing multiplexer sampling rates via the computer, and overall system synchronization.

4.1.3.12 Multiplexer and A-D Converter.- This equipment will sample, under computer control, the incoming analog signals and convert these signals into a digital format for computer processing.

4.1.3.13 Two Channel Pen Recorder.- A two channel pen recorder will be slaved to channels 3 and 4 of the CRT to provide a permanent record of analog waveforms being displayed thereon.

4.1.3.14 Four Channel CRT.- A four channel variable persistence oscilloscope is designated to provide a capability for displaying up to four channels of analog waveforms to an operator. Switching in the analog switching block, under computer/manual control, will permit an operator to override an initial program controlled set-up and display any data being accepted by the first twelve channels of the 16 channel pen recorder. In order to provide a 1 for 1 display of data being observed on the CRT, the last four pen recorders will be, respectively, slaved to the four CRT channels.

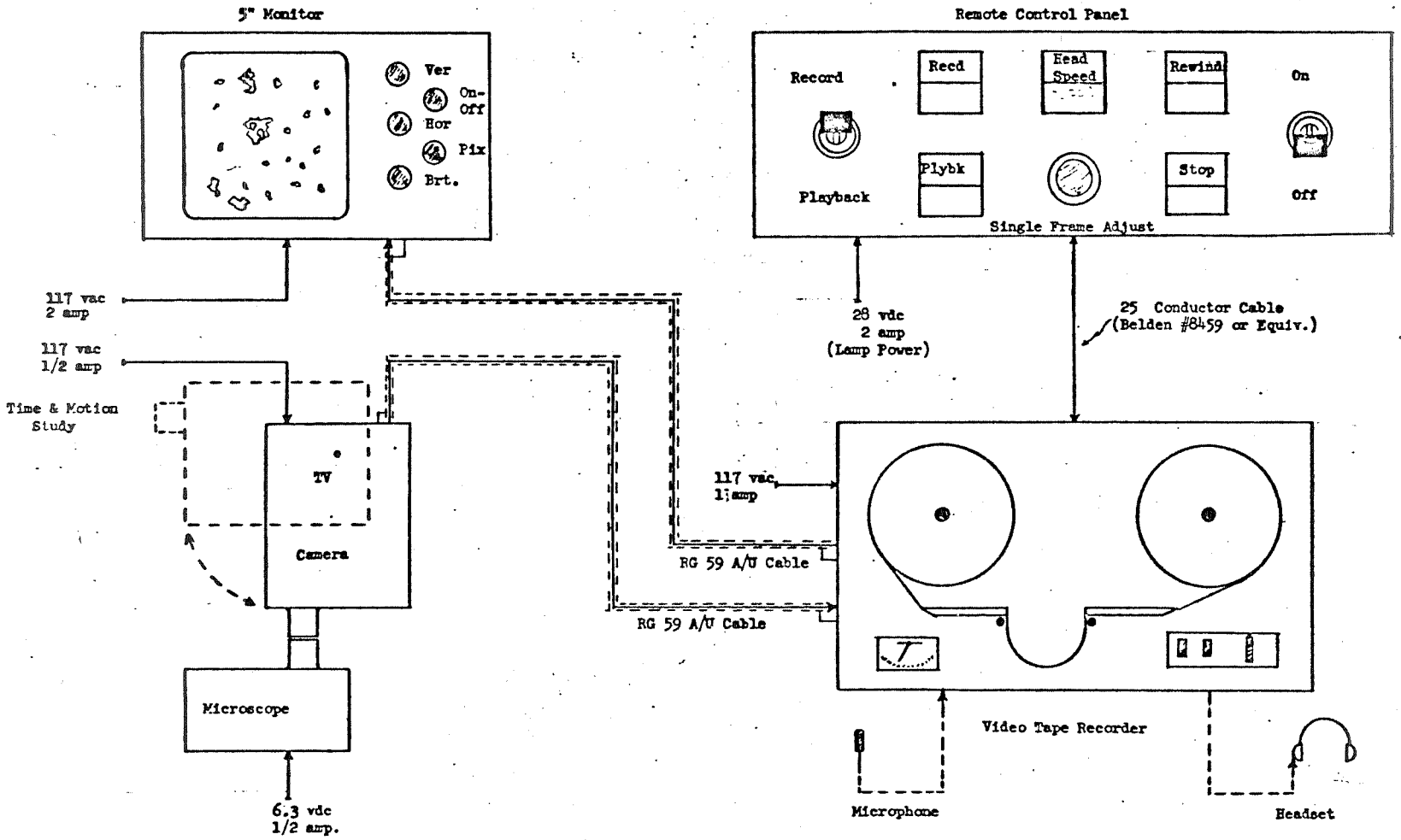
4.1.3.15 Sixteen Channel Pen Recorder, 14 Channel Magnetic Tape Recorder and Control Panel.- This equipment provides permanent records of incoming analog data which can be useful in measurement evaluation both in real-time and on a playback basis. A remote control panel will be provided to operate the magnetic tape recorder from the PBDM console.

4.1.4 DMS Digital Interfaces.- Figure 9 presents a more detailed approach towards the design of the digital portion of the DMS. Various registers are provided which, under a data/computer priority system will transfer incoming data to an output bus that communicates directly with the computer. A NASA computer interface is designated, that essentially parallels Lockheeds computer interface, however, because of differences in computer signal and control structures, will necessitate discrete electronics for its hook-up.

Output storage registers are used to enable computer operation and identification of various display, switching and other functions.

4.1.5 DMS Analog Switching and Interfaces.- Figure 10 presents, in additional detail, the various types of differential and discrete switches, digital to analog converter interfaces and amplifiers that comprise the analog switching and D-A conversion capability. Each of the measurement display requirements designated in Appendix A has been assigned a specific analog input switch location. The currently envisioned 6 pos/channel switches will provide for an input expansion of approximately 10 percent without disturbing or substituting the initial assignments. Panel meters requiring data derivation by the computer prior to readout are shown to interface with the computer via digital-to-analog converters and discrete solid-state switches. The 15 channel differential switches preceeding each of the 4 oscilloscope input channels provide the oscilloscope with the capability of viewing any of the data being routed to the 12 channels of the 16 channel pen recorder, or the outputs of the D-A's, or timing data during magnetic tape playback plus future expansion to other inputs. Since the magnetic tape recorder has 0-1 volt low impedence single-ended input/output characteristics, the pen recorders' post amplifiers are used to attenuate the normal 0-5 volt input signals (with a high impedance input) and separate 1:5 amplifiers are used to elevate the recorders output during playback. Other amplifiers shown in the diagram are primarily used to isolate the output device from the signal lines feeding that device.

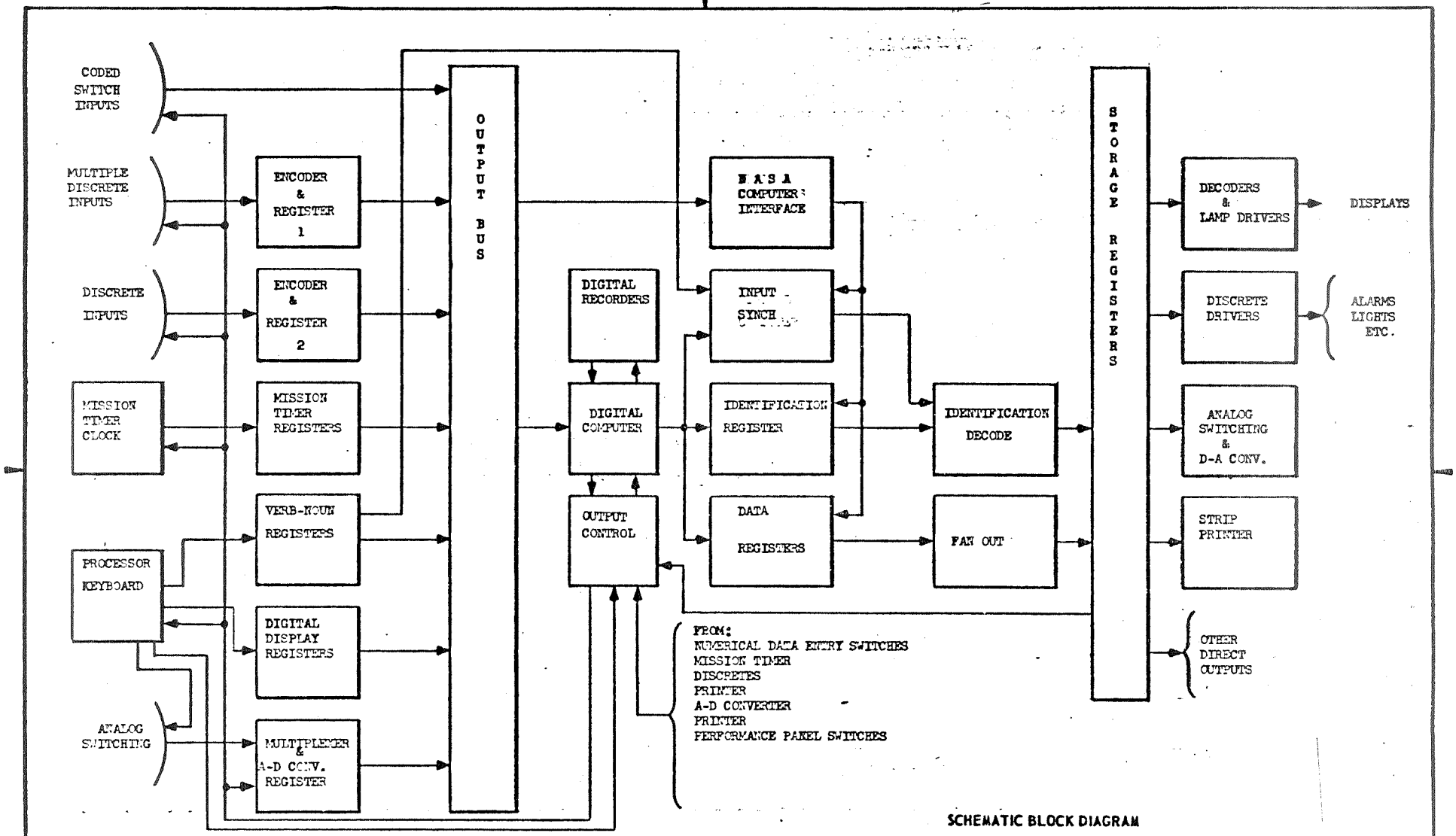
4.1.6 TV System.- Figure 11 is a detailed presentation of the entire TV system, including the microscope which is being used to view slide data. The diagram shows a video recorder remote control panel which will be mounted in the PBDM station. The video recorder (with some of its features shown in detail), because of its physical size, will be remotely located from the station, thus necessitating the remote control panel. A five inch video monitor will also be mounted in the PBDM station to aid in establishing the quality of camera viewed data prior to recording; and, viewing data during playback (a function normally provided by ground equipment in the flight IMBLMS concept but provided in the FBB for complete system operation).



SCHEMATIC BLOCK DIAGRAM

ORIGR DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIG.11 VIDEO SYSTEM COMMAND AND SIGNAL TRANSFER DIAGRAM	
CHK	APPD		CODE IDENT NO. [illegible]	DOCUMENT NO. III-J-38 REV
SUPV	APPD			
SYS ENGR	SPO/GSETD	CEI/FD NO / CONTR NO.	SIZE B SH OF	

Form LMSC 26708

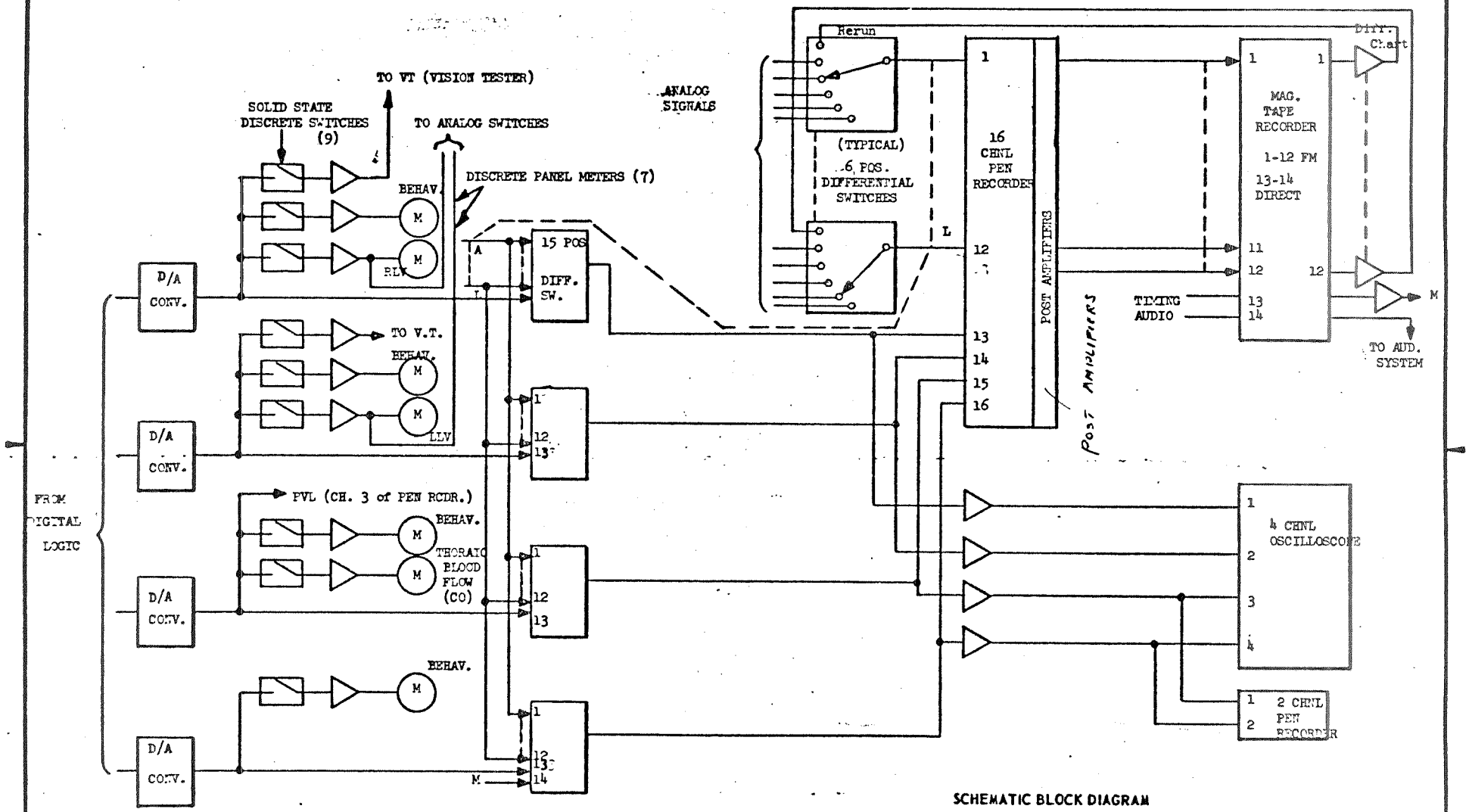


SCHEMATIC BLOCK DIAGRAM

ORIGR	DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 9. DMS DIGITAL INTERFACES		
CHK		APPD		CODE IDENT NO. 17077	DOCUMENT NO.	REV
SUPV		APPD		SIZE B	SH / OF	III-J-36
SYS ENGR		SPO/GSETD	CEI/FD NO	CONTR NO.		

Form LMSC 26708

17077



SCHEMATIC BLOCK DIAGRAM

ORIGR DATE	APPD	LOCKHEED MISSILES & SPACE COMPANY A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	TITLE FIGURE 10. DMI ANALOG SWITCHING & INTERFACES		
CHK	APPD		CODE IDENT NO. 17077	DOCUMENT NO.	REV
SUPV	APPD		SIZE B	SH OF	III-J-37
SYS ENGR	SPO/GSETD	CEI/FD NO / CONTR NO.			

Form LMSC 26208

Section III-J

Appendix

MEASUREMENT DISPLAY REQUIREMENTS

This appendix contains the display and recording requirements for the IMBLMS FBB data handling system, plus the appropriate abbreviations for these measurements. The indicated channel assignments are not fixed, and necessary adjustments will be made between, or from, experiment to experiment, to best implement these requirements.

Measurement	Page No.
Abbreviations	i
Cardiovascular	III-J-2A
EVA Monitoring	III-J-3A
Neurological	III-J-4A
Pulse Wave Contour	III-J-5A
Vector Cardiogram	III-J-6A
Clinical 12-Lead ECG	III-J-7A
Average Skin Temperature or Body Temperature	III-J-8A
Impedance Cardiogram	III-J-9A
Venous Press (Indirect & Direct)	III-J-10A
Exercise O_2 Consumption	III-J-11A
LBNP Procedures	III-J-12A
Standard Lung Volumes & Flows	III-J-13A
Maximum Breathing Capacity	III-J-14A
Minute Alveolar Volume	III-J-15A
Residual Volume	III-J-16A
Respiratory Dead Space	III-J-17A
Cardiac Output	III-J-18A
Diffusion Capacity	III-J-19A
Airway Resistance	III-J-20A
Lung Compliance	III-J-21A
Muscle Strength	III-J-22A
Body Mass	III-J-22A

ABBREVIATIONS

ACO_2 - Alveolar CO_2 Concentration
aCO_2 - Arterial Carbon Dioxide
AO_2 - Alveolar O_2 Concentration (%)
AP - Airway Pressure
AR - Airway Resistance
AST - Average Skin Temperature
AVP - Average Venous Pressure
AT - Air (Gas) Temperature
BT - Body Temperature (Ear)
CO - Cardiac Output
1CO - Initial Carbon Monoxide Concentration
2CO - Final Carbon Monoxide Concentration
CO_2 - Carbon Dioxide Concentration (%)
$CO_2 \uparrow$ - Carbon Dioxide Production
CP - Calibration Profile
CPP - Cuff Press. Profile
DC - Diffusion Capacity
DP - Diastolic Pressure
DS - Dead Space
ECG - Electrocardiogram
EEG_1 - Electroencephalogram Lead 1
EEG_2 - Electroencephalogram Lead 2
EMG - Electromyogram
EOG_H - Electro-oculogram (Horizontal)
EOG_V - Electro-oculogram (Vertical)
ERV - Expiratory Reserve Capacity
F - Flow
FRC - Functional Residual Capacity
FP - Force Profile
1HE - Initial Helium Concentration
2HE - Final Helium Concentration
HR - Heart Rate
IC - Inspiratory Capacity
LBNP - Lower Body Negative Pressure
LC - Lung Compliance
LEAD - I, II, III, AVR, AVL, AVF, V_1-V_6 (Standard ECG Leads)
LLV - Left Leg Volume
M - Body Mass
MAV - Minute Alveolar Volume
MBC - Maximum Breathing Capacity
MEF - Maximum Expiratory Flow
MHR - Mean Heart Rate
MIF - Maximum Inspiratory Flow
MTV - Minute Tidal Volume
N_2 - Nitrogen Concentration (%)
NW - Nitrogen Washout
ΔN_2 - Change in Nitorgen Concentration (%)
O_2 - Oxygen Concentration (%)
$O_2 \downarrow$ - Oxygen Consumption
OT - Oscillatory Time
PCG - Phonocardiogram
PF - Peak Force
PLP - Plethysmography Profile
PP - Pulse Pressure
PRS - Pressure/Korotkoff Sounds
PVL - Pressure Volume Loop
PWC - Pulse Wave Contour
RLP - Right Leg Pulse
RLV - Right Leg Volume
RR - Respiratory Rate
SCO_2 - Suit Carbondioxide Concentration
SP - Systolic Pressure
ST - Systole Time
SUF - Suit Flow
SUP - Suit Pressure
TLC - Total Lung Capacity
TP - Transducer Profile
TT - Transit Time
TV - Tidal Volume

V	- Volume
VC	- Vital Capacity
VC_1	- Timed Vital Capacity (1 sec.)
VC_3	- Timed Vital Capacity (3 sec.)
VCO_2	- Venous Carbon Dioxide
$V_x V_y V_z$	- Vectorcardiogram
ΔZ	- Extrapolated Maximum Impedence Change
$\dot{Z}$	- Maximum Negative Peak of 1st Derivative of ΔZ
Z_o	- Basic Impedance
ZPN	- Impedance Respiratory Waveform

MEASUREMENT DISPLAY REQUIREMENTS

CARDIOVASCULAR	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA	OK Active/Passive	P
MONITORING HARNESS						HR	( )			MEAN HR	q30"/q15'	
	1	( )	( )			RR	( )	( )		MEAN RR	q30"/q15'	
	2	PCG	( )			BT		PCG		MEAN T	q30"/q15'	
	3	ZPN		ZPN		( )		ZPN				
	4	ECG		EGG		( )		ECG				
	5				HR			HR				
	6				RR			RR				
	7				BT			BT				
a) WITH BLOOD PRESS.												
						HR	PP			MEAN HR	q30"/q15'	
	1	PRS	( )			RR	( )	PRS		MEAN RR	q30"/q15'	
	2	PCG	( )			BT	( )	PCG	*	MEAN PP	q30"/q15'	
	3	ZPN		ZPN		SP		ZPN	*	MEAN SP	q30"/q15'	
	4	ECG		ECG		DP		ECG	*	MEAN DP	q30"/q15'	
	5				HR			HR	*	MEAN BT	q30"/q15'	
	6				RR			RR		MEAN ST	q30"/q15'	
	7				BT			BT	*	MEAN BT, SP, DP, PP		
	8				SP			SP		instead of instantaneous value required only for q15'.		
	9				DP			DP				

MEASUREMENT DISPLAY REQUIREMENTS

EVA MONITORING	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA	
						HR	SUF			MEAN HR	q30"
	1	( )				RR	( )	( )		MEAN RR	q30"
	2	PCG				BT	( )	PCG		BT	q30"
	3	ZPN		ZPN		SUP		ZPN		MEAN SUP	q30"
	4	ECG		ECG		SCO_2		ECG		MEAN SCO_2	q30"
	5				HR			HR		MEAN SUF	q30"
	6				RR			RR		MEAN ST	q30"
	7				BT			BT			
	8				SUP			SUP			
	9				SUF			SUF			
	10				SCO_2			SCO_2			
	11										
	12	( )						( )			
										PCG ΔT	

MEASUREMENT DISPLAY REQUIREMENTS

NEUROLOGICAL HARNESS	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA	
	1	EMG						EMG		NONE	
	2	EOG_H						EOG_H			
	3	EEG_1	(PRS)	EEG_1				EOG_V			
	4	EEG_2	(PCG)	EEG_2				EEG_1			
	5	(EOG_V)						EEG_2			
	6	(ECG)				HR		ECG		Monitoring harness	
	7	(ZPN)				RR		ZPN		derived data	
When combined	8				HR	BT		HR			
with monitoring harness	9				RR	SP		RR			
	10				BT	DP		BT			
	11				SP	( )		SP			
	12				DP	( )		DP			

PRS and PCG only recorded if shown on CRT

MEASUREMENT DISPLAY REQUIREMENTS

PULSE WAVE	CONTOUR	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
With Monitoring Harness (No BP)													
		1	ZPN	( )			HR	( )	ZPN		MEAN TT	q30"	
		2	PCG	( )			RR	( )	PCG		MEAN HR	q30"	
		3	PWC		PWC		BT		PWC		MEAN RR	q30"	
		4	ECG		ECG		TT		ECG		MEAN ST	q30"	
		5				HR	ST		HR		BT	q30"	
		6				RR			RR				
		7				BT			BT				
		8				( )							
		9				( )							
		10					TT		TT				

MEASUREMENT DISPLAY REQUIREMENTS

VECTOR CARDIOGRAM	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA	
						HR					
	1		(PCG)			RR		PCG		MEAN HR	q30"
	2		(Vx)			ST		Vx		MEAN RR	q30"
	3	VxVyVz* or	(Vy)	Vy		( )		Vy		MEAN ST	q30"
	4		(Vz)	Vz		( )		Vz			
	5		(ZPN)					ZPN			
	6		( )		HR			HR			
	7				RR			RR			

* z AXIS MODULATION, PCG CAN NOT BE DISPLAYED WITH Vx, Vy, Vz

MEASUREMENT DISPLAY REQUIREMENTS

CLINICAL 12-LEAD ECG		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
	*												
							HR						
		1	( )				(MHR)				Mean HR	(For 12 Leads)	
		2	( )				( )						
		3	( )										
		4	ECG		ECG				ECG	Leads I, II, III, AVR, AVL, AVF, V1-V6			
		5				HR			HR				

Note: * SEQUENTIALLY SINGLE LEAD ECG'S ARE DETERMINED BY THE SELECTOR SWITCH ON THE DPM ARE RUN IN THE FOLLOWING MANNER: LEAD I, II, III, AVR, AVL, AVF, V1, V2, V3, V4, V5, V6 (THE V-LEAD IS A SINGLE SELECTOR POSITION WITH THE CHEST SENSOR PLACED SEQUENTIALLY IN SIX POSITIONS ON THE CHEST)

MEASUREMENT DISPLAY REQUIREMENTS

		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
AVERAGE SKIN TEMPERATURE OR BODY TEMP.	*						AST				AST	q30"	
		1											
		2											
		3											
		4											
		5				T							

* MAY SUBSTITUTE THIS MEASUREMENT FOR BODY TEMP USING SELECTOR SWITCH ON DPM.

MEASUREMENT DISPLAY REQUIREMENTS

		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
IMPEDANCE CARDIOGRAM													
						CO	ST				MEAN Zo	ql'	
		1	( )				Zo				ΔZ	ql'	
		2	( )				ΔZ				$\dot{Z}$	ql'	
		3	PCG		PCG		$\dot{Z}$				CO	ql'	
		4	ZCG		ZCG		CO				HR		
							HR						
	Note:	ZCG =	ΔZ										

MEASUREMENT DISPLAY REQUIREMENTS

		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
VENOUS PRESS													
INDIRECT													
												Venous Pressure will	
		1	( )									be a manual interpre-	
		2	( )				AVP				AVP	tation of tracing	
		3	CPP		CPP				CPP			records, entered	
		4	PLP		PLP				PLP			through numerical	
												data keyboard, plus	
												an automatic averagin	
												analysis.	
DIRECT METHOD													
		1									NONE	Same as above	
		2											
		3	TP		TP				TP				
		4	CP		CP				CP				

MEASUREMENT DISPLAY REQUIREMENTS

EXERCISE O_2 CONSUMPTION		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
		1	O_2 %	( )			HR	(O_2)	O_2		MEAN HR, ST, BT	RR, q30" q30"	SP, DP,
		2	CO_2 %	( )			RR *	(CO_2)	CO_2				
		3	PCG		PCG		$O_2 \downarrow$	(V)	PCG		MEAN O_2,	CO_2	ql'
		4	ECG		ECG		$CO_2 \uparrow$	(SP)	ECG		$O_2 \downarrow$	ql'	
		5	(PRS)				RQ	(DP)	PRS		$CO_2 \uparrow$	ql'	
		6	(V)					( )	V		RQ	ql'	
		7				HR		( )	HR		V	ql'	
		8				RR			RR		MEAN AT	ql'	
		9				BT			BT		MEAN WORK LOAD		ql'
		10				SP			SP		MEAN RPM (ergometer)		ql'
		11				DP			DP				
		12				AT			AT				
	*	Derived from flow meter or CO_2 analyzer											

MEASUREMENT DISPLAY REQUIREMENTS

LBNP PROCEDURE		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
							HR	SP					
							RR	DP					
		1	RLP				PP	BT	RLP		All data for monitoring harness		
		2	LLP				RLV	ST	LLP		MEAN LBNP ql'		
		3	ZPN		ZPN		LLV	LBNP	ZPN		RLV	ql'	
		4	ECG		ECG	SP			ECG		LLV	ql'	
		5		(PCG)		DP		( )	PCG				
		6		(PRS)		BT			PRS				
		7				HR			HR				
		8				RR			RR				
		9				LBNP			LBNP				
		10				RLV			RLV				
		11				LLV			LLV				
		12		( )					( )				

MEASUREMENT DISPLAY REQUIREMENTS

STANDARD LUNG VOLUMES AND FLOWS	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA	
						TV	(VC_1)			MTV	
	1	( )				ERV	(VC_3)			ERV	
	2	( )				MIF	(IC)			IC	
	3	F		F	F	MEF	( )	F		VC	
	4	V		V	V	VC	( )	V		VC_1	
	5				AT			AT		VC_3	MEAN OF THREE GOOD RUNS *
	6									MEF	
	7									MIF	

* After observing complete run on the scope, operator will indicate if this run is to be used for mean averaging purposes or discarded and repeated.

MEASUREMENT DISPLAY REQUIREMENTS

MAXIMUM CAPACITY	BREATHING	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
		1	( )				Time	←	(0 to 60" in 1" increments)				
		2	( )				RR* ql"						
		3	F		F	F	V ql"		F		MBC		
		4	V		V	V	MBC ql5"		V		MEAN RR		
						AT	( )		AT				

* RR for Flow Trace

MEASUREMENT DISPLAY REQUIREMENTS

MINUTE VOLUME	ALVEOLAR	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
							RR						
Alveolar	O_2	1	F			F	AO_2		F		MEAN AO_2	ql	
Alveolar	CO_2	2	V			V	ACO_2		V		MEAN ACO_2	ql'	
		3	O_2		O_2	O_2	MAV		O_2		MAV		
		4	CO_2		CO_2	CO_2			CO_2		MEAN AT	ql'	
		5				AT			AT		MEAN RR	ql'	
		6											
		7											
		8											
		9											
		10											
		11											
		12											

MEASUREMENT DISPLAY REQUIREMENTS

RESIDUAL		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
VOLUME													
Functional Residual Capacity							RV				RV		
Total Lung Capacity		1	( )				FRC				FRC		
Nitrogen Washout		2	V			V	TLC		V		TLC		
		3	VN_2		VN_2	AT	VC		VN_2		VC		
		4	N_2		N_2				N_2		NW (after 7')		
		5							AT				
		6											

MEASUREMENT DISPLAY REQUIREMENTS

RESPIRATORY	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
DEAD SPACE												
Alveolar Distribution						V	( )			DS		
	1	( )				N_2	( )			ΔN_2		
	2	( )				DS						
	3	V		V	V	ΔN_2		V				
	4	N_2		N_2	N_2			N_2				
	5				AT			AT				
	6											

MEASUREMENT DISPLAY REQUIREMENTS

CARDIAC OUTPUT		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
Rebreathing Techniques													
							VCO_2				VCO_2		
		1	( )				aCO_2				aCO_2		
		2	( )				CO				CO		
		3	$\%CO_2$		$\%CO_2$				$\%CO_2$				
		4	V		V	V			V				
		5				AT			AT				
		6											

MEASUREMENT DISPLAY REQUIREMENTS

DIMENSION	CAPACITY	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
							1HE				DC		
		1					2HE						
		2					1CO						
		3	F		F	F	2CO		F				
		4	V		V	V	DC		V				

MEASUREMENT DISPLAY REQUIREMENTS

AIRWAY RESISTANCE		ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
							AR				AR		
		1	( )										
		2	( )										
		3	AP		AP				AP				
		4	F		F	F			F				

MEASUREMENT DISPLAY REQUIREMENTS

LUNG COMPLIANCE	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA		
	1	( )				LC				LC		
	2	( )										
	3	( )										
	4	PVL		PVL				PVL		PVL		

MEASUREMENT DISPLAY REQUIREMENTS

FIELD STRENGTH	ANALOG TAPE CHANNEL	CRT	CRT OPTIONS	2-PEN RECORDER	ANALOG METERS	DIGITAL DISPLAYS	DIGITAL OPTIONS	12-PEN RECORDER		DERIVED DATA	
						PF					
										PF	Peak reading detector output & hold for 10"
	1										
	2										
	3										
	4	FP		FP				FP			
ODY MASS											
						OT				OT	
						M				M	
	1										
	2										
	3										
	4										