SUMMARY OF EQUIPMENT AND DATA MANAGEMENT REQUIREMENTS
FOR EXPERIMENT P-12

I. Purpose

The purpose of this report is to provide, (1) specific information concerning the equipment required to execute Experiment P-12 and, (2) a plan for properly storing and relaying experimental data collected in-flight.

II. Description of Experiment

The Biomedical and Physiological Evaluation Experiment (P-12) is presented in detail in a book prepared by the Aerospace Medical Division. A summary, also prepared by AMD, clearly defines experimental objectives and procedures. This document cross-references various tests and indicates the frequency and duration of data collection.

It is important to note that the Biomedical and Physiological Experiment actually consists of seven interrelated "sub-experiments". The sub-experiments represent the following body systems and functions:

A. Cardiovascular

B. Central Nervous-Neuromuscular

C. Gastroenteric-Nutritional

D. Metabolic

E. Renal, Fluid and Electrolyte

F. Respiratory

G. System Deconditioning

III. Measurements

A. General

The sub-experiments, or tests, listed above rely on a series of measurements for the collection of data. Obviously, some measurements can serve the needs of several sub-experiments. Others can utilize the same equipment.

Overlapping experimental requirements and multi-usage of equipment make accurate identification of essential test instrumentation difficult. This problem has been reduced to some extent by consolidating measurement demands into a single, comprehensive list that can be used as a reference for equipment requirements. The following is such a list. It includes major items of equipment.

B. Specific measurements and associated equipment

1. Heart rate (continuous)

a. Electrodes, amplifier, voltage controlled oscillator, FM transmitter and battery

b. FM receiver with built-in discriminator

2. Electrocardiogram

a. Electrodes and preamplifiers

3. Blood Pressure

a. Pressure cuff

b. Microphone

c. Amplifier with filter

d. Pressure transducer

e. Pressure gage

f. Control Unit

g. Cuff inflator and linear leak device

4. Cardiac Output

   a. Earpiece densitometer

   b. Control unit

5. Blood oxygen content

   a. Earpiece with light source and photocells

   b. Control unit

6. Venous pressure

   a. Pressure transducer

   b. Control unit

7. Electrooculogram

   a. Electrodes and preamplifier

8. Egocentric visual localization of the Horizon

   a. Special glasses

9. Muscle Tone

   a. Spring gauge

10. Muscle Strength and Grip

   a. Hand grip dynamometer

11. Electroencephalogram (During Sleep)

   a. Electrodes, amplifier and voltage controlled oscillator

12. Body Mass

   a. Pendulum device

   b. Transducer

13. Urine Volume

   a. Urine collector and aliquot

14. Samples of Plasma, Urine and Feces for post-flight analysis

   a. Lyophilizer

b. Packaging equipment

15. Serum Calcium, Glucose, Sodium, Potassium, pH, Creatinine, Hematocrit, and Blood Volume (T-1824 Dye)

a. Centrifuge

b. Chemical analyzer

16. Total Body Water

a. Deuterium

b. Mass spectrometer

17. Body Volume (using air lock)

a. Pressure transducer

b. Control unit

c. Gas supply

d. Thermistor thermometer

18. Urine Total Solids, pH, Protein and Glucose

a. Paper strips

b. Optical Refractometer

19. Sweat Analysis

a. Absorbent pack for post-flight analysis

20. Body Temperature

a. Oral thermometer

21. Timed Vital Capacity, Vital Capacity, Tidal Volume, Flow, Respiratory Rate and Maximum Breathing Capacity

a. Waterless spirometer

b. Amplifier and control unit

22. Alveolar pCO_2 and pO_2

a. Pump

b. Valves

c. CO_2 analyzer

d. O_2 electrode and amplifier

23. Oxygen Consumption and CO_2 Production

a. Dry test meter

b. CO_2 analyzer (same as #22)

c. Pump (same as #22)

d. Spirometer (same as #22)

24. Exercise Output

a. Ergometer (wattmeter)

25. Ear Pulse and Pressure

a. Pressure transducer (same as #6)

b. Earpiece capsule inflater, manual

c. Earpiece (same as #4 and #5)

d. Control unit

26. Airway Pressure

a. Pressure Transducer (same as #6)

b. Control unit

27. Anti G Suit Pressure

a. Pressure transducer (same as #6)

b. Control unit

IV. Equipment Characteristics

A. General

The measuring instruments and associated equipment listed in paragraph III. are described in detail in this section. The identification system employed in paragraph III. has been preserved for clarity.

It should be noted that the volume, weight and power figures presented below and in subsequent tables do not include mounting hardware, protective covers, connecting cables, data displays or other similar ancillary items. These units can not be clearly defined at this time. Ample provision should be made for such hardware since it can easily equal or exceed the volume, weight and/ or power of the device it is associated with.

B. Equipment

1. Heart Rate (continuous)

a. Personal telemetry unit

(1) Description: Each man will wear a small device containing a miniature high gain amplifier, a voltage controlled oscillator, a VHF transmitter, and a battery. Potentials of about a millivolt produced by the heart are picked up by electrodes attached to the chest. These signals are amplified by an amplifier having a relatively narrow pass band centered around 33 cps. This frequency characteristic permits selective amplification of the QRS component of the electrocardiogram and partial rejection of slow changes in electrode polarization potential, high frequency muscle action potentials, and stray alternating electric fields. The amplified heart potentials are fed to a tiny voltage controlled oscillator having a center frequency of 1,700 cps and a deviation limit of ± 40%. The

resulting signal frequency modulates an oscillator-radiator operating in the vicinity of 100-200 mc. The personal telemetry unit includes a battery power source.

(2) Sketch: SAM drawing #1.

(3) Volume: approximately 3.5 cubic inches including battery.

(4) Weight: approximately 3 ounces including battery.

(5) Power: single, easily replaceable mercury battery with a useful life-time of at least 48 hours under conditions of continuous operation.

(6) Heat output: negligible.

(7) Environmental limits: essentially the same as other flight rated electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: transmitter radiates a weak signal of known frequency. Transmission range is approximately 50 feet, signal radiation being achieved by a combination of inductive coupling and re-radiation from the subject's body. No transmitting devices should operate on or near the frequency used for the heart rate telemetry system.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: four additional units.

b. FM/FM Receiver unit.

(1) Description: A receiver generally similar to commercially available portable FM receivers will be used to pick up the signal from the personal telemetry unit. A separate frequency, and receiver, will be used for each man. The receiver frequency will be pre-set to match the transmitter.

Each receiver will be fed by an omni-directional antenna system designed to provide proper signal level regardless of the man's location. The receiving units will be equipped with automatic frequency control and a ± 40% discriminator. The discriminator output may be filtered and shaped before going to the telemetry transmitter and the on-board tape recorder.

(2) Sketch: GAC drawing #1.

(3) Volume: approximately 0.01 cubic feet per receiver.

(4) Weight: approximately 0.5 pounds per receiver.

(5) Power: continuous, 0.8 watts per receiver.

(6) Heat Output: 65.5 Btu per 24 hours per receiver.

(7) Environmental Limits: essentially the same as other flight rated electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: (see item a. 11)

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: plug-in printed circuit boards or modules.

2. Electrocardiogram

a. Electrodes and preamplifiers.

(1) Description: The electrical potentials of the heart will be picked up by a series of electrodes in contact with the body. These electrodes will be located and inter-connected in such a way that potentials may be measured simultaneously in three mutually perpendicular planes. The signals from the electrodes will be fed to three separate

preamplifiers mounted on the subject's vest. The preamplifiers will provide an impedance transformation and will raise the signal level by a factor of about one hundred to minimize pickup in the lines running from the subject to the recording equipment. The frequency response of the preamplifiers will extend from a fraction of a cycle per second to about 100 cps in conformance with AMA specifications for electrocardiographic equipment.

(2) Sketch: SAM drawing #2 (does not show preamplifiers).

(3) Volume: (preamplifiers) less than one cubic inch each.

(4) Weight: (preamplifiers) less than one ounce each.

(5) Power: approximately 10 milliwatts per channel during each test.

(6) Heat Output: negligible.

(7) Environmental limits: essentially the same as other flight rated electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: a one millivolt source that can be used to calibrate recordings. (Signal would be introduced across electrodes or by switching preamplifier inputs.) Calibrator would consist of a small battery and voltage divider. It will be less than four cubic inches in volume and weigh approximately two ounces.

(11) Spares for in-orbit maintenance: six additional preamplifiers.

3. Blood pressure

a. Pressure cuff

(1) Description: a more or less conventional blood pressure

cuff will be used for arterial occlusion.

(2) Sketch: SAM drawing #2.

(3) Volume: approximately 40 cubic inches.

(4) Weight: approximately 0.5 pounds.

(5) Power: none.

(6) Heat Output: none.

(7) Environmental limits: thermal limits approximately same as electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: none .

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: two.

b. Microphone

(1) Description: A small, specially designed microphone will be used for picking up the Korotkoff sound. This sound, which is produced by disturbances in blood flow, is of very low intensity. The microphone utilized must make proper contact with the skin, be positioned correctly, and have a unique spectral response.

(2) Sketch: SAM drawing #2.

(3) Volume: less than one cubic inch.

(4) Weight: less than one ounce.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: The microphone should be protected from mechanical shock and temperatures higher than 120° F.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: two.

c. Amplifier with filter

(1) Description: A small, low gain amplifier serves as an impedance matching device and a means of removing noise. The amplifier frequency response will be shaped with filters to match the spectral peculiarities of the Korotkoff sound and the microphone pickup.

(2) Sketch: none.

(3) Volume: approximately eight cubic inches.

(4) Weight: approximately four ounces:

(5) Power: approximately 50 milliwatts, intermittent.

(6) Heat output: negligible.

(7) Environmental limits: essentially the same as other flight rated electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: none

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: two.

d. Pressure transducer

(1) Description: The pressure in the blood pressure cuff will be converted into an electrical signal by a pressure transducer. The signal from the latter will be recorded on magnetic tape along with the Korotkoff sound. The pressure transducer may be of the strain gage, potentiometer or differential transformer type.

(2) Sketch: none.

(3) Volume: approximately 12 cubic inches.

(4) Weight: approximately 8 ounces.

(5) Power: See f. (5) below

(6) Heat output: negligible.

(7) Environmental limits: missile qualified hardware.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: pressure gage.

(11) Spares for in-orbit maintenance: two.

e. Pressure gage

(1) Description: Cuff pressure will be displayed on a conventional gage so that the astronaut can be sure that the cuff is inflated to the proper pressure. The pressure gage will also be used to verify the calibration of the pressure transducer.

(2) Sketch: none.

(3) Volume: approximately 14 cubic inches.

(4) Weight: approximately 7 ounces.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: should be protected from shock.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: two.

f. Control unit

(1) Description: The span and zero reading of the pressure transducer will be controlled by a unit containing controls and a regulated power source.

(2) Sketch: none.

(3) Volume: approximately 16 cubic inches.

(4) Weight: approximately 6 ounces.

(5) Power: approximately 50 milliwatts.

(6) Heat output: negligible.

(7) Environmental limits: same as other flight qualified electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: pressure gage (item 3 e.)

(11) Spares for in-orbit maintenance: one.

g. Cuff inflator and linear leak device

(1) Description: The blood pressure cuff will be inflated with a conventional squeeze bulb. Inflation will continue until a prescribed pressure, roughly 200 mm Hg, is reached. A mechanical valve

will then reduce the pressure in the cuff in a more or less linear fashion. The rate of pressure change will be slow enough to assure accurate blood pressure readings.

(The information below pertains only to the linear leak device.)

(2) Sketch: none.

(3) Volume: approximately 20 cubic inches.

(4) Weight: approximately one pound.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: should be protected from mechanical shock.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: one.

4. Cardiac output

a. Earpiece densitometer

(1) Description: Cardiac output will be determined by measuring the optical density of an indicator dye injected into the blood stream. The densitometer will be worn on the ear and will consist of a light source, photocells and optical filters. It is hoped that the same earpiece that will be used for oximetry (item 5) can be used for the densitometer.

(2) Sketch: SAM drawing #2 (same as ear oximeter).

(3) Volume: approximately 1.5 cubic inches.

(4) Weight: approximately one ounce.

(5) Power: approximately 0.4 watt.

(6) Heat output: negligible.

(7) Environmental limits: should be protected from shock and temperatures over 120° F.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: two.

b. Control unit

(1) Description: The control unit will supply power to the densitometer-oximeter earpiece. It will contain voltage regulating circuits for each light source.

(2) Sketch: none.

(3) Volume: approximately 10 cubic inches.

(4) Weight: approximately 0.3 pounds.

(5) Power: approximately 6 watts, intermittent.

(6) Heat output: approximately 3 Btu per test.

(7) Environmental limits: same as other flight qualified electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: none

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

5. Blood oxygen content

a. Earpiece with light source and photocells

(Equipment is consolidated with that for measurement 4. Cardiac output)

b. Control unit

The control unit for measurement 4. Cardiac output, supplies power to the oximeter)

6. Venous pressure

a. Pressure transducer

(1) Description: A transducer of the strain gage, potentiometer or differential transformer type will be used to measure venous pressure. The pressure transducer will be connected to a needle by plastic tubing filled with a fluid.

(2)Sketch: none.

(other characteristics same as item 3 d.)

b. Control unit

(same as item 3 f.)

7. Electrooculogram

a. Electrodes and preamplifier

(1) Description: The corneal-retinal potentials of the eye will be picked up by special non-polarizable electrodes. The signal from the electrodes is then amplified by a small, low gain, DC amplifier built into a glasses frame. The eye potentials will be recorded during certain visual tasks.

(2) Sketch: SAM drawing #4.

(3) Volume: approximately two cubic inches.

(4) Weight: approximately one ounce.

(5) Power: approximately 15 milliwatts.

(6) Heat output: negligible.

(7) Environmental limits: should not be subjected to temperatures above 150° F.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: small calibrated DC voltage source with voltage divider.

(11) Spares for in-orbit maintenance: two.

8. Exocentric visual localization of the horizon

a. Special glasses

(1) Description: The EVLH glasses will be the same size as ordinary glasses but will be provided with a means of covering one eye and rotating a slit over the other eye.

(2) Sketch: none.

(other characteristics essentially the same as item 7 a.)

9. Muscle tone

a. Spring gauge

(1) Description: The device will consist of a simple spring-pointer mechanism for measuring the flexion of a finger.

(2) Sketch: none.

(3) Volume: approximately 6 cubic inches.

(4) Weight: approximately 3 ounces.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: none.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

10. Muscle strength and grip

a. Hand grip dynamometer

(1) Description: Muscle strength will be measured with a Stoelting Hand Grip dynamometer.

(2) Sketch: none.

(3) Volume: approximately 10 cubic inches.

(4) Weight: approximately 8 ounces.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: none.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

11. Electroencephalogram (During Sleep)

a. Electrodes and preamplifier

(1) Description: The electrical activity of the brain will be detected by electrodes attached to the scalp. These voltages will be amplified by a factor of about one hundred by a tiny preamplifier attached to the head with a band. The output of the preamplifier will be connected

to the recording system.

(2) Sketch: SAM drawing #4.

(3) Volume: less than one cubic inch.

(4) Weight: less than one ounce.

(5) Power: approximately 10 milliwatts.

(6) Heat output: negligible.

(7) Environmental limits: should not be subjected to temperatures over 150° F.

(8) Hazards: none.

(9) Electromagnetic interference: measurement should not be performed in the vicinity of strong magnetic or electrical fields.

(10) Alignment and calibration equipment: small, low power voltage source with switch and calibrated voltage dividers.

(11) Spares for in-orbit maintenance: four.

12. Body mass

a. Pendulum device

(1) Description: A number of approaches have been considered for accurately measuring body mass during weightlessness. The technique that seems most likely to yield the resolution and accuracy desired is that of period measurement. If the period is measured with two lever arm lengths and the change in length is accurately known then it should be possible to minimize such sources of error as the spring constant and the distance between the center of rotation and the man's center of mass. (Appendix 1 presents a detailed description of the period method suggested for determining body mass)

(2) Sketch: SAM drawing #5.

(3) Volume: approximately 2 cubic feet.

(4) Weight: approximately 20 pounds.

(5) Power: none

(6) Heat output: none.

(7) Environmental limits: none.

(8) Hazards: none (the frequency of vibration will be kept under 1 cps to avoid injury to body organs and resonances.)

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

b. Transducer and control unit

(1) Description: A position sensing device will be used for measuring period of vibration, and possibly displacement. This device may be a strain sensitive transducer or an electro-optical position indicator. The transducer will be powered and controlled by a control unit.

(2) Sketch: SAM drawing #5.

(3) Volume: approximately 60 cubic inches.

(4) Weight: approximately one pound.

(5) Power: approximately 3 watts, intermittent.

(6) Heat output: approximately 1.8 Btu per day.

(7) Environmental limits: same as other electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: one.

13. Urine volume

a. Urine collector and aliquot

(1) Description: A mechanical-pneumatic device will be used for collecting urine samples and transferring them to a volume measuring container. The urine collecting unit consists of a rubber bag in a sealed container which can be pressurized or evacuated. Container pressure can be read by a small pressure gage. Valves control the direction of urine flow and the pressure in the urine collecting chamber. Urine volume is measured with a calibrated cylinder equipped with a plunger for urine transfer. Note should be made that the urine collecting device will require a source of both negative and positive air pressure (relative to cabin atmosphere). The pressures required need be only a few psi above and below ambient.

(2) Sketch: SAM drawing #6

(3) Volume: approximately 400 cubic inches.

(4) Weight: (empty) approximately 2 pounds.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: none.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

14. Samples of plasma, urine and feces for post-flight analysis.

a. Lyophilizer

(1) Description: A device of some type will be used for freeze-drying samples for post-flight analysis. The equipment details have not been defined. It is felt that a freeze-drying unit is technically feasible using the vacuum of space for drying. Freezing machinery for liquid samples not acted on by the forces of gravity will pose some engineering design problems. The type of refrigerant system that can be used successfully without bulky equipment and high power consumption also remains to be determined.

(2) Sketch: none.

(3) Volume: (estimated) 2 cubic feet.

(4) Weight: (estimated) 20 pounds.

(5) Power: (estimated) none, exclusive of the refrigerant system.

(6) Heat output: unknown.

(7) Environmental limits: unknown.

(8) Hazards: unknown.

(9) Electromagnetic interference: none enticipated.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: unknown.

b. Packaging equipment

(1) Description: A device of as yet undetermined nature will be used for packaging lyophilized samples. Samples will be sealed in a manner and contained in a material that will prevent contamination

by air and moisture. The sealing process may involve heat and mechanical pressure.

(2) Sketch: none.

(3) Volume: (estimated) one cubic foot.

(4) Weight: (estimated) 10 pounds.

(5) Power: (estimated) 50 watts intermittent, short duty cycle.

(6) Heat output: unknown except as inferred from item (5).

(7) Environmental limits: unknown.

(8) Hazards: unknown.

(9) Electromagnetic interference: none anticipated.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

15. Serum calcium, glucose, sodium, potassium, pH, creatinine, hematocrit, and blood volume (T-1824 dye)

a. Centrifuge

(1) Description: A small centrifuge driven by an electrical motor will be used for separating samples. The same device with appropriate head and speed changes can probably be used for micro-hematocrit samples.

(2) Sketch: none.

(3) Volume: approximately 0.7 cubic feet.

(4) Weight: approximately 23 pounds.

(5) Power: approximately 100 watts peak during test.

(6) Heat output: approximately 20 Btu per test.

(7) Environmental limits: none.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

b. Chemical analyzer

(1) Description: Blood determinations will probably be accomplished with a single analyzer that operates automatically. It will be capable of making various electrochemical and colorimetric measurements. The blood or serum sample introduced into the machine will be automatically pumped through a thermally regulated chamber, pH and sodium electrodes, reagent mixers, a dialyzer and a colorimeter. The outputs from the various sensors will be recorded on magnetic tape. Waste fluids will be collected in a bag. Calibration samples will be run before and after each sample to insure proper accuracy. It seems likely that commercially available instruments of a similar nature can be combined to form one machine that will operate in a weightless environment.

(2) Sketch: SAM drawings #7 and #8.

(3) Volume: (estimated) 2 cubic feet.

(4) Weight: (estimated)30 pounds.

(5) Power: (estimated) 30 watts peak required intermittently.

(6) Heat output: (estimated) 40 Btu per 24 hour day.

(7) Environmental limits: should be protected from shock, vibration and temperatures below 32° and 120° F.

(8) Hazards: none (the equipment would be designed to prevent chemicals from entering the atmosphere).

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none

(11) Spares for in-orbit maintenance: numerous small spare parts such as pumps, heaters, electrodes, photocells, etc.

16. Total body water

a. Mass spectrometer

(1) Description: Total body water will be determined by ingestion of deuterium and measurement of the antity of deuterium contained in the blood or urine. Measurement of deuterium will be accomplished with a mass spectrometer. The same mass spectrometer will also be used to identify trace contaminants in the atmosphere and verify O_2, CO_2 and N_2 measurements made by other devices. The mass spectrometer that shows the greatest promise of successful use is the coincidence type of instrument. Its characteristics are given below. It should be noted that the mass spectrometer will require a vacuum line to outer space.

(2) Sketch: none.

(3) Volume: 0.4 cubic feet.

(4) Weight: 30 pounds.

(5) Power: 20 watts.

(6) Heat output: estimated at 10 Btu during the total body water measurement. The heat output will be considerably higher per day if the mass spectrometer is used for other purposes and/or to operate in a standby mode for long periods of time to assure accurate measurements.

(7) Environmental limits: generally the same as electronic hardware although some protection from vibration might be desireable.

(8) Hazards: none.

(9) Electromagnetic interference: may generate RF interference and may be susceptible to strong magnetic fields.

(10) Alignment and calibration equipment: small quantities of standard gas mixtures and means of introducing these samples.

(11) Spares for in-orbit maintenance: possibly spare electron optics and electronic circuit boards.

17. Body volume (using an air lock)

a. Pressure transducer

(1) Description: Body volume will be determined from the pressure produced when a known quantity of gas is introduced into a sealed chamber of known volume containing the astronaut. The pressure transducer used for this purpose will have to have a fairly high sensitivity. To provide accurate readings of high resolution it will probably be necessary for the astronaut to hold his breath during the measurement and for air temperature to be measured. It is presumed that an air lock will exist on the vehicle which can be used for the body volume measurement. A means will have to be provided for connecting a pressure transducer to the chamber and introducing a known volume of gas.

(2) Sketch: none.

(The other characteristics of the pressure transducer will be the same as item 3 d.)

b. Control unit

(1) Description: same as item 3 f.

c. Gas Supply

(1) Description: The gas (probably 100% oxygen) used for the volume measurement will be contained in small high pressure cylinders comparable to a pilot's high altitude bailout bottle. One cylinder will be expended for each measurement. (A total of eight will be needed for the flight, four per astronaut.)

(2) Sketch: none.

(3) Volume: approximately 40 cubic inches, each.

(4) Weight: approximately 3 pounds, each.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: none.

(8) Hazards: high pressure oxygen.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

d. Thermistor thermometer

(1) Description: A thermistor with a control unit will be used to record the chamber air temperature at the same time that pressure is being recorded.

(2) Sketch: none.

(3) Volume: (control unit) approximately 8 cubic inches.

(4) Weight: approximately 3 ounces.

(5) Power: approximately 50 milliwatts.

(6) Heat output: negligible.

(7) Environmental limits: same as electronic equipment.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: mercury thermometer.

(11) Spares for in-orbit maintenance: none.

18. Urine total solids, pH, protein and glucose

a. Paper strips

(1) Description: Conventional paper strips containing indicator chemicals will be used for determining urine pH, protein and glucose. Further description of these strips is not considered necessary.

b. Optical refractometer

(1) Description: An optical refractometer will be used for measuring urine total solids. The device consists of a small telescope, prisms and a light source.

(2) Sketch: none.

(3) Volume: approximately 300 cubic inches.

(4) Weight: approximately 7 pounds.

(5) Power: approximately 15 watts intermittant.

(6) Heat output: approximately 5 Btu per test.

(7) Environmental limits: should be protected from shock and vibration.

(8) Hazards: none.

(9) Electromagnetic interference: unit contains an arc discharge type of light source which could produce RF interference.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: extra light.

19. Sweat analysis

a. Absorbant pack for post-flight analysis

(1) Description: A simple sponge-like device will be used for collecting sweat samples. The pads will be sealed after collection, possibly using the packaging device noted in item 14 b. Further description is considered UN necessary.

20. Body temperature

a. Oral thermometer

(1) Description: A thermistor type of oral thermometer will be used to measure body temperature. The control unit for item 17 d. will be used for temperature recording and readout. See item 17 d. for further descriptive information.

21. Timed vital capacity, vital capacity, tidal volume, flow, respiratory rate and maximum breathing capacity.

a. Waterless spirometer, amplifier and control unit

(1) Description: Respiratory measurements involving flow, volume and breathing capacity will be performed with a "waterless" type of spirometer. The unit consists of a movable diaphragm assembly, amplifier and control unit. The position of the diaphragm and its rate of travel are converted into electrical signals.

(2) Sketch: SAM drawing #3.

(3) Volume: 0.8 cubic feet.

(4) Weight: approximately 20 pounds.

(5) Power: approximately 15 watts.

(6) Heat output: approximately 5 Btu per test.

(7) Environmental limits: should be protected from shock, vibration and temperature extremes.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: possibly spare plug-in circuit boards or small mechanical parts.

22. Alveolar pCO_2 and pO_2

a. Pump

(1) Description: The O_2 and CO_2 content of the expired air will be measured during this test. A small diaphragm type of pump is required for pulling part of the expired air through the O_2 and CO_2 analyzers.

(2) Sketch: SAM drawing #3.

(3) Volume: approximately 21 cubic inches.

(4) Weight: approximately 2 pounds.

(5) Power: approximately 15 watts intermittent.

(6) Heat output: approximately 5 Btu during test.

(7) Environmental limits: none.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

b. Valves

(1) Description: Two mechanical valves will be used to switch inspiratory and expiratory air flow to the waterless spirometer. (See SAM drawing #3) No further descriptive detail is considered necessary.

c. CO_2 analyzer

(1) Description: A device, probably of the infra-red variety, will be used to measure expired CO_2. The vibrating filter type of infra-red CO_2 analyzer seems the most promising instrument for this purpose.

(2) Sketch: none.

(3) Volume: approximately 20 cubic inches.

(4) Weight: approximately 5 pounds.

(5) Power: approximately one watt.

(6) Heat output: negligible.

(7) Environmental limits: should be protected from shock and vibration.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: calibrated gases in small containers.

(11) Spares for in-orbit maintenance: none.

d. O_2 electrode and amplifier

(1) Description: A polarographic type of oxygen electrode will be used to measure alveolar pO_2. This device is small and rugged and potentially capable of a fast enough response for breath-to-breath analysis.

(2) Sketch: none.

(3) Volume: approximately 30 cubic inches including amplifier.

(4) Weight: approximately one pound.

(5) Power: approximately 0.5 watts.

(6) Heat output: negligible.

(7) Environmental limits: temperatures above 120° F and below 32° F should be avoided.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: small quantities of calibrated gas mixtures.

(11) Spares for in-orbit maintenance: extra oxygen electrode.

23. Oxygen consumption and CO_2 production

a. Dry test meter

(1) Description: A dry test gas meter will be used for measuring oxygen consumption. Readings will be taken from dials.

(2) Sketch: none.

(3) Volume: approximately 0.3 cubic foot.

(4) Weight: approximately 8.5 pounds.

(5) Power: none.

(6) Heat output: none.

(7) Environmental limits: should be protected from shock and vibration.

(8) Hazards: none.

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

b. CO_2 analyzer

(same as item 22 c.)

c. Pump

(same as item 22 a.)

d. Spirometer

(same as item 21 a.)

24. Exercise output

a. Ergometer with wattmeter

(1) Description: A bicycle type of ergometer will be used both for exercise and for measuring work output during physiological

tests. Both hands and feet can be exercised. The bicycle pedals will be connected to an electrical generator. Pedalling rate will be displayed on a tachometer. Work output will be determined by measuring the electrical power dissipated across a load at a given speed. The electrical power produced during exercise can be used to charge batteries or power equipment, although the complexity of load regulating and switching circuits may make practical usage of this power source unattractive.

(2) Sketch: SAM drawing # 10.

(3) Volume: approximately 1.5 cubic feet.

(4) Weight: approximately 30 pounds.

(5) Power: none consumed. Will probably generate about 25 watts average for approximately 20 minutes.

(6) Heat output: approximately 28 Btu per test or exercise period.

(7) Environmental limits: none.

(8) Hazards: none

(9) Electromagnetic interference: none.

(10) Alignment and calibration equipment: none.

(11) Spares for in-orbit maintenance: none.

25. Ear pulse and pressure

a. Earpiece and earpiece capsule inflator

(1) Description: Head level blood pressure and pulse volume will be estimated by measuring the pressure required to block blood flow in the ear. A small rubble capsule device will be mounted in the oxi-meter-densitometer earpiece. Inflation of the capsule with a squeeze

bulb will occlude blood flow as indicated by the oximeter and densitometer readouts. The pressure required to stop blood flow will be provided by a pressure transducer connected to the earpiece inflation capsule. Pressure readings and oximeter output will be recorded on magnetic tape. (For further information on the earpiece assembly see items 4 and 5.)

b. Pressure transducer

(1) Description: same as item d.

c. Control unit

(1) Description: same as item 3 f.

26. Airway pressure

a. Pressure transducer

(1) Description: A pressure transducer will be used to measure airway pressure during Valsalva responses and the calibrated Flack test. The characteristics of the transducer will be similar, if not identical, to those of the pressure transducer in item 6 a.

b. Control unit

(same as item 6 b.)

27. Anti G suit pressure

a. Pressure tranducer

(1) Description: An anti G suit type of device may be used to apply pressure to the lower extremities to preserve proper vascular response. It is desireable to measure the actual pressure applied to the suit. The pressure transducer used for this purpose will be similar to the one used in item 3 d.

b. Control unit

(same as item 3 f.)

C. Equipment summary

Table A contains a summary of major equipment items and their volume, weight and power requirements. Estimates of supply and miscellaneous equipment needs are also included.

V. Test Schedule

A. General

Experiment protocol, the nature of each specific measurement, a tentative data collection schedule, the duration of each measurement and the functional purpose of each measurement have all been considered in arriving at a grouping of tests. The grouping that seems most feasible is presented in Table B. It should be noted that tests have been grouped so that no more than five parameters need be recorded on magnetic tape at any one time. Voice comments will be recorded on the tape during each test along with clock time.

Table B also contains data on the total number of bits of information produced by each test and maximum power consumption. The test schedule, or measurement grouping, of Table B is used for equipment groupings and further dissection of test requirements.

Table C presents a breakdown of equipment required for each test.

Table D contains a complete schedule of all tests that are to be performed during the flight.

Table E provides a day-by-day compilation of power consumption, heat generation and total bits of information for each test.

VI. Data Management Requirements.

a. Basic assumptions.

Any data management plan must rest on a few reasonably firm assumptions. The following assumptions, which are entirely arbitrary, represent a point of departure for exploring the medical data management problem:

(1) All of the medical experiments data would be transmitted to one place. This location might be Cape Kennedy, Brooks AFB, Texas, or Sunnyvale, California. The individuals who designed the experiments and who will analyze the data would be at one location. This site would be equipped for telemetry reception, data processing, retrieval of astronaut base-line data, and special computer operations.

(2) Most of the medical experiments data would be stored on-board the vehicle and dumped at a fast rate over the medical data analysis site. Delayed data relays from other ZI sites might be employed for maximum continuity of data, assuming an information bandwidth compatible with Class "A" telephone lines.

(3) Processed medical data and results of analyses would be sent via teletype or voice to the Mission Control Center.

(4) Vehicle operational data; i.e., temperature, pressure, O_2 partial pressure, etc. would be sent to the Medical Data Analysis Center via teletype or voice from the Mission Control Center

(5) Any given telemetry receiving site will be able to receive signals for at least six minutes during an optiminal station pass.

(6) The orbit inclination will be less than 35 degrees and more than 25 degrees on flights involving medical experiments.

(7) The orbit will be nearly circular and have a period of approximately 90 minutes.

(8) A very limited number of tracking stations will be employed throughout the flight.

(9) A maximum of 19 hours may elapse between passes over the Medical Data Analysis Site. Actually, there will be a minimum of four passes per 24 hour day over any location under consideration. Signals would be received on at least two consecutive passes separated by a period of 17-19 hours when there would be two more consecutive passes that could be picked up.

(10) The Medical Data Analysis Center can have direct voice contact with the vehicle on overhead passes or indirect communication through the Mission Control Center.

b. Data characteristics.

The medical experiments vary both as to the amount of data collected at any one time and the specific time at which any given measurement is made. Two channels of low frequency information (heart rate) must be recorded continuously except when ECG is recorded. The accuracy requirement of many of the measurements is 1% or better. Frequency modulation tape recording techniques can not provide this accuracy and would be extremely wasteful of tape. A seven-channel FM tape recorder, for example, would be sufficient to handle the maximum channel load; however, during

a large part of the time, only two chanels of information would be recorded and 5/7ths of the tape capability would be wasted due to the parallel manner in which the data is recorded. If the data is put in serial format using PCM techniques then the tape may be packed with data and the most efficient use made of the tape storage capability. In addition, the 1% accuracy requirement of certain measurements can now be met.

The medical experiments may require as many as six simultaneous channels of information recorded for periods of 2 to 20 minutes. (See Table "B") During the remaining time, only two channels need be recorded; however, these two channels need to be recorded continuously between medical data playbacks to the ground.

c. Design approach.

The attached drawing illustrates a data management system capable of handling all medical experiments data. This concept is based on the use of a separate data management system for the medical experiments. The medical experiments data could be fed into a central vehicle data storage-transmission system, data load from the other experiments permitting. The same general design considerations are applicable.

The system illustrated consists of standard components, which while they may not be "off-the-shelf", have been developed and are within the "state-of-the-art". It is envisaged that 5 channels of analog data are the maximum required at any one time. A sixth channel has been included in the planning which may be used for unforeseen analog data, or could be used as a voice channel (superconmutated at a higher commutation rate).

A control panel to provide manual programming to select tape speed, number of data channels commutated, etc, is indicated in the lower left hand corner. The panel would be designed to simplify manual operation. The appropriate number of channels used and tape speed would be selected by a switch marked in terms of the particular test being performed.

Time code would be inserted on a digital basis, with one second markers and minute and hour identification only on the minute or hour respectively, thus reducing to a minimum the bits required for time marks.

To prevent loss of data it is important that the tape recorder when dumping be capable of starting at the point at which the previous dump stopped. A simple search mechanism can be incorporated in the tape recorder to satisfy this requirement by inserting a tone on an unused track at the beginning and end of dump. This could be controlled by the astronaut or by ground command.

The maximum number of bits stored in any one day (24 hours) from the information in Table "B", and including 50% additional bits for frame synchronization and time code, is approximately 730 megabits. The maximum storage capacity of a suitable [1] tape recorder is 864 megabits. In terms of tape length, approximately 24,400 inches of tape would be required for 24 hours of storage. The reel capacity is 2400 feet, or 28,800 inches.

If VHF telemetry were used the maximum transmission bit rate (500 KC bandwidth) is 330 kilobits/second.[2] Assuming a packing density of 1000 bits/linear inch/track (30 tracks) the maximum playback speed is

11 inches/sec.. The highest compression ratio of playback/record speed is 32:1, maintaining compatibility with IRIG standard ground tape recorder speeds. At this ratio the record speed would be approximately 0.33 inches/second. A record speed of 0.33 inches/second is within tape recorder capabilities, and would allow recording of heart rate and sleep EEG. A speed of .67 inches/second would be necessary when the other test data are recorded.

The limiting factor of 330 kilobits/second using VHF telemetry would require a dump time of 30 minutes for every 16 hours of record time. Although the orbits are not available at this time it would appear that this dump time is greater than would be available.

If, however, UHF telemetry were used, the maximum transmission bit rate would be 800 kilobits/second[3] (1.5 MC bandwidth). At this higher bit rate a compression ratio of 64:1 would be feasible.

Assuming a minimum practical tape speed of 0.33 inches/second the playback speed would be approximately 22 inches/second. At this speed the bit rate would be approximately 600 kilobits/second (1MC bandwidth). This rate would drop the dump time to 15 minutes for 16 hours record, a figure that could probably be realized.

Footnotes:

Note 1: The Parsons AIR 2400 PCM recorder was used as a basis of this study. The recorder has a standard IRIG PCM 31 track head configuration, a packing density of 1000 bits/linear inch/track, and a playback

capability of 120 K bits/second. (It is assumed that this is the bit rate per track.) It is available with four electrically selectable tape speeds, using 2 motors. Two speeds are obtained from each motor; these two speeds must have a 2:1 ratio. The other two speeds are obtained from tthe other motor in the same ratio, 2:1. The ratio between the speeds obtained from one motor to those obtained from another motor may be 32:1, or 64:1, as an example, as long as maximum speed is not exceeded.

The tape capacity of the recorder is 2400 feet of 1 mil tape. It can be equipped with an automatic search capability.

Note 2: IRIG standards

Note 3: IRIG standards

TABLE A——Summary of Equipment for Experiment P-12 (Volume, weight and power)

Measuring Instruments:	Vol.($ft.^3$)	Weight(lbs.)	Power(watts)
Heart rate	0.024	1.38	1.60
Electrocardiogram	0.002	0.13	0.02
Blood pressure	0.064	3.13	0.05
Cardiac Output	0.007	0.36	6.00
Blood oxygen content	0.007	0.36	6.00
Venous pressure	0.016	0.09	0.05
Electrooculogram	0.001	0.06	0.015
Egocentric visual localization of the horizon	0.001	0.06	
Muscle tone	0.004	0.19	
Muscle strength and grip	0.002	0.50	
Electroencephalogram	0.001	0.06	0.01
Body mass	2.004	21.00	3.00
Urine volume	0.233	2.00	
Samples of plasma, urine and feces for post-flight analysis	3.000	30.00	50.00
Serum calcium, glucose, sodium, potassium, pH, creatinine, hematocrit, and blood volume	2.700	53.00	130.00
Total body water	0.400	30.00	20.00
Body volume	0.037	3.56	0.10
Urine total solids, pH, protein and glucose	0.174	7.00	15.00
Sweat analysis			15.00
Total - - - - - - -	8.677	152.88	

TABLE A (continued)

Measuring Instruments:	Vol.($ft.^3$)	Weight(lbs.)	Power(watts)
Body temperature	0.005	0.19	0.05
Timed vital capacity, vital capacity, tidal volume, flow, respiratory rate, and maximum breathing capacity	0.800	20.00	15.00
Alveolar pCO_2 and pO_2	0.012	7.00	15.00
Oxygen consumption and CO_2 production	0.300	8.50	1.00
Exercise output	1.500	30.00	
Ear pulse and pressure	0.016	0.88	0.05
Airway pressure	0.016	0.88	0.05
Anti G suit pressure	0.016	0.88	0.05
Total - - - - - - - -	2.665	68.33	

Other Equipment:	Vol.($ft.^3$)	Weight(lbs.)	Power(watts)
Group 1			
PCM encoder	0.02	1.0	1
PCM tape recorder	0.23	20.0	20
Control panel with controls, signal input connectors and time code display	0.50	10.0	7
Group 2			
Record-reproduce amplifiers	0.01	2.0	2
Parallel-serial converter	0.01	1.0	1
PCM transmitter	0.50	30.0	40
Total - - - - - - -	1.27	64.0	

TABLE A (continued)

	Vol.($ft.^3$)	Weight(lbs.)	Power(watts)
Spare parts, supplies, tools and miscellaneous equipment	4.00	60.00	
Grand Total - - - -	16.61	345.21	

Table B. Test Schedule -- Physiological Measurements

Test	Time Rqd (min)	Info* Bits ($X10^6$)	Power Watts
I. Cardiovascular			
A. 3 VCG leads 1 Blood pressure (sound on pressure)	2	1.44	28
B. 3 VCG leads 1 Blood pressure 1 Airway pressure transducer	4	3.6	28
C. 1 Blood pressure 1 oximeter earpiece capsule pressure transducer 3 oximeter (red, infrared, for infrared)	3	2.7	34
D. 3 oximeter 1 airway pressure Transducer 1 ECG	3	2.7	35
E. 3 Vectorcardiogram 1 Venous pressure transducer 1 Spirometer (timed volume)	2	1.8	43
F. 1 Blood pressure 3 Oximeter 1 Spirometer	2	1.8	59
G. 3 Vectorcardiogram 1 Venous pressure transducer 1 Ergometer power	4	3.6	28
H. 1 Blood pressure 3 Oximeter 1 Ergometer power	3	2.7	34
I. 3 Vectorcardiogram 1 Blood Pressure 1 Suit pressure transducer	5	4.5	28

*For each test per man

TABLE "B" cont'd

Test	Time Rqd (min)	Info* Bits ($\times 10^6$)	Power Watts
II. Respiratory			
A. 1 Alveolar pO_2 1 Alveolar pCO_2	16	11.52	43
B. 1 Expired Air pO_2 1 Expired air pCO_2	6	2.16	43
C. 1 Alveolar pCO_2 1 Spirometer	5	1.8	43
III. Body Composition			
A. 1 Body mass (position transducer)	5	5.4	31
B. 1 Body volume (pressure transducer) 1 Temperature sensor	2	.72	28
C. 2 Mass spectrometer	4	1.44	48
IV. Biochemical Analyses			
A. 5 channels of data (total)	20	18	58
V. Miscellaneous (single recording)			
A. 2 Heart rate (1 each man) continuous		129.6	11.6
B. 1 EOG (alternate)	5	.9	28
C. 1 EEG (alternate)	8 hrs	86.4	28
D. 1 Temperature	3	.54	28
E. 1 Ergometer (power)	20	3.6	28
F. Voice	variable	2.7/min	

*For each test per man

TABLE "C"

EQUIPMENT BREAKDOWN FOR EACH TEST
(for each man)

Test	Equip Req.	Vol (ft^3)	Wt (lb)	Power (watts)
I A	Group 1	.76	33	28
B	Group 1	.76	33	28
C	Group 1	.76	33	28
	Oximeter	.005	.3	6
	Total I C	.81		34
D	Group 1	.76	33	28
	Oximeter	.005	.3	6
	Airway press strain gage	.007	1	1
	Total I D	.82		35
E	Group 1	.76	33	28
	Spirometer	.8	20	14
				43
F	Group 1			28
	Oximeter			6
	Spirometer			15
				59
G	Group 1			28
	Ergometer	1.5	30	
				28
H	Group 1			28
	Ergometer			
	Oximeter			6
				34
I	Group 1			28

TABLE "C ' cont'd

Test	Equip. Req.	Vol (ft^3)	Wt (lb)	Power (watts)
II.A.	Group 1			28
	Spirometer and PAO_2 and $PACO_2$	.8	20	15
				43
B.	Spirometer & PAO_2 & $PACO_2$	.8	20	15
	Group 1			28
				43
C.	Spirometer			15
	Group 1			28
				43
III.A.	Group 1			28
	Mass measurement structure	2.0	20	3
				31
B.	Group 1			
C.	2 Mass spec.	.4	30	20
	Group 1			28
				48
IV. A.	Group 1			28
	Biochem. analyzer	2.	30	30
				58
V.	Miscellaneous			
A.	2 heart rate:			cont.
	2 transmitters.	0.004	.5	Batteries
	2 receivers	0.02	1.	1.6 (both)
	Group 1 (slow speed on tape recorder)			10.
				11.6
B.	Group 1			28
C.	Group 1			28
D.	Group 1			28
E.	Group 1			28
	Ergometer			

Table D. Daily Test Schedule (Requiring Electronic Instrumentation)

Day	Test No.										V				
	IA	IB	IC thru H	II	II A	IIB	IIC	IIIA	IIIB	IIIC	IVA	A	B	C	D	E
1	6				4	4	4	2							2	2
2		2	2		4	4	4	2	2	2	1		1	1	2	2
3		2			4	4	4	2					1	1	2	2
4					4	4	4	2					1	1	2	2
5		2			4	4	4	2			1		1	1	2	2
6					4	4	4	2					1	1	2	2
7					4	4	4	2					1	1	2	2
8		2	2		2	2	2	2	2	2	1		1	1	2	2
9					2	2	2	2					1	1	2	2
0					2	2	2	2					1	1	2	2
1		2			2	2	2	2					1	1	2	2
2					2	2	2	2					1	1	2	2
3					2	2	2	2					1	1	2	2
4		2			2	2	2	2			1		1	1	2	2
5					2	2	2	2					1	1	2	2
6					2	2	2	2					1	1	2	2
7					2	2	2	2					1	1	2	2
8					2	2	2	2					1	1	2	2
9					2	2	2	2					1	1	2	2
0		2	2		2	2	2	2	2	2	1		1	1	2	2
1					2	2	2	2					1	1	2	2
2					2	2	2	2					1	1	2	2
3					2	2	2	2					1	1	2	2
4		2			2	2	2	2					1	1	2	2
5					2	2	2	2					1	1	2	2
6					2	2	2	2			1		1	1	2	2
7					2	2	2	2					1	1	2	2
8		2	2		2	2	2	2	2	2	1		1	1	2	2
9		2		2	2	2	2	2					1	1	2	2
0				2	2	2	2	2								

Continuous

One for both astronauts

Both astronauts

Astronauts alternate days

" "

" "

Table E -- Daily Total Test Time & Power Requirements

Day	Test	No. Tests	Power Rqd (watts)	Time Ea Test (min)	Total Time (min)	Heat Btu	Info Bits ($X10^6$)
1	I A	6	28	2	12	19.2	8.64
	II A	4	31	16	64	113.0	46.08
	B	4	43	6	24	58.7	8.64
	C	4	43	5	20	49.2	7.2
	III A	2	31	5	10	17.6	10.8
	V A	2	11.6	24 hrs (simultaneous)	24 hrs	950.0	259.2
	D	2	28	3	6	9.6	1.08
	E	2	28	20	40	63.7	7.2
						1281.0	348.84
2.	I B	2	28	4	8	12.7	7.2
	C	2	34	3	6	11.6	5.4
	D	2	35	3	6	12.0	5.4
	E	2	43	2	4	10.0	3.6
	F	2	59	2	4	13.4	3.6
	G	2	28	4	8	12.7	7.2
	H	2	34	3	6	11.6	5.4
	II A	4	43	16	64	156.0	46.08
	B	4	43	6	24	58.7	8.64
	C	4	43	5	20	49.2	7.2
	III A	2	31	5	10	17.6	10.8
	B	2	28	2	4	6.4	1.44
	C	2	48	4	8	22.0	2.88
	IV A	1	58	20	20	66.0	18
	V A	2	11.6	24 hrs	24 hrs	950.00	259.2
	B	1	28	5	5	7.9	.9
	C	1	28	8 hrs	8 hrs	765.0	86.4
	D	2	28	3	6	9.6	1.08
	E	2	28	20	40	63.8	7.2
						2256.2	487.62

TABLE 'E' cont'd

Day	Test	No. Tests	Power Rqd (watts)	Time Ea Test	Total Time (minutes)	Heat Btu	Info Bits ($X10^6$)
3	I B	2	28	4	8	12.7	7.2
	II A	4	43	16	64	156.0)	
	B	4	43	6	24	58.7)	61.92
	C	4	43	5	20	49.2)	
	III A	2	31	5	10	17.6	10.8
	V A	2	11.6	24 hrs	24 hrs	950.0)	
	B	1	28	5	5	7.9)	
	C	1	28	8 hrs	8 hrs	765.0)	354.78
	D	2	28	3	6	9.6)	
	E	2	28	20	40	63.8	
						2090.5	434.7
4	II A	4	43	16	64	156.0)	
	B	4	43	6	24	58.7)	61.92
	C	4	43	5	20	49.2)	
	III A	2	31	5	10	17.6	10.8
	V A	2	11.6	24 hrs	24 hrs	950.0)	
	B	1	28	5	5	7.9)	
	C	1	28	8 hrs	8 hrs	765.0)	354.78
	D	2	28	3	6	9.6)	
	E	2	28	20	40	63.8)	
						2077.8	427.5
5	I B	2	28	4	8	12.7	72
	II A	4	43	16	64	156.0)	
	B	4	43	6	24	58.7)	61.92
	C	4	43	5	20	49.2)	
	III A	2	31	5	10	17.6	10.8
	IV A	2	58	20	40	132.0	18
	V A	2	11.6	24 hrs	24 hrs	950.0)	434.7
	B	1	28	5	5	7.9)	
	C	1	28	8 hrs	8 hrs	765.0)	354.78
	D	2	28	3	6	9.6)	
	E	2	28	20	40	63.8)	
						2222.5	452.7

TABLE "E" cont'd

Day	Test	No. Tests	Power Rqd (watts)	Time Ea Test	Total Time (min)	Heat Btu	Info Bits ($X10^6$)
6 II (Same as Day 4)	A	4	43	16	64	156.0	
	B	4	43	6	24	58.7	
	C	4	43	5	20	49.2	
III	A	2	31	5	10	17.6	
V	A	2 (sim)	11.6	24 hrs	24 hrs	950.0	
	B	1	28	5	5	7.9	
	C	1	28	8 hrs	8 hrs	765.0	
	D	2	28	3	6	9.6	
	E	2	28	20	40	63.8	
						2077.8	427.5
7 II (Same as Day 4)	A	4	43	16	64	156.0	
	B	4	43	6	24	58.7	
	C	4	43	5	20	49.2	
III	A	2	31	5	10	17.6	
V	A	2	11.6	24 hrs	24 hrs	950.0	
	B	1	28	5	5	7.9	
	C	1	28	8 hrs	8 hrs	765.0	
	D	2	28	3	6	9.6	
	E	2	28	20	40	63.8	
						2077.8	427.5
8 I	B	2	28	4	8	12.7	7.2
	C	2	34	3	6	11.6	5.4)
	D	2	35	3	6	12.0	5.4)
	E	2	43	2	4	10.0	3.6) 30.6
	F	2	59	2	4	13.4	3.6)
	G	2	28	4	8	12.7	7.2)
	H	2	34	3	6	11.6	5.4)
II	A	2	43	16	32	78.2)	
	B	2	43	6	12	29.3)	30.96
	C	2	43	5	10	24.5)	
III	A	2	31	5	10	17.6)	
	B	2	28	2	4	6.4)	15.12
	C	2	48	4	8	22.0)	
IV	A	1	58	20	20	66.0	18
V	A	2	11.6	24 hrs	24 hrs	950.0)	
	B	1	28	5	5	7.9)	354.78
	C	1	28	8 hrs	8 hrs	765.0)	
	D	2	28	3	6	9.6)	
	E	2	28	20	40	63.8)	
						2143.3	449.46

TABLE "E" cont'd

Day	Test	No. Tests	Power Rod Watts	Time Ea Test	Total Time (min)	Heat (Btu)	Info Bits (X 10^6)
14	I B	2	28	4	8	12.7)	
	II A	2	43	16	32	78.3)	
	B	2	43	6	12	29.3)	
	C	2	43	5	10	24.5)	
	III A	2	31	5	10	17.6)	
	IV A	1	58	20	20	66	18
	V A	2	11.6	24 hrs	24 hrs	950.0)	
	B	1	28	5	5	7.9)	
	C	1	28	8 hrs	8 hrs	765.0)	403.74
	D	2	28	3	6	9.6)	
	E	2	28	20	40	63.8)	
						2024.7	421.74
15	Same as Day 9					1946	396.54
16	" "					1946	396.54
17	" "					1946	396.54
18	" "					1946	396.54
19	" "					1946	396.54
20	Same as Day 8					2124.3	449.46
21	Same as Day 9					1946	396.54
22	Same as Day 9					1946	396.54
23	Same as Day 9					1946	396.54
24	Same as Day 11					1958.6	403.74
25	Same as Day 9					1946	396.54
26	IIA	2	43	16	32	78.3)	
	B	2	43	6	12	29.3)	30.96
	C	2	43	5	10	24.5)	
	III A	2	31	5	10	17.6	10.8
	IV A	1	58	20	20	66.0	18
	V A	2	11.6	24 hrs	24 hrs	950.0)	
	B	1	28	5	5	7.9)	
	C	1	28	8 hrs	8 hrs	765.0)	354.78
	D	2	28	3	6	9.6)	
	E	2	28	20	40	63.8)	
						2012.0	432.54

TABLE "E" cont'd

Day	Test	No. Test	Power Rad (watts)	Time Ea Test	Total Time	Heat Btu	Info Bits ($X10^6$)
9	II A	2	43	16	32	78.3)	
	B	2	43	6	12	29.3)	30.96
	C	2	43	5	10	24.5)	
	III A	2	31	5	10	17.6	10.8
	V A	2	11.6	24 hrs	24 hrs	950.0)	
	B	1	28	5	5	7.9)	
	C	1	28	8 hrs	8 hrs	765.0)	354.78
	D	2	28	3	6	8.6)	
	E	2	28	20	40	63.8)	
						1946.0	396.54
10	(Same as Day 9)					1946 Btu	396.54 X 10^6 Bits
11	I B	2	28	4	8	12.7	7.2
	II A	2	43	16	32	78.2)	
	B	2	43	6	12	29.3)	
	C	2	43	5	10	24.5)	
	III A	2	31	5	10	17.6)	
	V A	2	11.6 (both)	24 hrs	24 hrs	950.0)	396.54
	B	1	28	5	5	7.9)	
	C	1	28	8 hrs	8 hrs	765.0)	
	D	2	28	3	6	9.6)	
	E	2	28	20	40	63.8)	
						1958.6	403.74
12	(Same as Day 9)					1946 Btu	396.54
13	(Same as Day 9)					1946	396.54

TABLE "E" cont'd

Day	Test		No. Test	Power Rqd (watts)	Time Ea Test	Total Time (min)	Heat Btu	Info Bits ($X10^6$)
27	Same as Day 9						1946	396.54
28	Same as Day 8						2124.3	449.46
29	I	B	2	28	4	8	12.7	7.2
	I	I	2	28	5	10	15.9	9
	II	A	2	43	16	32	78.3)	
		B	2	43	6	12	29.3)	30.96
		C	2	43	5	10	24.5)	
	III	A	2	31	5	10	17.6	10.8
	V	A	2	11.6	24 hrs	24 hrs	950.0)	
		B	1	28	5	5	7.9)	
		C	1	28	8 hrs	8 hrs	765.0)	354.78
		D	2	28	3	6	9.6)	
		E	2	28	20	40	63.8)	
							1974.6	412.74
30	I	I	2	28	5	10	15.9)	9
	II	A	2	43	16	32	78.3)	
		B	2	43	6	12	29.3)	30.96
		C	2	43	5	10	24.5)	
	III	A	2	31	5	10	17.6	10.8
	V	A	2	11.6	24 hrs	24 hrs	950.0	259.2
							1115.6	309.96

Appendix A. Method for Determining Mass Under Zero-G Conditions:

Body mass determination in space is more complex than on earth due to the lack of net forces produced by gravitational attraction. The problem becomes particularly difficult if sufficient accuracy is to be obtained to give meaningful data.

Several methods utilizing Newton's laws have been considered: for example, linear acceleration and measurement of velocity; linear mass-spring oscillation and measurement of period of oscillation; and a torsion spring and variable length arm system and measurement of period of oscillation. The latter system was selected because of relative ease in construction of a model under gravitational forces and relative ease in obtaining useful information. A sketch of this system is shown in Fig. 1.

The proposed method will involve measurements of two periods of oscillation: one with the mass at the length $\ell_1 + \ell + \Delta\ell$ and the other at the length $\ell_1 + \Delta\ell$. The incremental length $\Delta\ell$ is included due to the difficulty in determining the center of mass of a man. The length $\Delta\ell$ is assumed to be constant for the two measurements.

The mass of a man is obtained mathematically as follows. Initially, a force-torque diagram is drawn to obtain force-torque equations of motion (Fig. 2).

Equations of motion are obtained from the diagram assuming an equilibrium condition:

$$F_x = -Ma_x = -M\frac{d^2x}{dt^2} \qquad (1)$$

$$T_{\ell_T} = +\frac{K_T\theta}{\ell_T} = -M\ell_T\frac{d^2\theta}{dt^2} \qquad (2)$$

LUMPED MASS
OF VAN
OSCILLATORY
MOTION
TORSION SPRINGS

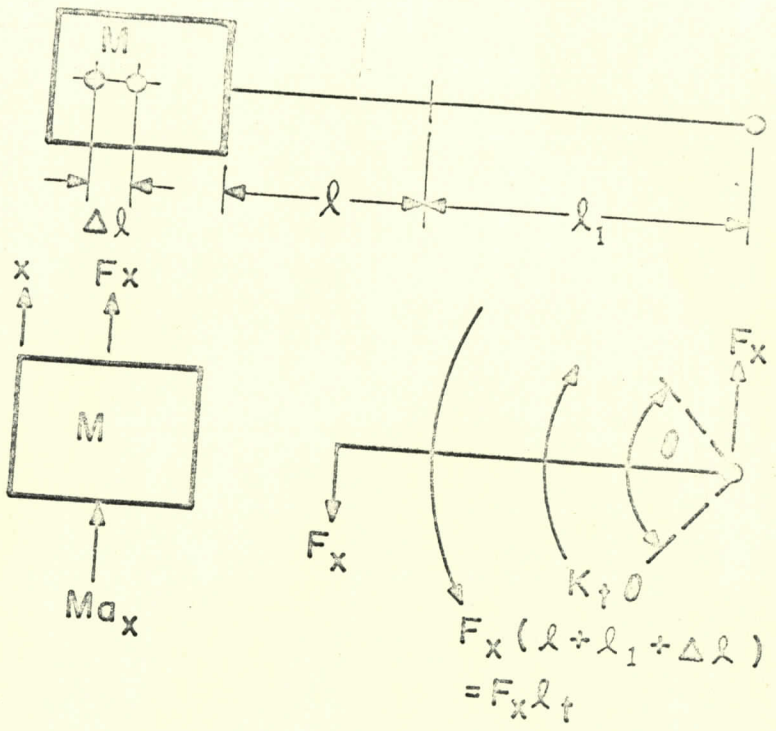

Fig. 2. Force - moment diagram where Fx = restoring force presented by torsion bars at end of support member upon center of mass

M = mass of man in slugs

M ax = force due to acceleration opposing Fx (lb.)

K_T = angular, or torque, spring constant at pivot point in lb-ft/rad.

The generalized equation of motion is -

$$\frac{d^2\theta}{dt^2} + 2\zeta\omega_n\frac{d\theta}{dt} + \omega_n^2\theta = 0 \tag{3}$$

The term $2\zeta\omega_n\frac{d\theta}{dt}$ where ζ is the damping factor is assumed to be negligible in the equation of motion because of very little damping. Therefore, Eq. (3) is reduced to --

$$\frac{d^2\theta}{dt^2} + \omega_n^2\theta = 0 \tag{4}$$

Rearranging Eq. (2) in the form of Eq. (4) yields:

$$\frac{d^2\theta}{dt^2} + \frac{K_T}{M\ell_T^2}\theta = 0 \tag{5}$$

Equating of coefficients in Eqs. (4) and (5) yields

$$\omega_n^2 = K_T/M\ell_T^2$$

$$\omega_n = \frac{1}{\ell_T}\sqrt{\frac{K_T}{M}} \tag{6}$$

The natural resonant frequency is dependent upon the mass of the man and other oscillating masses, the torque constant K_T, and the total length from the torsion bars to the center of mass of the man.

The proposed method for determination of mass utilizes a moment arm of variable length to eliminate the requirement that an accurate measurement be made from the torsion bars to the center of mass of the man. A simplified sketch of the system is shown in Fig. 3.

Mass is obtained from Eq. 6:

$$M = \frac{K_T}{\omega_n^2\ell_T^2} \tag{7}$$

where $\ell_T = \ell_1 + \ell + \Delta\ell$ in Fig. 3a and $\ell_T = \ell_1 + \Delta\ell$ in Fig. 3b.

From Fig. 3a --

$$M = \frac{K_T}{(\ell_1 + \ell + \Delta\ell)^2\omega_n^2} \tag{8}$$

From Fig. 3b, $M = \dfrac{K_T}{(L_1 + \Delta\ell)^2 \omega_{n2}^2}$ (9)

Where ω_{n1} and ω_{n2} are the frequencies of oscillation from Figs. 3a and 3b respectively.

An expression for $\Delta\ell$ is obtained from Eqs. (8) and (9):

$$\omega_{n2}(L_1 + \Delta\ell) = \omega_{n1}(L_1 + \ell + \Delta\ell)$$

$$\Delta\ell = \frac{(\omega_{n1} - \omega_{n2})L_1 + \omega_{n1}\ell}{\omega_{n2} - \omega_{n1}} \quad (10)$$

Substitution of Eq. (10) into Eq. (9) yields

$$M = \frac{K_T}{\left(L_1 + \dfrac{(\omega_{n1} - \omega_{n2})L_1 + \omega_{n1}\ell}{\omega_{n2} - \omega_{n1}}\right)^2 \ell^2}$$

$$= \frac{K_T}{\left(\dfrac{\omega_{n1}\omega_{n2}}{\omega_{n2} - \omega_{n1}}\right)^2 \ell^2}$$

$$= \frac{K_T}{4\pi^2 \ell^2 / (T_2 - T_1)^2} = \frac{K_T (T_1 - T_2)^2}{4\pi^2 \ell^2} \quad (11)$$

Where K_T is the torque contant in ft-lb/rad, T_1 and T_2 are the periods of oscillation in sec, ℓ is the change in length of the moment arm in ft, and M is mass in slugs (lb/32.2). Therefore, this method yields the mass M in terms of two periods of oscillation, the torque constant K_T, and the change in length of the moment arm.

Accuracies in measuring the parameters in Eq. (11) are expected to be within 0.1% for each of the periods, 0.01% for the length of change in moment arm, and 0.1% for the torque constant K_T. Greater accuracy is possible if a known reference mass is also tested for calibration purposes. The above accuracies would yield an overall accuracy (worst case) of approximately, 0.7%. Actual weight measure-

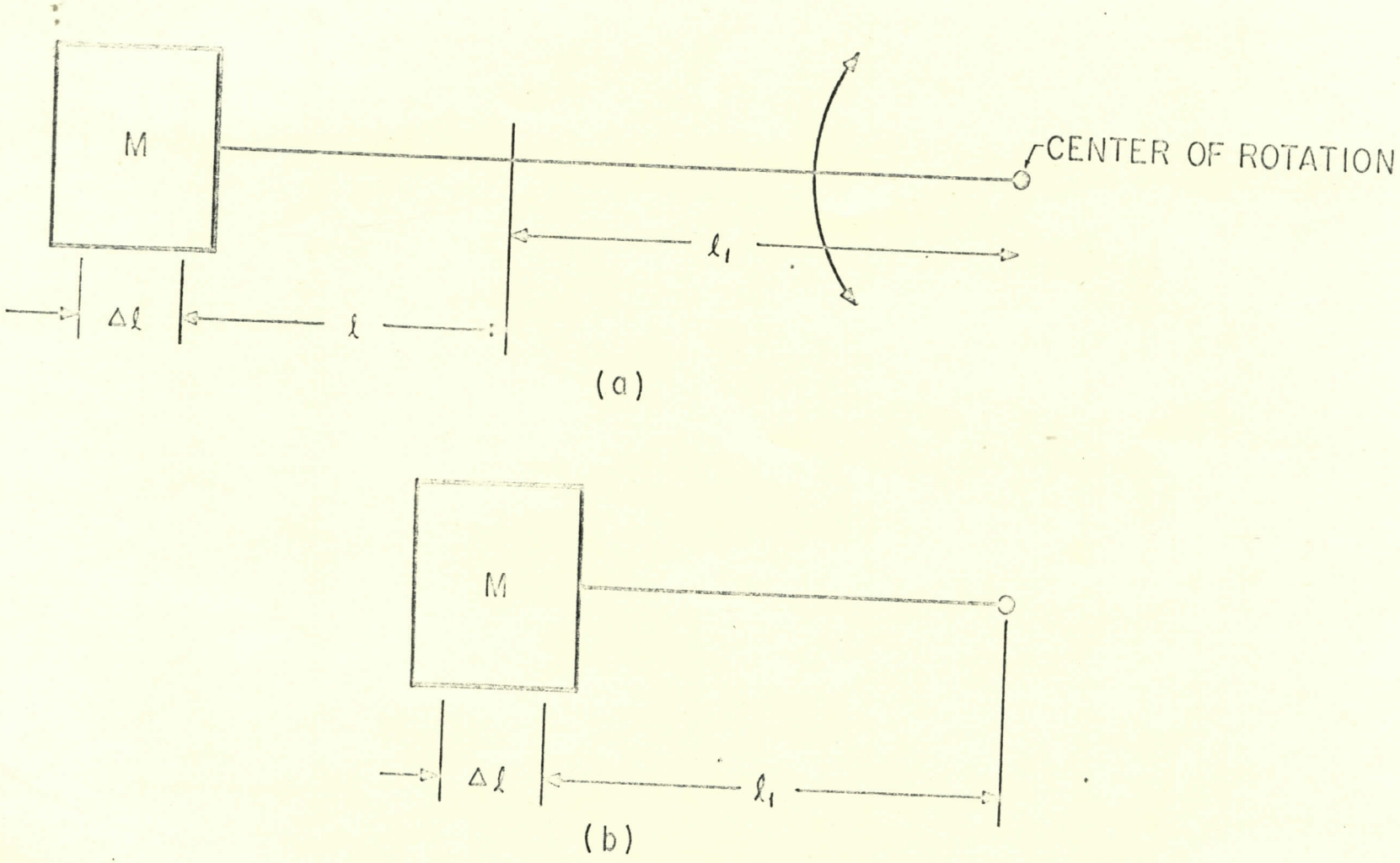

Fig. 3. Simplified sketch of proposed system.

EXPERIMENT P-12 DATA MANAGEMENT PLAN

REVISION NUMBER 1

The data load of Experiment P-12 places a severe burden on the on-board recording and telemetry equipment envisioned for the MOL. It has become apparent that this load must be reduced, particularly if plans are made to use the Gemini tape recorder and VHF telemetry rather than a newer recorder and UHF telemetry. This revision represents an attempt at reducing the total data bits per day without serious compromise of P-12 measurement objectives.

The parameter that contributes the most to the Experiment P-12 data load is the heart rate measurement (continuous). This analog signal, which is essentially an electrocardiogram, has a bandwidth of 33 cps and creates a data load of 129.6 megabits per man per day. It is the only physiological parameter that is to be sensed continuously.

It was originally felt that it would be more desirable to convert the electrocardiogram into a rate signal on the ground rather than on-board the vehicle. This approach offered greater reliability and an opportunity to use the raw information for medical monitoring purposes should this be desired. Unfortunately, it now appears to be an extravagent procedure in terms of data transfer capability.

Since continuity of heart rate data is highly important the only acceptable point of retreat for reduction of data load is on-board compression of the electrocardiographic signal.

There are two methods that have merit. First, a signal conditioner might be developed which could reliably and accurately detect the R wave of the ECG. The conditioner would generate a pulse of uniform amplitude and width of approximately 80-100 milliseconds. The pulse train would be sampled at a rate sufficient for the desired accuracy. The presence of a pulse would generate a "1" bit, and the absence would generate a "0" bit. Bit saving would be accomplished by removing the requirement for describing each sample in amplitude and sign. Channel coding would still be required, however, and the ground decoding equipment would probably become more complicated. An accuracy of 1% in heart rate measurement could be obtained even at rates of 240 beats per minute by sampling at a rate of 400 bits per second. Compared to a bit rate of 1320 bits per second for transmitting the analog signal, this technique would reduce the bit rate by a factor of at least 3.

A second approach would be to measure the interval between heart beats on-board and transmit only the rate signal to the ground. If this can be accomplished satisfactorily the bit rate may be reduced by an appreciable factor. Assuming an accuracy requirement of 1% and a redundancy requirement of 3 at the highest heart rate (240 beats per minute), then the heart rate data would require only 4 beats per second X 8 bits per sample X 3 samples per beat, or 96 bits per second. This reduces the bit rate compared to analog reproduction of the wave form by a factor greater than 100. Depending on the sampling rate, S/N ratio, etc., more than 3 samples per beat may be required to make certain that at least one sample is received accurately. Even so, the bit saving may still be quite high.

The second largest quantity of data from the standpoint of total bits is the electroencephalogram (EEG). Previous efforts to reduce the data load from EEG resulted in the decision to monitor only one astronaut per 24 hours rather than both. Also, only one channel of EEG is being taken, instead of the more useful four channels. If necessary, it is believed that meaningful data could be obtained if EEG data is collected on a sampling basis, i.e., 2 minutes on, 1 minute off. The data load would thus be reduced by one-third, but the data gathered would also be reduced by the same factor. At this stage it is not possible to determine if interpretability of the data will be reduced to an injurious extent. A more preferable alternate may be to reduce the frequency response of the EEG channel from 67 cps to 45 cps. This will result in an EEG record which, while not clinically acceptable, will be suitable for diagnostic monitoring. The bit load per day will not be greater than that obtained by the "2 on - 1 off" method and it does have the advantage of providing a continuous recording during sleep.

The above discussion outlines several methods for reducing the data load for heart rate and EEG monitoring. The first method of sending pulses instead of actual wave form is preferable to sending rate, and results in one-third less data load, or approximately 86 megabits per day for both astronauts. The EEG may be reduced by either approach outlined above, thus bringing the load to 57.6 magabits per day.

Using day #2 as an example since the bit load is highest on this day the bit load may be decreased from 487.62 megabits to 286 megabits. This

reduces the dump time from 30 minutes every sixteen hours to 18 minutes per sixteen hours, assuming a VHF telemetry system with a bit rate of 330 kilobits per second.

The second method of reducing the heart rate data load increases the on-board equipment complexity but may simplify the ground decoding equipment. Using this method the heart rate bit load is reduced to 1.63 megabits, and the total bit load for day #2 is brought down to 201 megabits. The dump time is correspondingly reduced to approximately 13 minutes.

reduces the dump time from 30 minutes every sixteen hours to 18 minutes per sixteen hours, assuming a VHF telemetry system with a bit rate of 330 kilobits per second.

The second method of reducing the heart rate data load increases the on-board equipment complexity but may simplify the ground decoding equipment. Using this method the heart rate bit load is reduced to 1.63 megabits, and the total bit load for day #2 is brought down to 201 megabits. The dump time is correspondingly reduced to approximately 13 minutes.