

- Any physical damage or degradation which impairs the operational design characteristics of the component
- Any loose, bent, cracked, or otherwise damaged or improperly adjusted parts resulting from the test inputs

5.4.7 Testing Level

Tests will be conducted at the system level of assembly if practical. If testing at this point is not practical because of equipment size and complexity, the testing will be performed at the next lower level of assembly.

5.4.8 Test Mounting

Equipment will be mounted in a manner simulating the actual mounting in the spacecraft for all environmental tests in which such mounting is expected to affect the equipment.

5.4.9 Failure Reports

Failures (as defined in Section 5.4.6) encountered during environmental qualification testing must be reported immediately, followed by a Failure Analysis and Corrective Action Report for review. Modification of hardware configuration as a result of failures will invalidate previous testing. The extent of retesting will be subject to NASA approval.

5.4.10 Qualification Approval

A final environmental qualification test report must be submitted for approval. The qualification test program must be scheduled so as to allow sufficient time for failures, rework during testing, preparation of the final test report, and review after submittal. Qualification approval may be considered and granted, on a case-to-case basis, upon presentation of documentation that the equipment was tested to equivalent or more rigorous levels of environmental testing.

5.4.11 Qualification Status

A status report of the qualification testing will be included by the contractor in the Monthly Progress Report. This status report will indicate those tests which have been completed at the time of the report and those yet to be performed.

5.4.12 Inspection

Government source inspection is required for all environmental qualification testing.

5.4.13 Ambient Laboratory Conditions

Unless otherwise specified, tests will be performed under the following ambient conditions:

- Temperature: $25^{\circ} \pm 10^{\circ} \text{C}$ ($77^{\circ} \pm 18^{\circ} \text{F}$)
- Relative humidity: 15% to 90%
- Barometric pressure: Local ambient

5.4.14 Test Parameter Measurement and Tolerances

A list of all measuring equipment (described by make, model serial number, accuracy, range, and date of last calibration) will be included in the reports of the tests for which they were used. Instrument calibration will be traceable to the prime standards at the U. S. Bureau of Standards. The instruments will be sufficiently accurate to assure that errors are less than one-fifth the tolerance for the variable to be measured. Maximum allowable tolerances, unless otherwise specified, will be as follows:

- Temperature: $\pm 2^{\circ} \text{C}$ (3.6°F)
- Altitude: $\pm 5\%$
- Relative humidity: $+5\%$ to -0% (of R.H. value)
- Vibration amplitude: $\pm 10\%$
- Vibration frequency: $\pm 2\%$

5.4.15 Stabilization of Test Temperatures

Unless otherwise specified, temperature stabilization will be considered attained when the temperature of a centrally located experiment hardware component, or that part of the experiment hardware with the largest mass, does not change more than 2° C/hr.

5.4.16 Environmental Test Requirements

The environmental tests to be accomplished for qualification of experiment hardware are separated into the following test groups:

- Earth environment
- Spacecraft environment
- Space environment
- Orbiting workshop or module environment

Test required for more than one group may be combined into a single test if the various test objectives are not compromised.

5.4.16.1 Earth Environment. Specifications and tests for this category are as follows:

- Temperature/Humidity. The equipment will be subjected to a humidity test in accordance with Method 507 of MIL-STD-810 (USAF), except that the maximum test temperature will be 49° C (120° F).
- Salt Fog. MIL-STD-810A (Method 509.1) will apply. This test may be eliminated on certain articles if it is shown that the equipment will not be exposed to this type of atmosphere.
- Fungus. MIL-STD-810A (Method 508.1) will apply. Fungus test may be eliminated upon certification that fungus nutrient materials have not been used, or that, where used, adequate protective treatment has been provided.
- Vibration. MIL-STD-810A (Method 514.1, Curve A, Fig. 514-6) will apply. Time Schedule IV of Table 514.1 applies except that resonance dwell time shall be ten minutes per equipment axis per resonant frequency. If the random vibration test (Spacecraft Environment) is to be conducted, this test will be eliminated.

- Sand and Dust. MIL-STD-810A (Method 510.1) will apply. This test may be eliminated if exposure to this type of atmosphere will not occur.
- Rain. MIL-E-5272C(ASG), Procedure II, will apply. This test may be eliminated for components which will not be exposed to rain.
- High and Low Temperature. These tests are covered in Section 5.4.16.2.

5.4.16.2 Spacecraft Environment. This group includes the following tests and requirements:

- Shock. MIL-STD-5272, Procedure IV, will apply, except that the unit will be subjected to a peak acceleration of 30 g for 8.5 ms duration.
- Acoustical Noise. MIL-STD-810A (Method 515.1) will apply, except that the exposure time will be 10 min.
- Pressure (Positive). This test will apply to any hermetically sealed equipment. The test specimen will be placed in a chamber and pressurized to 25 psia $\pm$ 0.5 psia for a period of not less than 15 min. This test will not be conducted if the test equipment is not to be pressurized.
- Acceleration. MIL-STD-810A (Method 513.1, Procedure I) will apply, except under the following circumstances:
 - Longitudinal Axes. Linear increase in acceleration from 1 g to 7 g in 60 sec.
 - Lateral Axes. Linear increase in acceleration from 1 g to 4 g in 5 sec.
- Vibration. MIL-STD-810A (Method 514.1 for ground-launched missiles) will apply. The test equipment will not be in operation during the test.
- High and Low Temperature and Low Pressure. Since the IMBLMS may be located in either a vacuum or pressurized area within the spacecraft, the equipment, including the experiment canisters, must be subjected as completely as possible to full ascent and orbital temperature and pressure conditions and testing.
 - High Temperature Test. MIL-STD-810A (Method 501.1) will apply, except that the exposure period will be at least 4 hr at the stabilized temperature condition.

- Low Temperature Test. MIL-STD-810A (Method 502.1) will apply, except that the temperature will be stabilized for 4 hr at -22° F.
- Low Pressure. MIL-STD-810A (Method 500.1, Procedure II) will apply. The minimum test chamber pressure will be equal to or less than 1×10^{-5} mm Hg.
- Electromagnetic Interference (EMI) Compatibility. Electrical, electromechanical, and electronic equipment will be tested to MIL-STD-826 for EMI generation and susceptibility.
- Magnetic Fields. Where permanent or residual magnetic fields exist in the equipment, they will be measured and field strength reported for distances of 1 and 2 ft from the source. Acceptable field strength will be determined, depending on mission requirements and magnetically susceptible equipment to be flown.

5.4.16.3 Space Environment. Test requirements for this category are as follows:

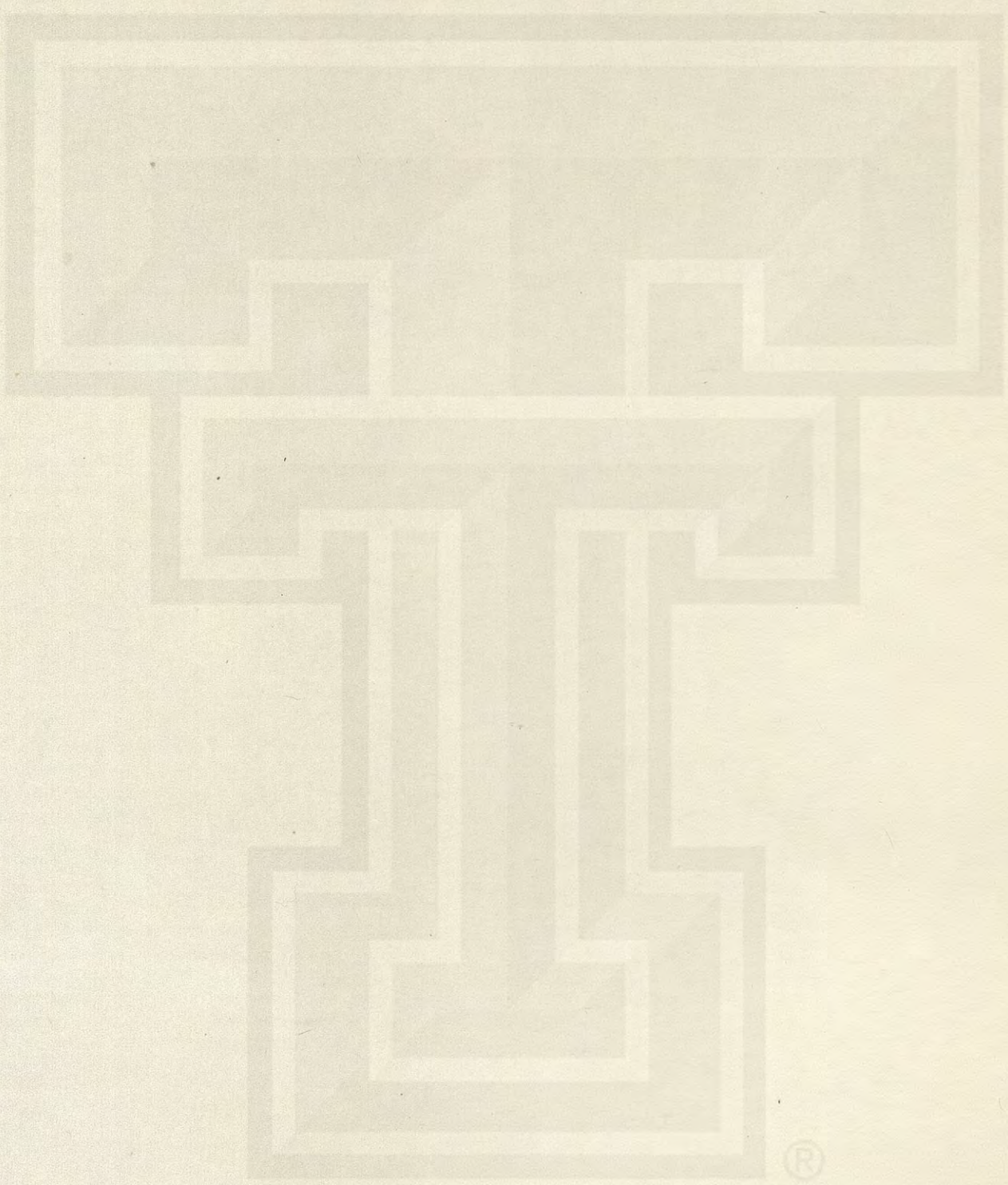
- Low Pressure. MIL-STD-810A (Method 500.1, Procedure II) will apply. The minimum test chamber pressure will be equal to or less than 1×10^{-5} mm Hg.
- Low Pressure Solar Energy and Meteoroid Impact. These tests are waived since IMBLMS equipment will not be subjected to these environments during flight.

5.4.16.4 Workshop - Space-Module Environment (Equipment Operational Checkout).

All IMBLMS equipment will be tested for satisfactory operation under ambient environmental conditions before being tested under any special environmental conditions. These checks will include but not be limited to the following tests:

- Electrical Compatibility. The following tests will be performed:
 - Power. Electrical components and assemblies will be tested for operation within specified performance criteria when subjected to abnormal power inputs.
 - Output. Tests will be conducted to verify workload range, voltage, frequency response, and impedance.

- Electromagnetic Interference and Isolation and Grounding.
- Structural Member Verification. This test will be conducted to ensure a 1.4 structural safety factor. It must be performed once on each component for which it is applicable, but repeated performances may be waived if visual inspection does not reveal any structural change in the component.
- Operational Testing. These tests will be considered accomplished by verifying equipment operation in an ambient environment under laboratory conditions and by performing the oxygen compatibility test.
- Oxygen Compatibility. The equipment will be operated in the workshop - space-module environment for 24 hr. Equipment which does not operate continuously will be operated through one duty cycle during the last hour of exposure. The temperature will be maintained at workshop ambient level during the first 16 hr and then raised to 49° C (120° F) and maintained for 8 hr. Performance will be within specification tolerance. Visible burning, creation of toxic gases or obnoxious odors, or deterioration of seals or lubricants during the exposure will render the equipment item unacceptable. Nonmetallic materials used must meet the requirements established in Ref. 5-4.



Section 6

DATA MANAGEMENT AND DISPLAY

6.1 OBJECTIVES

The major objective of the data management system is to accept, handle, process, display, and/or transmit efficiently the results of the medical and behavioral measurements performed with the IMBLMS. The following operational rules were established to aid in obtaining these objectives:

- Minimization of manual tasks required of the astronauts
- Maximum on-board preprocessing of data to reduce telemetry down-link time, particularly for advanced AAP flights
- Maximum use of the carrier digital up-link equipment, rather than voice, for ground-to-vehicle communications
- Minimization of ground station data processing

Further, to reduce the amount of new (to be developed and/or qualified) equipment, the use of existing, flight-qualified equipment was examined for implementation of an IMBLMS data management system.

Studies have indicated that the Manned Space Flight Network (MSFN) capabilities will approach saturation when it is necessary to accommodate data inputs from other programs running concurrently with the IMBLMS and AAP programs. Emphasis therefore will be placed on preprocessing data before transmission to the ground. Such preprocessing will permit faster ground station response and a subsequent reduction in ground station traffic.

6.2 REQUIREMENTS

A typical data management system for a space vehicle consists of fixed installation equipment which samples data from various transducers, puts the data in appropriate format for recording, records the data and plays them back through the spacecraft transmitters for relay to the ground. An on-board computer is provided primarily to perform computations on guidance-type data.

The IMBLMS, however, requires a data management system which, in addition to performing as a typical data system, can fulfill a multiplicity of special tasks unique to the IMBLMS concept. These special requirements are as follows:

- Modular construction to permit on-orbit system assembly and capability expansion
- Automatic data routing in response to measurement requirements
- Ability to log manual entry of numerical data
- A portable physiological monitoring unit for operation in the S-IVB, AM, CM, or LM, or in an IMBLMS console
- Programming of and acceptance of data from a behavioral test module and scoring of results
- Handling and processing visual data (e.g., slides, photographs, and specimens)
- Extraction of data from rotating devices
- Interface with an existing spacecraft data management system

6.3 CARRIER CONSTRAINTS

Table 6-1 contains a brief summary of the data management capabilities provided by the various candidate carriers for IMBLMS. The impact of these constraints on an IMBLMS data management system is discussed in the following pages.

Table 6-1
CANDIDATE-CARRIER CONSTRAINTS

ELEMENTS	RCM	LM	S-IVB OWS	Cluster
RF Equipment	VHF equipment removed; S-band retained	VHF and S-band equipment retained	Uses AM VHF (only) equipment	Also uses AM VHF equipment
Instrumentation	Timing equipment deleted; LM data processing equipment added; LM TV replaces CM TV; tape recorder modified for earth orbit; 30-min to 60-min record time	Possible addition: On-board checkout system using modified guidance computer equipment; vehicle tape recorder modified for earth orbit; 30-min to 60-min record time	Interconnect with LM, CM, or RCM by means of audio/power link only; AM has Gemini (4 hr) recorder which cannot accept sample rates required by IMBLMS; recorder W/FM mode needed; no processing equipment available	Interconnect with other vehicles via audio/power link only
Controls and Display	Deletion of CM unused equipment leaves 8 ft ² panel space	Added ATM equipment; if various ascent and descent equipment removed, 6 ft ² of panel space available; added keyboard and some biomedical monitoring capability (not completely defined)	Minimal; in AM only, needs extension of controls and/or displays in OWS	Same as OWS
Ground Stations	Scheduling of data reception may become problem when interleaved with Apollo in-line programs; reduction in ground contact to minimize problem (24-hr repeat orbit, time sharing of ground equipment, etc.) will necessitate some on-board preprocessing of biomedical and behavioral data; problem increases in intensity with lengthening missions and complex cluster configurations generating additional housekeeping data.			

6.3.1 Candidate-Carrier Capabilities

Two areas of capability – interspacecraft and down-link and up-link – are the major aspects considered in this section.

6.3.1.1 Interspacecraft and Down-Link. The S-IVB orbital workshop uses the airlock module (AM) data management system. The AM telemetry link with the ground is provided by VHF equipment. It has a dual transmitter and can simultaneously transmit real-time and stored data. As proposed, the AM has an input switch enabling an experiment data system to use either its transmitter or recorders.

The AM voice link to the ground is normally handled by means of a separate, duplex VHF link with the CM; the voice signals are relayed from the VHF link to the ground on the CM unified S-band (USB) equipment. Simplex voice communication for backup can be accomplished directly with the ground using these same transmitters. Figure 6-1 shows the communication links within the various carrier spacecraft, among the carriers, and with the ground links for the cluster configuration.

The CM normally communicates (voice and data) with the ground through its USB equipment. Biomedical data are transmitted only in real-time whereas other data can be transmitted in real or delayed time. Communication between the CM and the AM and for EVA purposes is obtained by means of the CM VHF equipment.

The LM communicates (pulse code modulation and voice) with the ground in real-time by means of its USB equipment. Communication between the LM and the other carriers, and for EVA, is accomplished through the VHF equipment. Since recorded data cannot be played back while the spacecraft is on orbit, delayed transmissions are not possible unless the data received by the CM are recorded and played back through the USB/ground link of the CM.

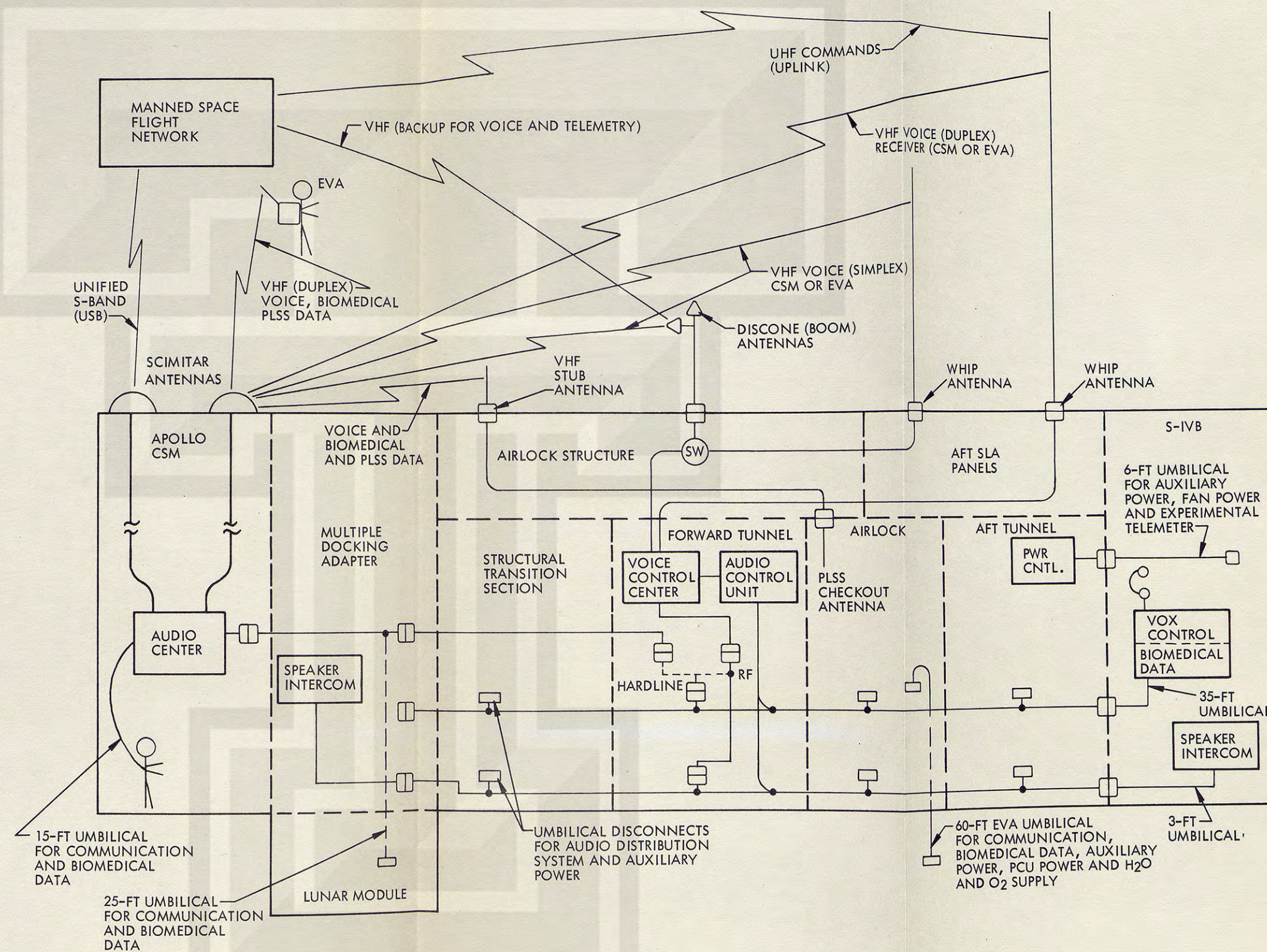


Fig. 6-1 Cluster Hardline and Radiofrequency Communication Lines

6.3.1.2 Up-Link. The AM will have 96 real-time, digital command functions on its UHF receiver (up-link) of which 18 are presently unassigned. The IMBLMS will consider the use of these 18 command channels for the following functions:

- Transmittal of experiment change and correction instructions
- Operation of an on-board digital printer for a communication link other than voice
- Ground control of IMBLMS recorder readouts, etc.

6.3.2 IMBLMS Compatibility

Operation of the IMBLMS should introduce no major data management problems (other than scheduling interface with carrier status data) when the CSM/LM is the candidate carrier.

Operation of IMBLMS with the S-IVB presents a bandwidth problem for the proposed TV system. A 1-mHz bandwidth is desired for maximum definition while the AM VHF transmitters are limited (FCC and IRIG standards) to a 500-kHz bandwidth. Video data compression is under consideration for resolution of the problem; however, the installation of USB equipment in the AM will make the module compatible with all spacecraft and ground stations and alleviate bandwidth problems, and warrants serious consideration by NASA.

Because each candidate carrier has its own tailor-made data management system for vehicle status data, the IMBLMS will generally interface only with the carrier transmitters and command receivers. None of the existing carrier data management systems can completely fulfill the IMBLMS requirements. Separate transmitters and receivers have been considered for the IMBLMS; however, this will require additional ground equipment and definitely overtax the data-handling capabilities of the MSFN.

Although the existing candidate carrier data management systems will not be used by the IMBLMS, the various individual flight-qualified items of equipment that make up those systems have been reviewed for IMBLMS use (see Section 6.5).

6.4 SPECIFIC PROBLEMS

Data entry, on-board computation, storage and return of test specimens, portability requirements, and up-link data receipt are major concerns of the IMBLMS data management system.

6.4.1 Data Entry

Data to be entered into the IMBLMS data management system takes many forms, each having its own peculiar handling requirements.

Analog data will be routed, in most cases, directly to the data management magnetic-tape recording equipment and/or an oscillographic display. Actual recordings will be accomplished under the astronauts' direct manual control. Playback for transmission to the ground will be under astronaut direct manual control or the digital command up-link.

Logging numerical data presents a different problem. These data include information which is manually recorded at various locations in the carriers during an actual measurement/test situation and then returned to a central data management console for entry and transmission to the ground. The foregoing data can be vocally recorded and "dumped" to the ground during ground contact although, in general, voice data are easily garbled and lost. Further, the volume of data that can be recorded and played back in a given unit of time is relatively small when compared to other methods. Also, the handling of numerical data on a vocal basis will prevent its being available for on-board preprocessing, automatic computation, etc. Logging of numerical data by vocal means is therefore unreliable, inefficient, and noncompatible. Numerical data can also be logged by means of an on-board video camera and recorder combination. However, the quality of the data will be subject to handwriting clarity; the data will again be unavailable for on-board automatic preprocessing. This approach therefore represents an inefficient use of the bandwidth required by video transmission.

Numerical data therefore should be converted to an analog or digital format for recording and subsequent transmission to the ground during ground communications. Data

converted to an analog or digital format will also be available to the data management system for such functions as on-board processing and analysis before transmission to the ground.

Manual logs for the transmitted data will be preserved and returned at the end of a mission to provide redundant information. Although equipment for entering data at these remote locations is being considered, the added weight, space requirements, and necessary manipulation of this equipment during an actual measurement/test situation may preclude application of this approach.

White blood count, differential count, red blood-cell morphology, and urine sediment data are entered on slides which will, at a later time, be viewed and relayed to the ground by a telemicroscope - video-recorder combination. Identification data (e.g., astronaut, time of sample, type of test, etc.) can be placed on each slide and similarly recorded and transmitted. Details of this equipment are discussed in Section 6.5.

Some measurements require that the results be recorded/entered photographically by means of motion or still pictures or both. Since there are no unusual requirements in this area, such as high-speed filming, the IMBLMS will utilize photographic equipment planned for AAP use. It is not intended, due to the complexity of the development process and lack of a need, to produce film for playback in the spacecraft; however, the use of Polaroid-type still pictures for later return and/or immediate presentation to the IMBLMS television system will be reviewed.

A peculiar data handling and entry requirement occurs in the REVS experiment since electronystagmogram (EOG) data must be obtained from a test subject while he is seated in a revolving chair and at least two channels of data are required. Generally, slip rings are used to obtain data from rotating test fixtures. However, such rings tend to contribute noise to the data signals, and the character of the EEG and EOG signals makes it difficult to remove the slip-ring noise from the data signals. A short-range telemetry system therefore will be considered for transmission of the data from the test subject to the display and recording equipment.

The interior of the metal space laboratory acts as a large nonresonant cavity for radio-frequency electromagnetic fields. A rotating antenna will create rapidly varying standing wave patterns in the laboratory which cause large variations in signal strength at the receiver. In the REVS case, however, use of antennas to obtain the required data should be unnecessary. An inductive coupler mounted coaxially with the axis of rotation of the chair will result in most of the transmitted energy being coupled directly to the receiver with little variation in signal strength. The inductive coupler can be shielded sufficiently to prevent interference with experiment or communication equipment resulting from the use of this telemetry system.

A number of telemetry modulation methods can be utilized for the REVS telemetry system. Use of an amplitude-modulated system only is undesirable since residual signal strength variations due to the inductive coupler will create data accuracy problems. On the other hand, the accuracy of a pulse-code-modulated (PCM) system does not justify the greatly increased equipment complexity that would be involved.

The data bandwidths for EOG and EEG are 50 and 100 Hz, respectively, and are well within the limitations of standard, constant-bandwidth, FM subcarrier oscillators. Four of these bandwidths could be used in either an FM/FM or an FM/AM mode of transmission. There is little to choose between the two methods from a systems standpoint although circuit details may indicate a clear-cut choice. Space-qualified, sub-carrier oscillators are available, and few design difficulties should be encountered.

The telemetry transmitter and experiment signal conditioners will require a battery power supply if all slip rings are to be eliminated. This power source can be supplied as part of the REVS chair package or as part of the EEG and EOG experiment packages.

If additional data channels are required as part of the experiment, they can be supplied as additional FM subcarrier channels. The practical limit for this additional capacity is 15 channels if IRIG standard, constant-bandwidth channel assignments are specified. The complexity of the telemetry system will increase directly in relation to the number of data channels.

6.4.2 On-Board Computation

Data evaluation activity requiring astronaut visual and mental evaluation is required for the performance of such tasks as making adjustments to obtain optimum TV camera output or previewing data prior to recording in order to aid in minimizing the quantity of data ultimately transmitted to the ground. Color comparison charts and other miscellaneous instructional and procedural aids will be necessary to support these functions. In general, except for some controls directly associated with the data management equipment, these aids will be considered an integral part of the measurement equipment.

In most cases, automatic evaluation of data will be performed by a special-purpose IMBLMS digital data processor. The processor will provide an astronaut/physician with measurement results from numerous tests of which the following are representative:

- Average heart rate over specific time periods
- Mean integrated gas concentration from mass spectrometer input
- Derivation of cardiac electromechanical delay and isometric contraction phase from simultaneous measurement of ECG, PCG, and pulse contour values
- Computation of cardiac output by the carbon-dioxide rebreathing technique, using parametric input from the mass spectrometer
- Acceptance of data (pressure) from an esophageal catheter to measure negative chest pressures for CRT display and digital printout of pulmonary compliance

The preprocessing of data will reduce the amount of data to be telemetered to the ground regardless of the presence of an on-board astronaut/physician. If an astronaut/physician is a member of the spacecraft crew, his presence will improve the selectivity of the on-board processing.

Total tasks assigned to the on-board processor may be summarized as follows:

- Storage and control of behavioral tasks
- Establishment of signal routing for each measurement task

- Computation of task scores
- Acceptance of ground instructions for display and program correction
- Conversion of data for on-board alphanumeric display
- Removal of redundant data to minimize spacecraft-to-ground transmission time
- Performance of other computation as required

Processor software and hardware specifications will be presented in the final report.

6.4.3 Stored Specimens

Some IMBLMS measurements, mostly in the biochemical area, will require the on-board storage of specimens (e.g., blood, feces, and urine). Space required for this storage will be included as an integral aspect of the modular packaging concepts being established for the various potential carrier spacecraft. The return of stored specimens to earth can be accomplished at the completion of the mission, or by data capsules returned to earth before mission completion. Data capsules are tentatively proposed for the AAP, and will be considered as a secondary method of partially returning hard information.

6.4.4 Portability Requirements

As previously mentioned, one of the goals of the data management system was to provide a portable module for displaying and recording dynamic physiological data obtained at various locations throughout the spacecraft cluster (including the LM, CSM, MDA, and S-IVB carriers). Further, present AAP plans call for relaying EVA and LM biomedical data to the ground in real time, without any intervening on-board recording. (This elimination of on-board recording is probably due to the inability of the CM recorder to accommodate 0 to 50-Hz data.) It is planned therefore that the IMBLMS will extract the biomedical data from the receiver for recording and display on the IMBLMS dynamic physiologic monitor, and that EVA and LM voice signals will be similarly recorded. Communication among the CSM, LM, and EVA is normally handled by means of the VHF equipment, and the IMBLMS design will assure compatibility with this equipment.

6.4.5 Up-Link Data

On the longer missions proposed for AAP flights in which IMBLMS will be carried, ground-to-spacecraft contacts apparently will be more restricted (i.e., reduced in number) than on the current shorter missions. Problems underlying this potential restriction involve the number of personnel required for long-term manning of MSFN ground stations and other simultaneous Apollo missions, which also require use of MSFN ground stations. By providing an on-board digital printer, and judicious use of the processor storage capability, IMBLMS will be capable of receiving a large volume of up-link information in the shortest period of time. Printout of such information will provide hard copy for astronaut use. Also, if an on-board digital printer were available, records of biochemical and other data could be printed, thus avoiding manual logging.

6.5 EQUIPMENT EVALUATION AND INTEGRATION

Performance of IMBLMS data management requires the use of data recorders, memo recorders (voice), a video recorder and television equipment, equipment to perform data entry, display and control equipment, etc. Each of these items has been carefully considered by LMSC and, where applicable, a tradeoff evaluation has been made for final selection.

6.5.1 Numerical Data Entry Equipment

Numerical data must include, as a minimum, identification of the astronaut and the test, the time the test was made, and the value obtained for the test. Lockheed has concentrated on several approaches toward partial automation of the logging of data. One approach is to furnish each astronaut with a notebook providing space for describing the test and for writing the values and time. This information could then be entered into the master tape by means of a keyboard. Unfortunately, this keyboard entry method is susceptible to human error since it provides opportunity for the transposition

of digits during the keyboard entry process. Displays of keyboard selections prior to entry, should minimize such opportunity for human error.

Another approach is to furnish three half-size IBM cards with each test -- one for each astronaut. Each card will be identified for each astronaut in the following ways:

- Color-coded for the particular astronaut
- Astronaut name printed on card (together with test instructions)
- Prepunching to identify astronaut and test

Upon completion of the test, the astronaut will insert the card into the card reader, dial the digits required to express the value obtained for the test and the time of the test, and push the record button. At this point, the prepunched information, the values obtained, and the time will be entered into the master tape. The only possible human error with this procedure lies in the dialing to enter the test value and time.

On-board record maintenance also offers the advantage of allowing the astronauts to observe any trends in tests performed periodically. The availability of this information is likely to heighten astronaut interest in conducting time-line trend studies. It is suggested that the reverse side of each data transmission card be treated so that the date and test value can be entered in pencil.

The IBM card does present some disadvantages, such as the necessity of searching a stack of cards to locate a particular experiment, the possibility of card loss or mutilation, the continuing need to record data manually since measurement values will generally be obtained in locations remote from the data management system and an inherent inflexibility regarding the incorporation of changes or corrections required for a particular measurement procedure.

A third approach under investigation is the use of an on-board, alphanumeric printer which provides, in conjunction with entry switches, a hard copy of the data entered into IMBLMS for immediate (i. e., next ground-station contact) return to ground. This

technique will aid the astronaut in verifying his entry and also provide clean, clear data at the end of the mission for ground verification and further study, analysis, or other use.

Various types of entry switches, such as digit dials, rotary switches, and pushbuttons, have been considered, and two candidate configurations are presently under evaluation. A human factors evaluation indicated that the amount of astronaut time required to enter data on either type of switch was relatively equal; however, the flight-qualification status of these switches must be verified.

6.5.2 Magnetic Tape Recorders

Analog data will be recorded on an on-board magnetic tape recorder with a high-speed playback capability. This feature will enable the recorder to "dump" this data into the carrier telemetry transmitters for return to the ground. Playback of previously recorded analog and/or PCM data for possible display or data editing (more easily performed on the ground) will require extensive additional electronics. At this point in the study, this capability does not appear sufficiently important to warrant the added complexity.

Of the various magnetic tape-recorder requirements reviewed, portability (with or without a battery power source), ability to change reels, analog and digital recording capability, and cathode ray tube image reintensification for ZNP loop measurements have received major attention. A tradeoff was performed to compare the various recorder requirements against such factors as existing flight-qualified units, development costs, and weight penalties. It appears that the present Apollo CM recorder with some added electronics best meets the IMBLMS requirements. However, the CM recorder size and weight are not compatible with the IMBLMS modular requirements for portability when used with the dynamic physiological monitor; this lack represents a major drawback.

6.5.2.1 Data Recorder Requirements. At present, it is known that the CM recorder does not permit easy access to the tape reels and that it cannot record analog data for the 0 to 50-Hz range without additional electronics. The reel-changing ability was primarily considered for various behavioral auditory tasks and has been delegated to a separate memo recorder.

The CM recorder accepts five channels of digital information and seven channels of analog information (for direct recording). Four of the seven analog channels were not originally implemented but can be easily added. The direct recording analog capability does provide recordings with the widest frequency bandwidth but at the sacrifice of the lower frequencies. There are several approaches for extending the lower frequency capabilities; however, the simplest (an FM recording technique) requires voltage-controlled oscillators (VCO) to accept the analog signal and then record the oscillator output. Such a modification is proposed to meet the lower frequency requirements of the IMBLMS for performing such measurements as vectorcardiograph measurements (1 to 100 Hz), cardiovascular function assessment (1 to 100 Hz), human vestibular-function assessment (1 to 50 Hz), and neurological study (1 to 100 Hz). This modification should not affect the existing flight-qualified status of the CM recorder.

Among other recorders considered, those proposed for recording status information and experiment data in the AM are designed to record PCM data only. Any measurements resulting in analog data would have to be converted to PCM prior to recording. Without this analog capability, pertinent vocal comments could not be directly recorded on this unit. Airlock Module groundrules indicate that any voice recording will be handled with the CM recorder. Placing measurement data and voice data on two different data management systems (and subsequently on two different spacecraft-to-ground links), will create major data-correlation problems when the data are to be presented to ground-based observers.

The lunar module (LM) recorder was also considered but was immediately rejected since the unit had a record-only capability without provision for on-orbit playback. The recorder used for biomedical data on various Gemini missions was rejected for the same reasons.

6.5.2.2 Video Recorder. The proposed TV system for the IMBLMS is discussed in Section 6.5.3. It will require an on-board video recorder for which there is no flight-qualified unit. Under consideration for this purpose is a tentative LMSC design. This unit will weigh about 25 lb, consume approximately 20 w of power, and be about 8 in. × 10 in. × 6 in. in size. It will operate at 100 ips using 10 tracks (channels) on 0.5-in. tape, for a total recording capability of 24 min (2.4 min/track). Operating in the FM mode, it will utilize a 1.5-MHz carrier (giving about 1-MHz total information bandwidth) with a signal-to-noise ratio greater than 24 db.

Its purpose will be to record information on blood and urine specimens on slides, general cabin conditions, and some specific physical information, such as astronaut suit donning and doffing before and after EVA operations.

Further analysis will be conducted to finalize all the necessary parameters needed for the transmission and reception of specimen information in either black and white or color TV. The color system will use the same general method, with minor modifications, as that used under the Surveyor Program to obtain color photographs of the lunar surface. The color capability dictates that at least three frames of video (red, green, and blue) must be used to look at each field. Mechanical construction of the recorder necessitates a 3-sec run-up time to allow the recorder to reach the desired speed and 3 sec of coast-down time upon deactivation.

Medical requirements have established that the astronaut will perform at least three distinct tasks in which recording of the specimen will be needed. These tasks are as follows:

- WBC Count. For this measurement, 5 to 10 fields of interest will be manually located and recorded from the specimen slide. Automatic movement of the microscope stage is under consideration. Time savings and other advantages are being evaluated.
- Blood Morphology – Differential Count. The microscope slide stage will be located with a discrete area of interest positioned under the lens, and the

stage then will be automatically moved to allow scanning of 35 separate fields in a preprogrammed sequence.

- Urine Sediment. This measurement will repeat the WBC task, with 5 to 10 fields observed and recorded.

With a total of 55 fields to be recorded at a video rate of 1 frame/sec, there are two possibilities for videotape recorder utilization. If a color system is used, it will require, at 3 frames/field, a maximum of about 3 min/slide (including run-up and coast-down time of the recorder). Since the total recording time is limited to 24 min, these handling requirements limit the recording to 8 specimen slides at a time.

With a black and white system, 24 specimen slides can be recorded. Since the design time limit for videotape recorder operation is 24 min (within the constraints of reasonable size, weight, and power considerations necessary for spacecraft operation), it is apparent that further capability will require investigation of data compression techniques, or slower video frame rates. Data compression will require some development effort while a slower video frame rate will inject further complications in implementing the fast-erase feature needed to eliminate smearing or ghost images.

All information will be recorded utilizing the full 1.5-MHz bandwidth of the video recorder to provide the best possible resolution. However, the 500-kHz video-bandwidth constraint created by the AM VHF telemetry system will limit the readout rate to half-speed, thus requiring 48 min total readout time. Since the spacecraft period within range of each ground station is only 6 to 8 min, and since there will be 48 min of recorded information to be transmitted, the video information can be read out in segments while the spacecraft is within range of various remote ground stations equipped for video reception and recording. The segments could then be relayed (by RF links or physically) to the MCC for integration and analysis.

If readout can be made only over the MCC at MSC-Houston, and assuming total access to the ground station recorder, it will require approximately 2 days to dump each 48 min of video information. This is computed on a basis of 3 passes per day (24 hr) and a time-of-transmission of 8 min maximum.

6.5.2.3 Memo Recorder. A memo (scratch-pad) recorder is proposed for operation in only an audio mode. This recorder will be available to record running audio comments during an entire experiment or a measurement procedure whereas data from the measurement (with subjective auditory comments) will be recorded at preset intervals. These running comments will then be available to the astronauts and/or physicians for playback and manual numerical data entry after the experiment is concluded. By providing this memo recorder with interchangeable cartridges, it can also be used for various behavioral auditory tasks. Several memo recorders have been in use, or proposed for the various manned spaceflight programs, but none of these units provides for cartridge changing or on-orbit playback.

The proposed memo recorder will meet the following requirements:

- Recording time - 1 hr at 1 ips
- Replaceable cartridge - 300 ft of tape on 3-in. reel (changeable with gloved hands)
- Frequency response - 0.3 kHz to 3.0 kHz; direct record, voice only, single channel
- Speeds - fast forward and reverse; slow forward for recording only
- Compatibility - with astronaut microphone, earphones, and carrier audio center
- Size - 8 in. × 4 in. × 3 in. (96 in.³)
- Weight - 2 lb
- Power - 35 w; 28 vdc, unregulated

6.5.3 Television Systems

It is proposed that biochemical data (slides) be recorded by means of an on-board tele-microscope (integrated TV camera and microscope) and a video recorder. A second camera is to be provided for general observation and recording, particularly for the suit donning and doffing task. The camera redundancy also increases the reliability of this recording technique.

The TV system will be a 1,200 to 1,500 line/frame, high-resolution type in order to produce highest contrast and resolution. The Apollo TV camera is not suitable because it is not a high-resolution system, and is not set up for on-board recording. The cameras will interface with a CRT monitor (Section 6.5.4) and a tape recorder (Section 6.5.2).

6.5.3.1 Telemicroscope. As each slide is inserted into the telemicroscope, it will be necessary for the astronaut to recheck focus visually before exposure to the vidicon camera head. Since there is a wide range in the ability of the human eye to adjust when bringing an image into focus, and since the vidicon tube cannot duplicate this capability, a positive method is required for assuring consistency between the physiological and electronic focusing. Consistency is achieved by first focusing the reticle attached to the optical train leading to the vidicon, and then bringing the real image (slide) into focus until it falls on exactly the same plane as the reticle. The shutter in front of the vidicon will be equipped with circuitry attached to a photocell in order to vary the speed of the shutter in relationship to the amount of light available (similar to the electric-eye device employed in the Polaroid Land camera). This variation is necessary because the amount of light needed by the operator to view the specimen is far different from that needed for good resolution on the vidicon tube. This provision also assures uniform and optimum picture quality for each specimen.

Once the operator is assured that an optical focus has been achieved, he will press a switch to display the image on a 5-in TV monitor, and thus enabling him to verify that optimum visual conditions are present. The operator will then activate the videotape recorder, bring it up to proper speed, thus reducing excess tape usage, and then press another switch to start tape movement and recording at the same instant.

The recorder will be programmed to shut itself off as soon as a recording cycle is complete, and the entire process then will be repeated for the next slide. A high-speed erase feature will be provided for the camera so that when the shutter closes on the vidicon tube after exposure, it will completely erase itself and be ready to accept the next image with the highest possible resolution capability (i.e., without any ghost image).

Such information as astronaut name or number, date, time, and specimen description will be imprinted or taped on a small square on the side of the specimen slide. The astronaut will fill in the blanks, position the square under a 1 to 1 lens in the microscope, and scan one frame of video, thus providing identification for each specimen before it is viewed. The information therefore will not only appear in the video display but be physically recorded on each specimen slide for later ground analysis.

6.5.3.2 Color Capability. Additional information can be obtained from the telemicroscope equipment if the images are transmitted in color. Examination of the possibility of adding a color capability to the IMBLMS telemicroscope unit has indicated the feasibility of using the color wheel (three primary colors) filter method similar to that used to transmit color photos from the moon on the Surveyor program. It is not practical at this time to consider a commercial-type color-camera for the monitor system for the following reasons:

- This type of color equipment is beyond the present state-of-the-art for space applications.
- It presents a high development cost factor.
- The required bandwidth is beyond the Apollo constraints.
- The size, weight, and power requirements are prohibitive.
- The picture quality inherent in a complete color system is not really required since the IMBLMS television unit will be an instrumentation system required to observe only certain reasonably static chromatic conditions that will be present to some degree in each specimen slide.

Two methods were considered to implement the three-color scheme. The first provides for three separate sources (lamps) within the telemicroscope, with a filter of each primary color placed in front of each lamp, and then optical alignment to project through the image plane within the microscope. This approach is a prohibitive one since achieving the required alignment will involve an extremely delicate, sensitive, and difficult operation. A second and better method is to design a color wheel with the three primary colors built into it. This wheel will be positioned in front of the source and

electronically synchronized with the TV camera or rotated manually. The vidicon will then slow the scan to one frame per second and, for each frame or sequence of frames, a different color will be rotated in front of the source. Each desired image will require three frames or more of video to filter each of the three red, blue, and green color components within the image, and this information will be stored, frame by frame, on the video recorder for later transmission to the ground. At the ground station control, a Polaroid camera containing color film will be set up in front of the monitor, and the camera will be activated as each frame is received. The three frames containing the three primary colors will be photographed through the same types of filters as those used in the IMBLMS telemicroscope unit on-board the spacecraft and all will be impinged on the same film.

The IMBLMS telemicroscope unit can thus be implemented and a RETMA color chart can be used for chromatic calibration and verification. The possibility of having color filters available for use, only if required and under the direct control of the astronauts, is being studied.

6.5.4 Displays

A variety of approaches were considered regarding the display functions of the IMBLMS.

6.5.4.1 General. A display, on request, of an astronaut's respiration and heart rates, with out-of-tolerance alarm capability, was considered mandatory for monitoring of EVA and stressful conditioning requirements. These displays, together with other somewhat less critical information, will be displayed on vertical meters having adjustable high and low limit (visual and auditory) alarm points. Other non-set point types of display will be presented (wherever possible) on dual-range vertical meters or dual-range circular meters, depending on the scale and resolution requirements.

As previously discussed, the physiologic monitoring module containing the heart rate and respiration rate displays will be sufficiently portable to permit monitoring to be accomplished at various measurement locations in the candidate carriers.

6.5.4.2 Cathode Ray Tube. The dynamic physiologic monitoring module will contain a miniature cathode ray tube (CRT). This can be used to view sensor data before or during recording or transmitting. Viewing the sensor output will establish confidence in the correctness of the circuits, connections, and other operations and will be of assistance during calibration procedures.

A standard TV monitor, with an approximate viewing area of 25 in.² is proposed for use with the IMBLMS telemicroscope and other TV equipment. This monitor can be used to optimize the telemicroscope output and other TV observations made prior to video recording. The monitor will also have a capability for displaying a $\dot{V} - V$ loop, a ZNP loop for evaluation, a moving spot for the behavioral tracking task, and the same analog data as was presented on the miniature oscilloscope, but with much greater resolution.

6.5.4.3 Alphanumeric Display. This type of display has been considered for the presentation of the following information:

- Cardiometer output
- Verification of 0 to 9 keyboard activation before entry into a processor
- Analog signal amplitudes
- Blood pressure computations
- Processor register status
- Behavioral test scores
- Respiratory measurements
- Other miscellaneous measurements handled by the processor

Two types of alphanumeric display have been considered. One is the semipermanent illuminated type display which can be viewed, and which provides information that can be entered manually in a log (if necessary); the other is a permanent hard-copy display that can be achieved with an alphanumeric printer. The latter type will be used with the IMBLMS and will be available for verification of numerical data before entry into IMBLMS, for printout of computational results from an IMBLMS data processor,

and for printout of ground instructions containing measurement changes and deviations. This third function will most certainly occur on the long missions in which the IMBLMS will be used.

6.5.4.4 Miscellaneous. Certain biochemical measurement equipment will possess or require the inclusion of integrated displays which are not of an analog format and which cannot be directly entered into the data management system. These displays, requiring interpretation, analysis, logging, or other effort by the astronaut, will not be considered part of the data management system. The resultant interpretation, however, will be under the data management cognizance.

6.5.5 Data Processor

The possible utilization of the LM or Apollo guidance computers (representative of existing flight-qualified units) has been considered; however, their use presents two major drawbacks. The largest portion of the memories of these computers consists of a "rope" core which is fixed and can only be modified by ground-based equipment. However, a fixed memory will seriously hamper any changes or program revisions that may be necessary to meet unanticipated conditions during the long missions envisioned for IMBLMS application. Secondly, the Apollo computers are primarily intended for processing guidance equations and their use, if possible, for other types of curve fitting, computations, and similar operations, will be less efficient. General-purpose airborne computers available from other vendors will be studied, but appear to fall into the inefficient category. Consequently, a new special-purpose processor, with an NDRO memory capable of accommodating on-orbit revisions, will be designed to meet the unique computational requirement of the IMBLMS. It is anticipated that this processor, using microcircuitry and airborne packaging techniques well within the current state-of-the-art, can be housed in one IMBLMS module with a maximum dimension of 8.5 in. $\times$ 8.5 in. $\times$ 15 in.

6.5.6 Controls

There are no unique control requirements for IMBLMS; however, pertinent groundrules are presented in Section 6.6.

6.6 INTEGRATION OF IMBLMS EQUIPMENT AND SYSTEM REQUIREMENTS

In accordance with the LMSC modular approach to implementing the IMBLMS, the various data management system equipment units have been modularly configured to meet system requirements.

6.6.1 General Control and Display Rules

Final module designs will incorporate the following control and display philosophies:

- Arrangement of Controls and Displays – Determined on the basis of the following considerations:
 - Function (i.e., by subsystem)
 - Criticality of response time
 - Crew task loading
 - Mission phase
 - Control and display relationship (i.e., controls as close as possible to their associated displays)
 - Control operating ease and display legibility
- Types of Controls and Displays – Determined on the basis of the following considerations:
 - Hand operation with pressurized glove wherever possible
 - Display/control placement
 - Lighting conditions
 - Zero-g environment
 - Operating ranges
 - Resolution requirements
 - NAA/GAEC commonality
 - Function

6.6.2 Dynamic Physiologic Monitor

Figure 6-2 shows the concept of this module. Although it is not strictly a data management module, it contains (with appropriate controls) the data management data recorder and instrumentation oscilloscope (miniature).

This module can be used either in the data management section of the IMBLMS console or at any remote location where power is available. In its remote mode of operation, neither the oscilloscope nor the recorder can be used for other than the physiological data displayed by the various meters. All controls and displays are self-explanatory except the recorder slew button which causes the tape to advance or reverse at high speed.

6.6.3 Video and Display Monitor

Figure 6-3 presents the concept of an on-board combined video image and oscillographic display unit. This unit also contains the controls and displays associated with the video recorder.

The majority of the controls and displays are self-explanatory, except perhaps the input selection (INT/EXT). When this switch is in the EXT(external) position it activates the input coaxial connector so that only one input can be displayed on the screen. This mode is employed more often for maintenance purposes and allows external testing of transducer outputs and other aspects. In the INT (internal) position, this switch activates the four-channel input controls (directly above it) which automatically receive (under program control) appropriate measurement data for verification and other purposes, or which receive inputs manually selected through the CRT controls at the data management control module.*

*See Fig. 6-8.

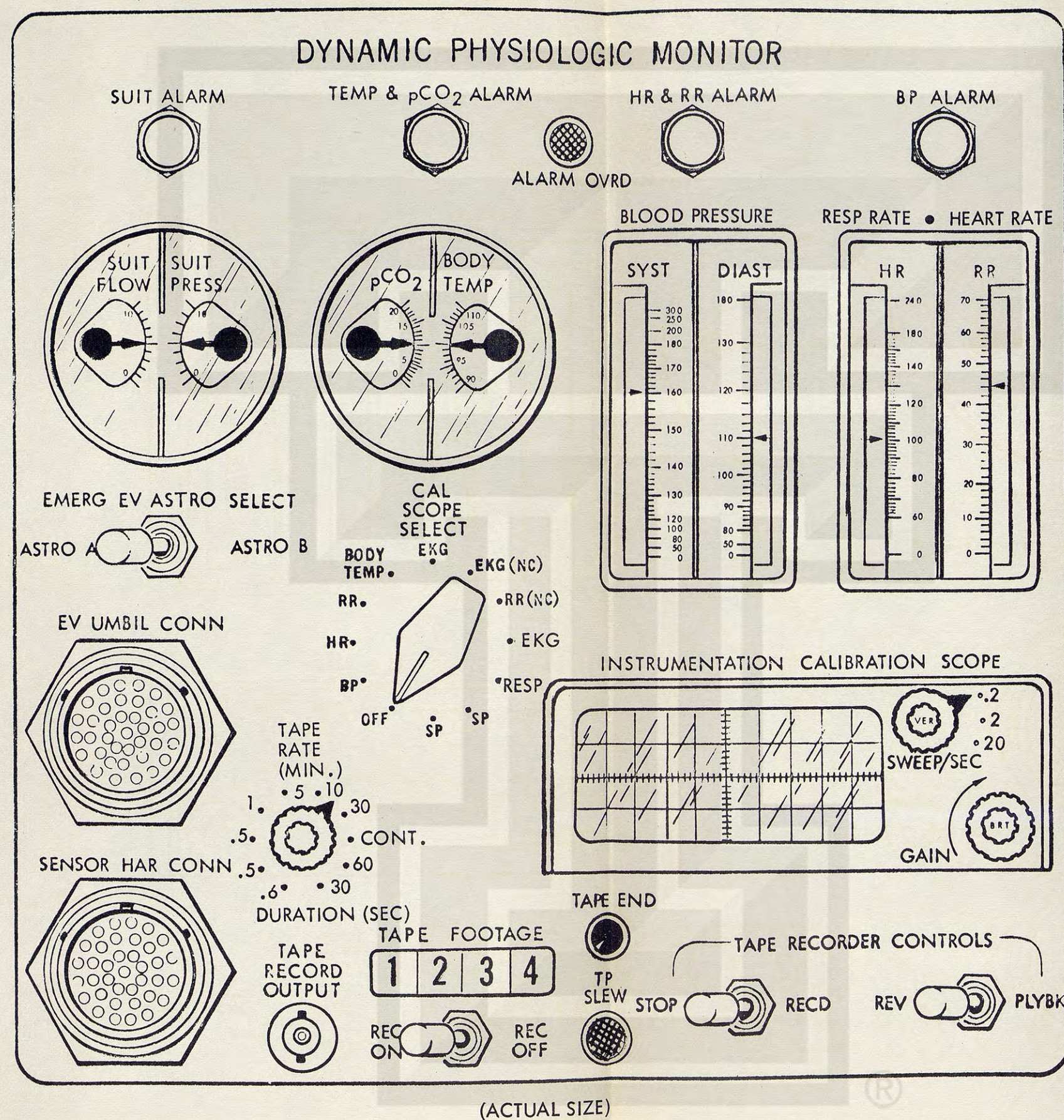


Fig. 6-2 Dynamic Physiologic Monitor

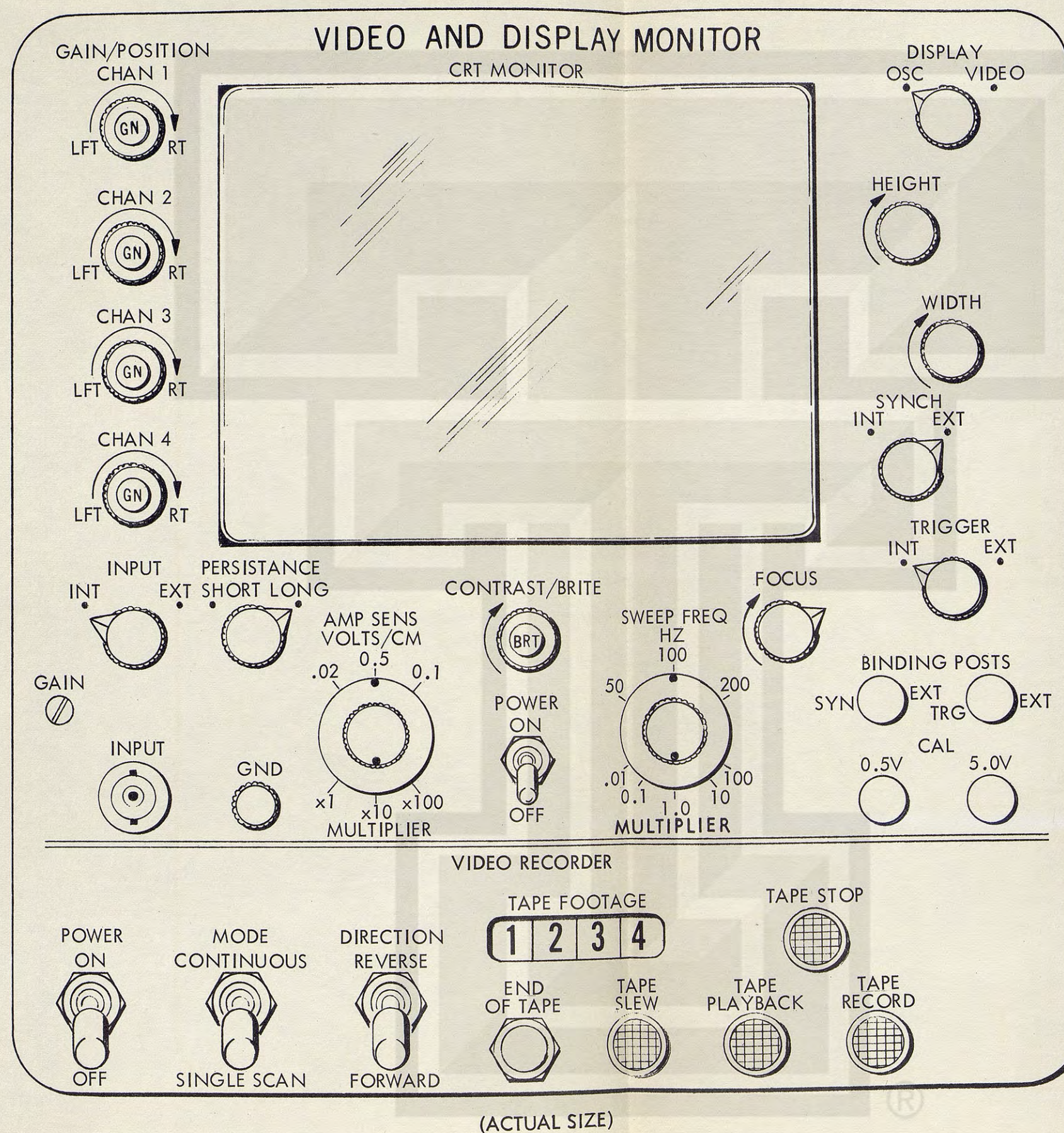


Fig. 6-3 Video and Display Monitor

6.6.4 Numerical Data Entry and Printer

Figures 6-4 and 6-5 present two candidate modules for the entry of numerical data into the IMBLMS, together with provisions for a hard-copy printout before actual recording. An interim storage area provides this capability. The printer, shown in both illustrations, is available for printing out computations occurring in the IMBLMS processor, ground (up-link) instructions, and similar data.

The candidate in Fig. 6-4, using digit dial switches, provides for entry of numerical data which have been obtained elsewhere, logged, and then brought to this station. After such items as day, organ system, test number, and test time i. e., (time of actual measurement) have been dialed in, a series of test values then can be entered. Only new values are recorded. The status data are only recorded with the first entry or if any of the status dials are changed. Printout of the dialed-in data can be obtained, prior to recording, by initiating the PRINT button. If an error is made, the CLEAR button can be activated and the data reentered. Once the data has been recorded, however, corrections cannot be made nor printout obtained. This is the LMSC-recommended candidate; however, it must remain a candidate until flight-qualifiable, digit-dial switches can be obtained. An alternate candidate, shown in Fig. 6-5, was created and utilizes the IMBLMS processor keyboard for entering the appropriate data. As the keys are selected for the day, organ system, test number, and test time, the selection will be displayed on alphanumeric displays. Actual entry of displayed data for recording, printout, and other operations will be made at this panel.

6.6.5 Data Management Processor

The data management processor module contains the necessary controls and displays for astronaut communications with the processor. Two candidates for this module were prepared. The candidate shown in Fig. 6-6 uses a pushbutton entry somewhat less complicated than the Apollo guidance computer keyboard and displays system, and the candidate shown in Fig. 6-7 uses the entire Apollo keyboard and displays, except that

the keyboard is recessed for ease of operation and for protection from inadvertent operation. Since the astronauts will be familiar with the Apollo unit, it therefore may be a more advisable choice; however, such selection may present the possibility of astronaut confusion and resulting improper program call-up.

Information on operation of the various controls and interpretation of the displays will be provided to astronauts through training and the issuance of an instruction handbook.

6.6.6 Data Management Control

This module (Fig. 6-8) is multifunctional. It provides remote control of the carriers' real-time (R/T) and delayed-time (D/T) transmitters, controls, and inputs for the TV cameras; a mission cumulative timer and an event timer; manual control of the four-channel inputs to the video and display monitor; and controls and displays (plus a housing) for the memo recorder.

Many of the controls are self-explanatory; however, any attempt to put more than one device on the same transmitter will cause the operator error (OPR ERR) display to be illuminated.

When one TV camera is in operation, it will automatically be displayed on the video and display monitor, provided the video and display monitor OSC/IMAGE switch is in the image position. Turning on both cameras will cause the OPR ERR display to be illuminated.

The memo-pad recorder can be operated either manually or automatically by means of voice-controlled relays. Fast-forward and fast-reverse controls are provided to reposition the tape.

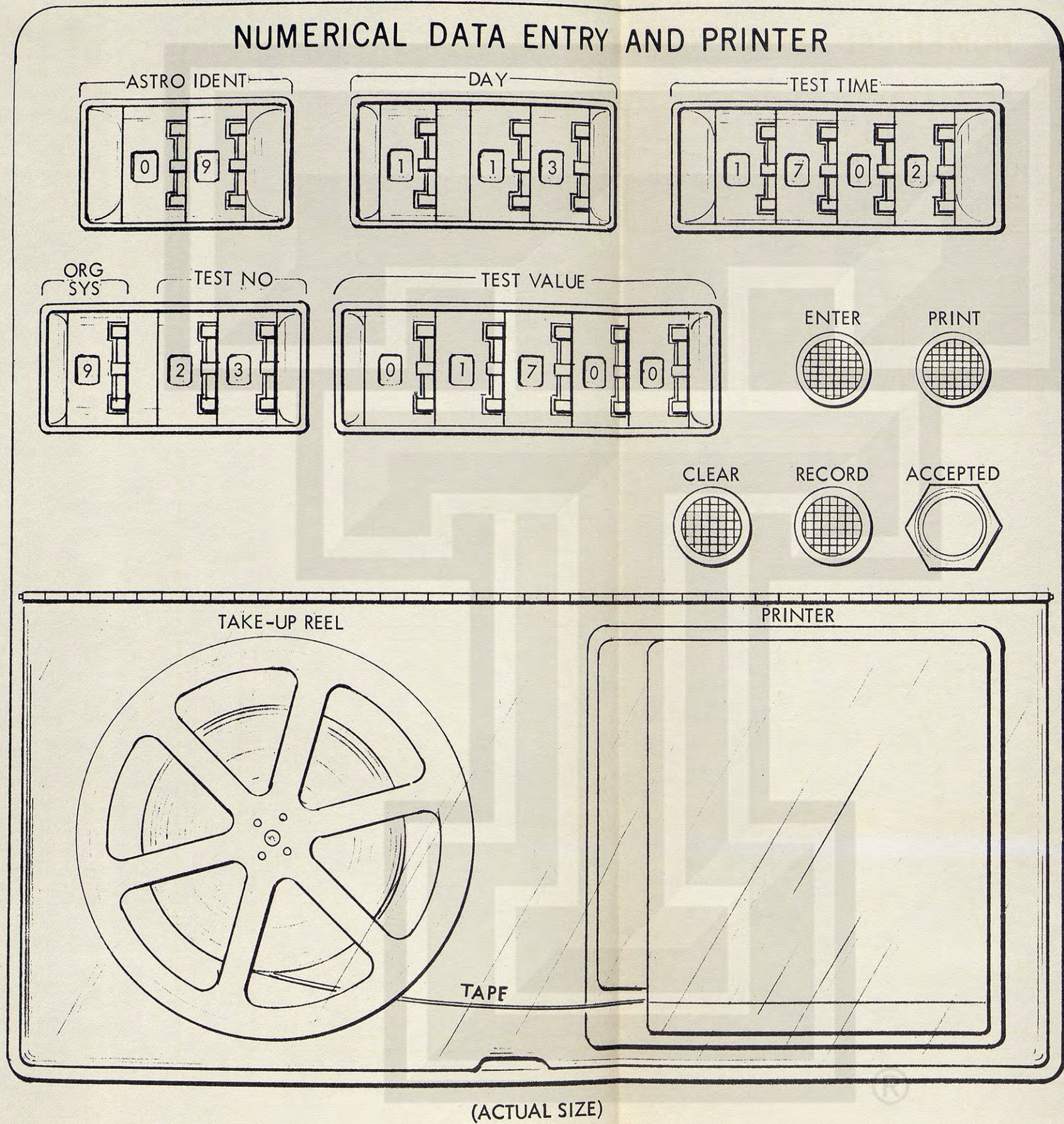


Fig. 6-4 Numerical Data Entry and Printer -
Candidate 1

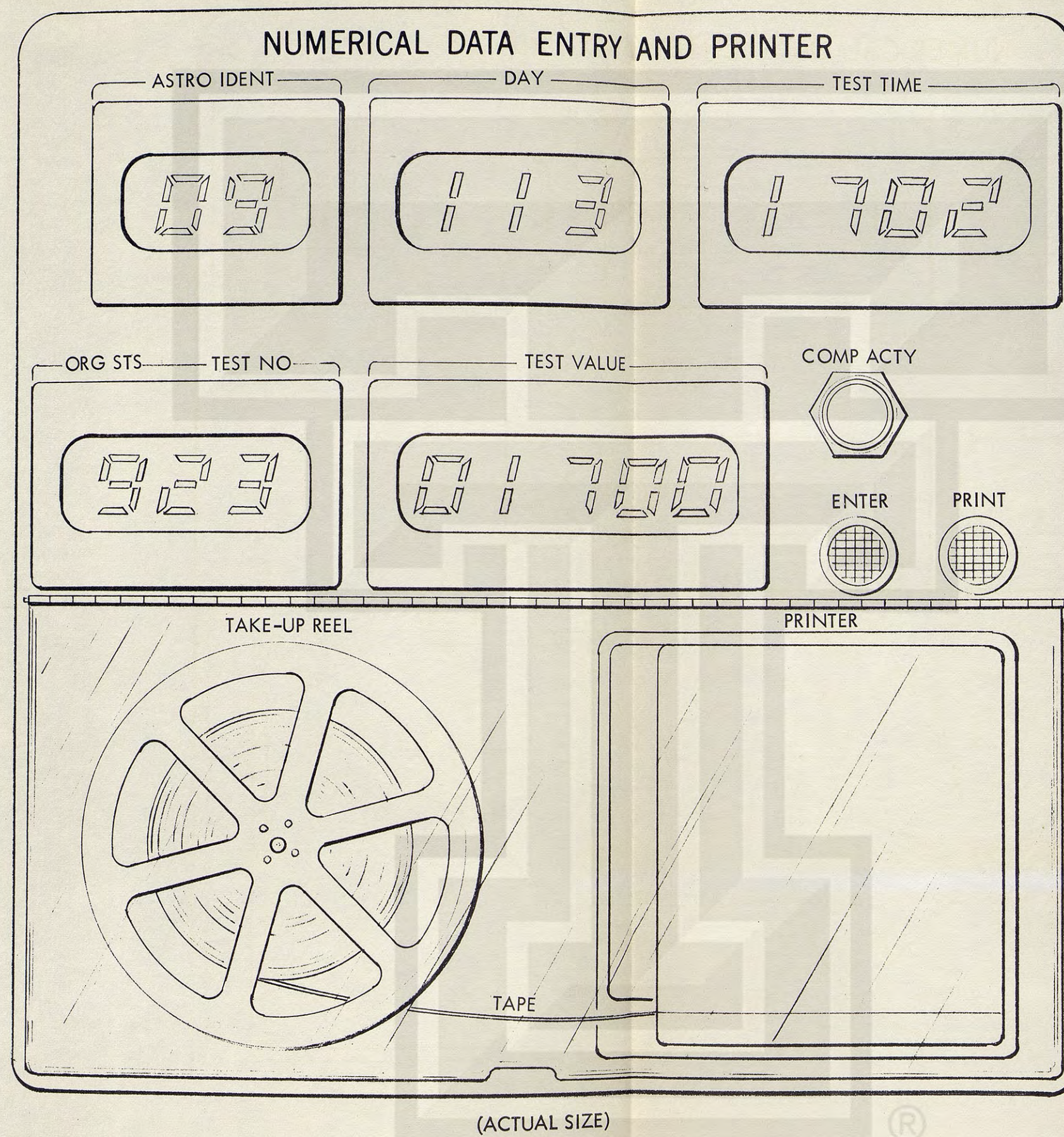


Fig. 6-5 Numerical Data Entry and Printer –
Candidate 2 (Alternate)

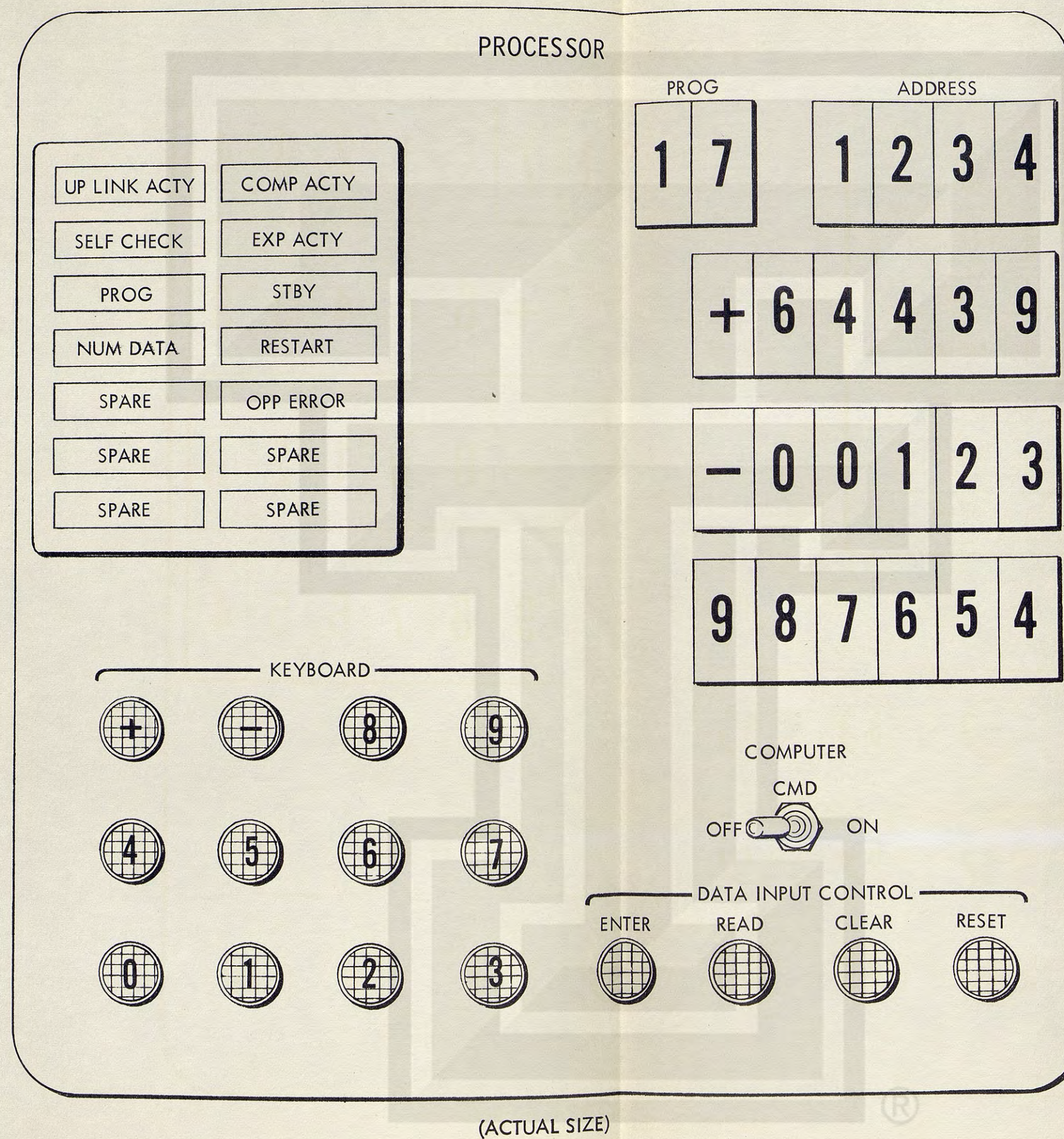
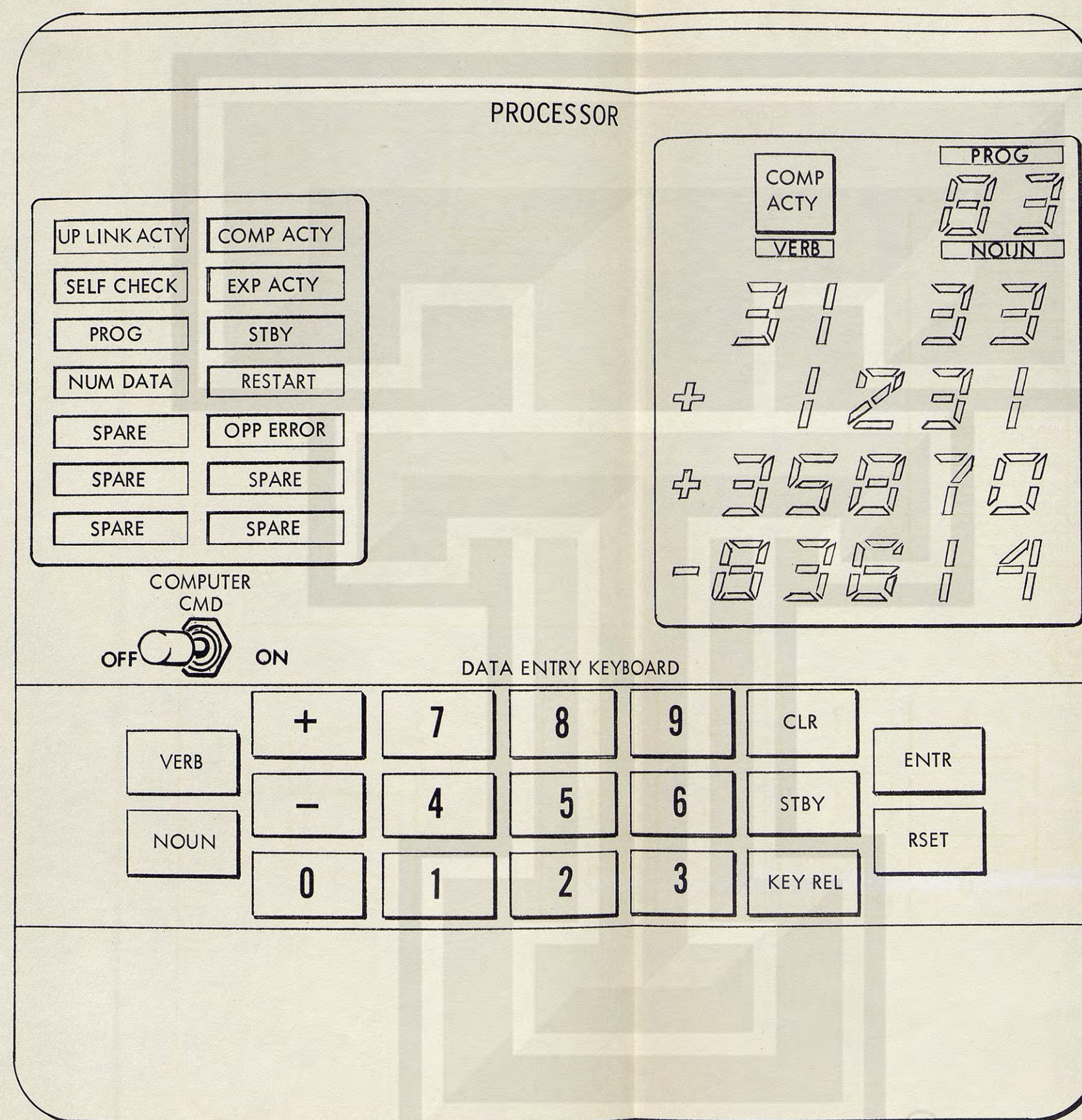


Fig. 6-6 Processor — Pushbutton Data Entry



(ACTUAL SIZE)

Fig. 6-7 Processor - Keyboard Data Entry
(Apollo)

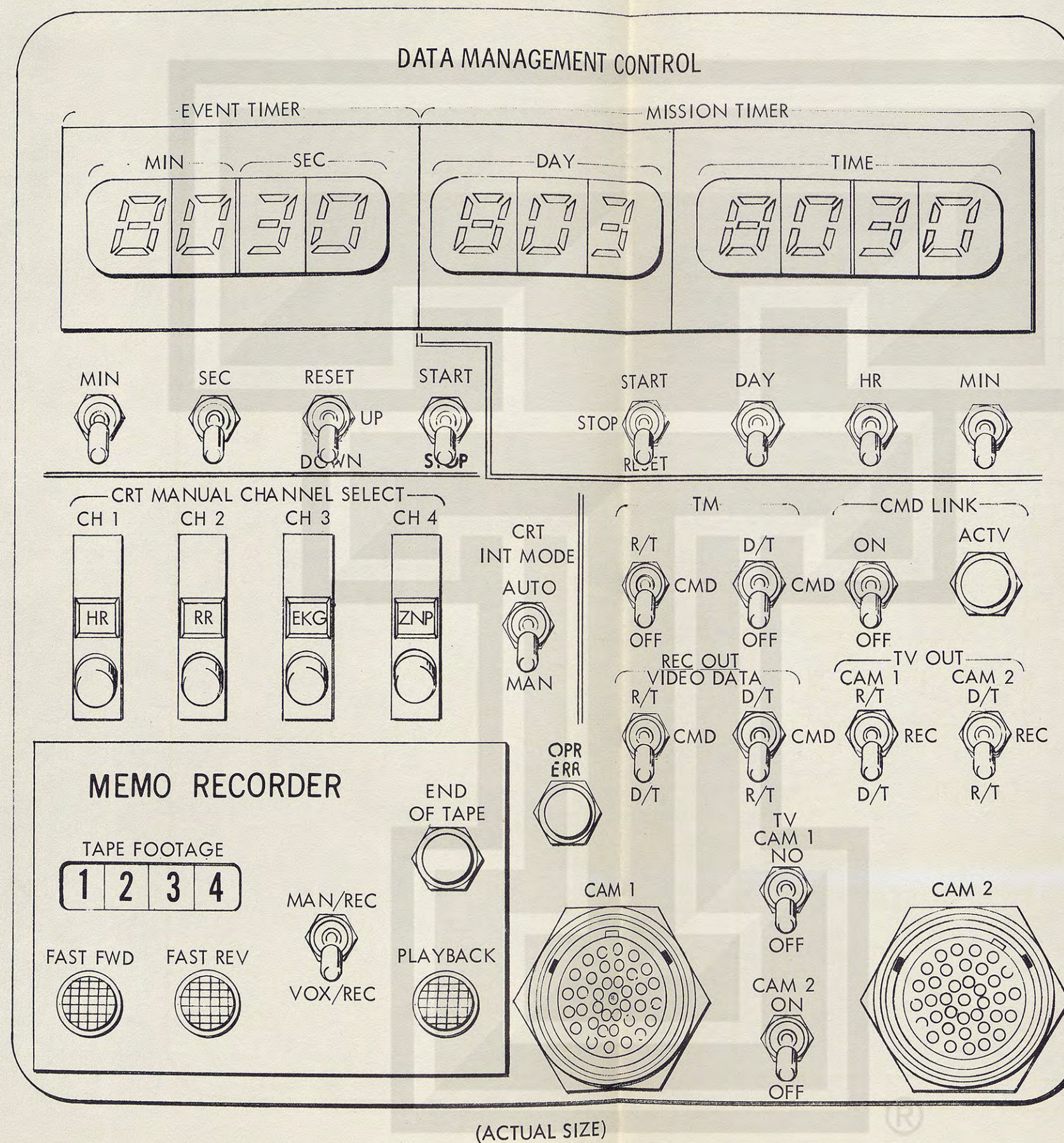


Fig. 6-8 Data Management Control Module

6.7 GROUND NETWORK CONSTRAINTS

Two sources of constraint due to ground network requirements have been considered.

6.7.1 Manned Space Flight Network (MSFN)

The ground stations of the MSFN serve as the remote arms for the MCC-Houston. There are 11 ground stations with 30-ft S-band antennas, three with 85-ft S-band antennas, 5 shipboard stations, and 8 Apollo range-instrumented aircraft. These stations should be available for support of the IMBLMS data, but care must be taken to minimize interference with in-line Apollo support requirements. The 30-ft ground stations will provide primary support to the early low-orbital-altitude missions for which the IMBLMS will be utilized. All stations have USB equipment, UHF command equipment, VHF telemetry receivers, two computers, at least two PCM decommutators (probably three or four), two wideband magnetic-tape recorders and other associated equipment. Each of the 30-ft, single, USB ground stations can handle one S-band I-M circuit, one S-band FM down-link, at least three UHF down-links, and a UHF up-link. The dual USB stations can accommodate two coherent PM circuits, two FM down-links (at those stations with four S-band receivers), and UHF and VHF links.

With the cluster-concept carrier, up to six data links must be simultaneously received and recorded at the dual USB stations (4 S-band and 2 VHF) and 4 links at the single USB stations (2 S-band and 2 VHF). NASCOM circuits for Apollo, between the ground stations and the MCC consist of the following:

- 1 TTY circuit (duplex)
- 1 or 2 voice circuits
- 1 biomedical data circuit
- 2 or 3 digital-data circuits
- 1 command circuit

Data processing, reduction, and archiving will present a problem. Data compression, both on-orbit and at the ground stations, will help relieve this situation.

6.7.2 Manned Space Center

The nerve center for the ground support of a manned space mission is at MCC-Houston. For the IMBLMS, MCC-Houston will be utilized in a similar manner as for in-line Apollo missions. This MCC-Houston complex consists of two mission operation control rooms (MOCR) each with a set of staff support rooms. The MOCR contains a series of consoles with the necessary controls and displays for flight control personnel. There are 16 console positions with at least one more position required to support experiment systems. Staff support rooms include Flight Dynamics SSR, Vehicle Systems SSR, Life Systems SSR, Flight Crew SSR, Networks SSR, and Operations and Procedures SSR. Experiment support will be required either as part of the Vehicle Systems SSR or in a separate room reasonably accessible to the MOCR.

Off-line data-reduction facilities are available at MSFC, MSC, and GSFC for use in data processing and reduction. Large scale computer systems are available at each of these NASA centers. However, with the MSFN obtaining data from many different programs, the greatest problem, besides manning the ground stations, is the transmission of these data to the large-scale computer centers at these facilities for performance of the necessary complete processing.

6.8 CONCEPTS STILL UNDER INVESTIGATION

General additional concepts for various elements of the data management system are still under consideration.

- TV Signal Compression. As previously mentioned, the bandwidth required for the TV system was not compatible with the AM VHF-transmitter bandwidth, and compression of the video signal therefore is being studied. The signal can be compressed in its analog form, digitized, and then recorded in a PCM format, thus eliminating the need for a video recorder, or it can be compressed and recorded in an analog form, with compression occurring after the information is reviewed on the monitor. Results of this evaluation will be provided in the final IMBLMS report.

- Flight-Qualifiable Hardware. As previously mentioned under the numerical data entry function, some of the candidates revolve around the lack of hardware, etc., that is, or which can be, flight-qualified. Various vendors are being contacted to resolve these questions before completion of final report.

6.9 OVERALL VIEW OF DATA MANAGEMENT SYSTEM

Figure 6-9 presents a preliminary, simplified block diagram of the on-board IMBLMS data management system equipment. This diagram also shows, by means of symbolic switches S1, S2, and S3, an equipment growth and system expansion concept that continues to utilize all the initial configuration equipment except several voltage-controlled oscillators. An early data management system could handle basic physiologic data along with numerical data. Follow-on equipment could include such items as the TV system and automatic data processing. A more detailed diagram to be presented in the final report will show the modular interconnections and signal routing between various modules and candidate carrier interfaces.

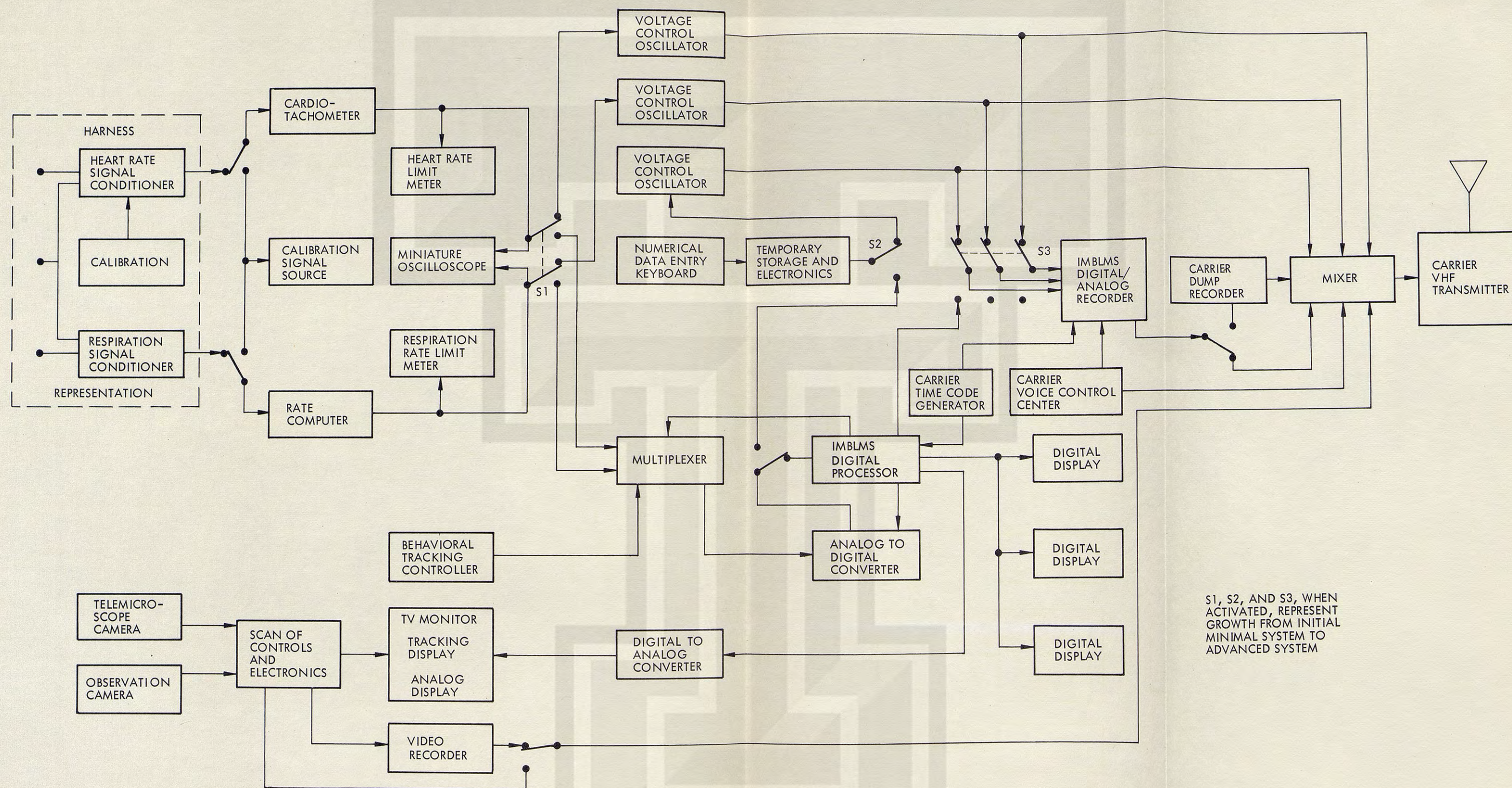
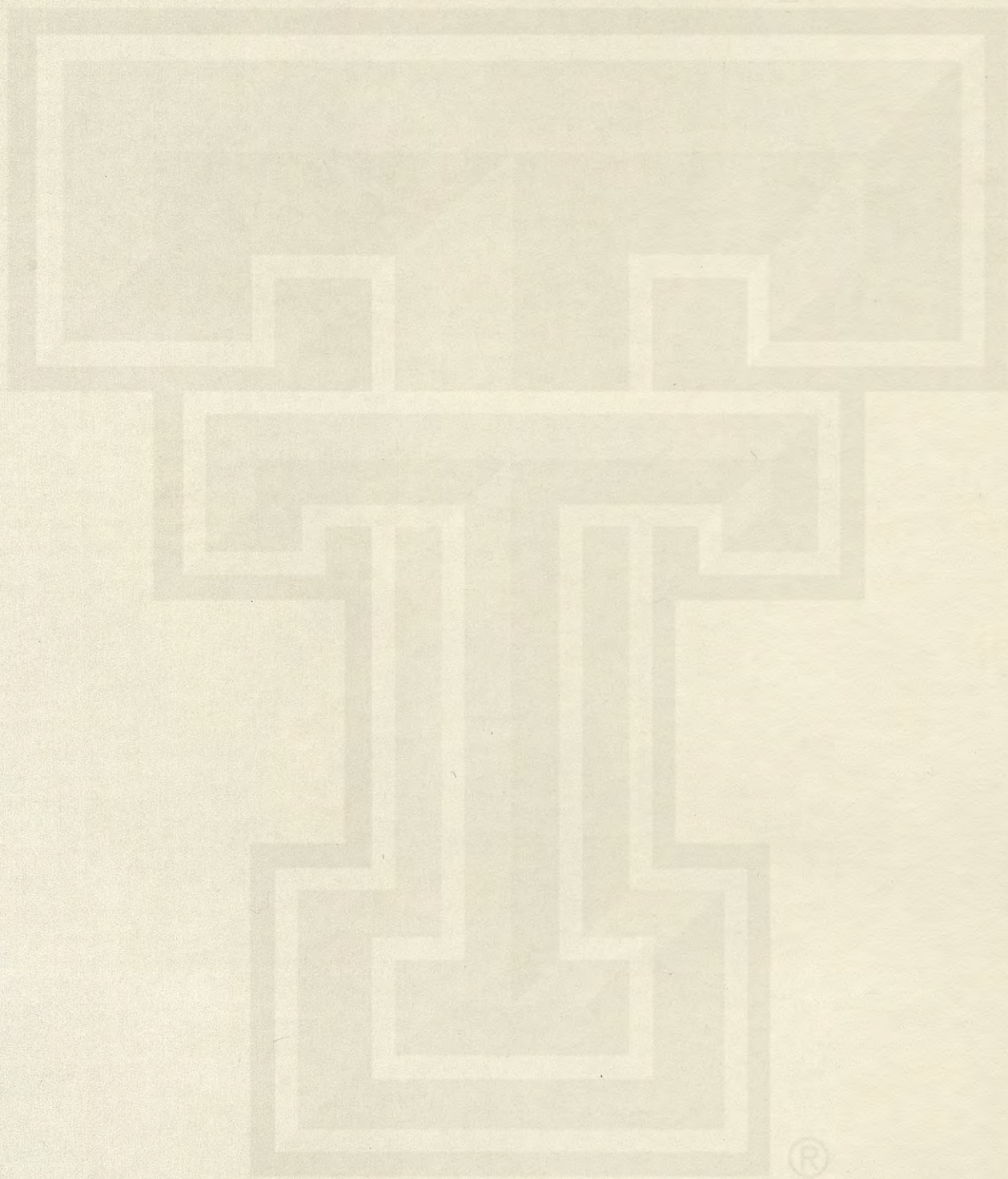


Fig. 6-9 Data Management System (Including Growth Concepts)



Section 7

PRELIMINARY SYSTEM DESIGN CONCEPT

This section delineates the initial systems approach for the IMBLMS, based on the system requirements definition and mission/spacecraft analysis. The major consideration influencing a specific modular approach is the need to group commonly used measurement equipment and associated display and controls in proximity to each other. The major advantage to such a grouping is that it permits adding or subtracting major equipment without redesigning the entire package.

7.1 BASIS OF IMBLMS DESIGN CONCEPT

The overall IMBLMS concept consists of the following:

- Physiological/behavioral/data management (PBDM) station
- Biochemical station
- Major peripheral measurement equipment
- Storage

The following basic design decisions were made:

- Grouping of measurement equipment in accordance with a specific body organ or class of measurement (e.g., cardiovascular and respiratory)
- Centralizing data management and control so that storage, recording, display, evaluation, and control can be accomplished for all modules
- Physical separation of physiological/behavioral measurements from biochemical measurement, and provision of a filtered compartment for those measurements involving liquid or gas
- Provisions for interconnect at a centralized biostation for all peripheral measurement equipment such as LBNP, ergometer, mass measurement system, and for total body exercise.

- Use of displays and controls similar to those specified for the AAP
- Use of the IMBLMS in MDA within experiment canister

The primary objective of this initial design effort is to establish the feasibility of accommodating all the measurement equipment and to uncover any design problems associated with packaging, human engineering, and operation.

7.2 PHYSIOLOGICAL/BEHAVIORAL/DATA MANAGEMENT (PBDM) STATION

The PBDM station is packaged in a 20- × 30- × 40-in. experiment canister that is stowable. The canister is an integral part of the station and provides major support when the station is set up for operation. The station itself has 12 removable modules, as shown in Fig. 7-1. One removable module (dynamic physiological monitor) can be used at remote sites and is particularly suited to making dynamic measurement of vital signs, such as heart rate, respiration rate, temperature, and blood pressure. Preliminary estimates have indicated that all equipment associated with a particular organ function can be housed in a 9- × 9- × 15-in. module, thus permitting standardization of the housing, rails, frames, and fasteners, as well as addition or removal of a module with a minimum of effort.

7.2.1 Dynamic Physiologic Monitor (Fig. 7-2)

This is the most versatile module in IMBLMS. It has the capability of being removed from the PBDM station and transported to remote sites such as the CM, LM, AM, or MDA. For EVA, two modules should be provided — one at the CM and one at the AM.

The dynamic monitor will obtain standard physiological measurements (body temperature, heart rate, respiration rate, and blood pressure) and major critical pressure suit measurements (suit flow and pressure, and pCO_2). Dual limit meters are provided for both heart rate and respiration rate, and for systolic and diastolic blood pressure. Dual round indicators are provided for suit flow and pressure and for pCO_2 and body

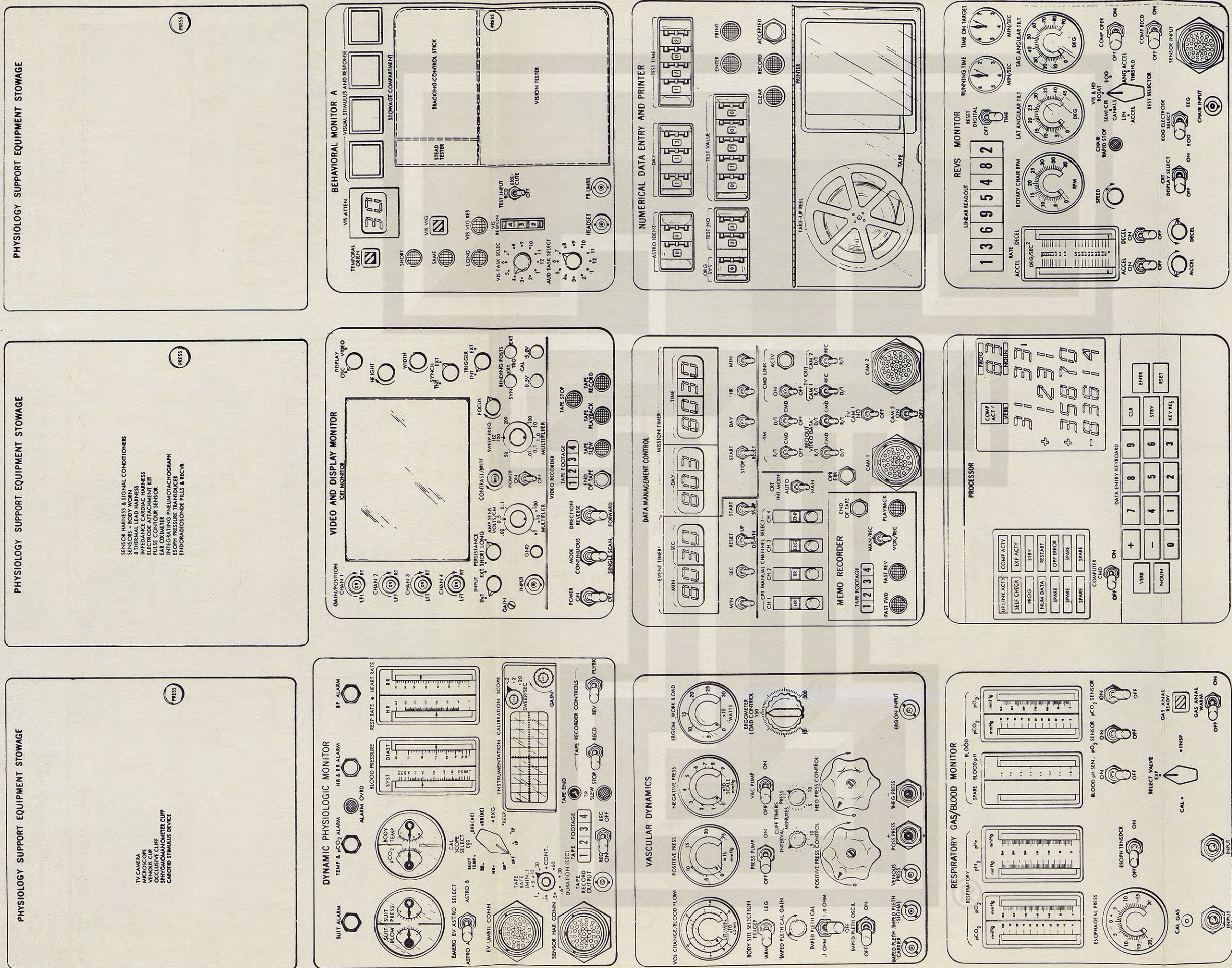


Fig. 7-1 Physiological/Behavioral/Data Management Station

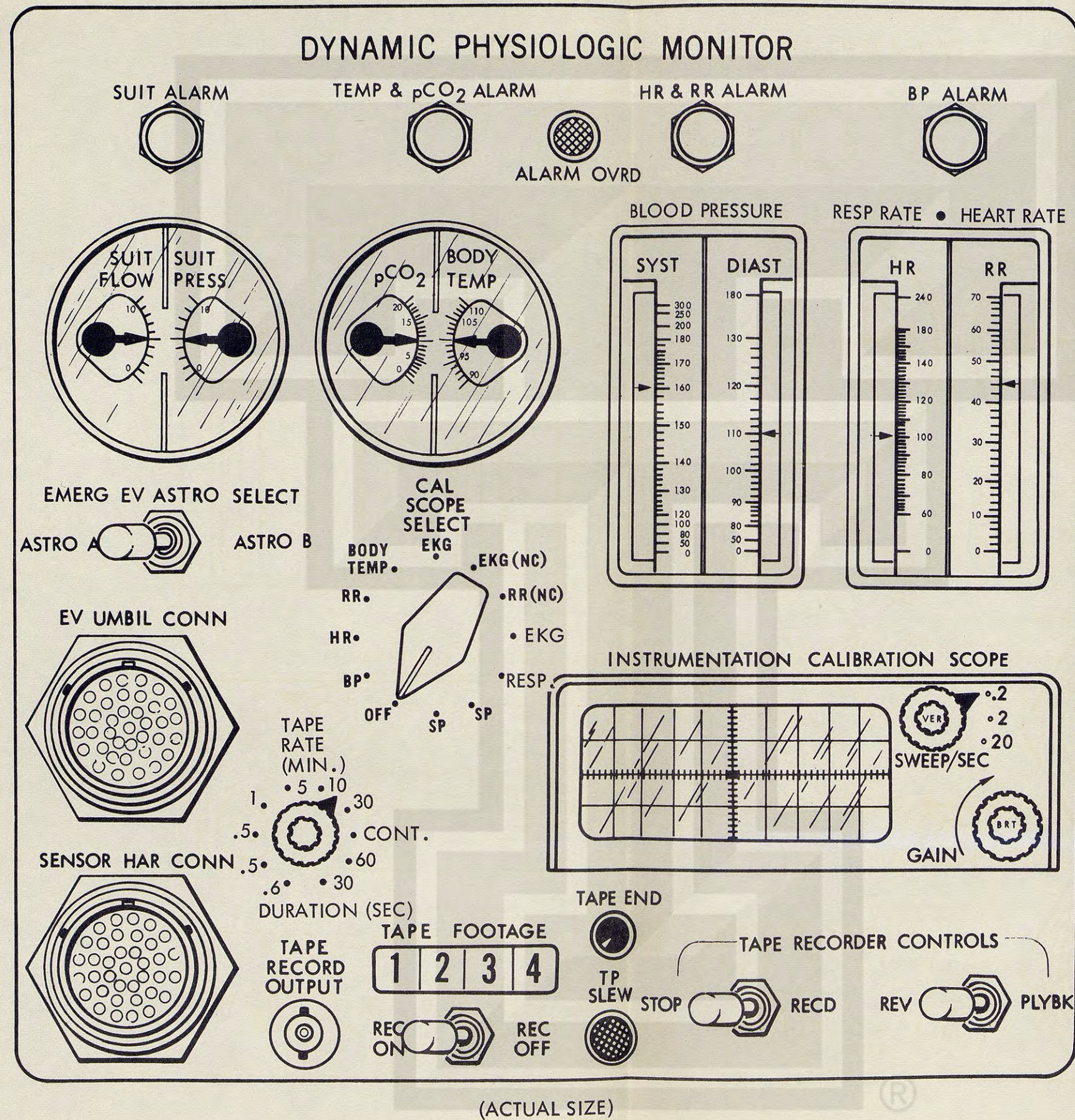


Fig. 7-2 Dynamic Physiologic Monitor

temperature. End instrument calibration is provided, using a signal generator with display on a miniature CRT. Calibration scope selector is provided for all measurements. A tape recorder is positioned at this module.

Emergency provisions consist of alarm lights and an audio alarm. An additional safety feature is provided for an EVA emergency. Normally when an astronaut is performing EVA, one crewman will be stationed in the command module and the other crewman will be suited in the unpressurized airlock module. In an emergency, the astronaut in the airlock module will egress. By means of a switching arrangement the crewman in the command module can continue to monitor both EVA astronauts.

Equipment requirements other than those displayed on the panel layout are the switching network, calibration circuitry, and the digital tape recorder. Figure 7-3 presents a block diagram of the dynamic physiological monitor. All operating elements are shown for both the basic monitor unit and the peripheral sensors and signal conditioners. The physiological signals are first acquired by the sensors, then processed by the signal conditioners to be raised to significant levels before long-line transmission to the monitor. Once the signals reach the monitor, they are either distributed to display and recording elements, or are further processed to extract additional information required for complete display and record keeping. In addition to the meters and alarm devices, a distinctive feature of the display devices is the calibration oscilloscope, which permits verification and level adjustment of all parameters.

7.2.2 Respiratory Gas/Blood Monitor (Fig. 7-4)

Several methods were considered for analysis of O_2 , CO_2 , N_2 , and H_2O . The recommended one, using a mass spectrometer, is depicted in the panel layout. Two dual meters for respiratory gases and two for blood gases are shown. Toggle switches permit controlling displays. Two electrical interconnects for the gas analyzer are provided. Coaxial connectors are provided for the esophageal pressure input and for the ear oximeter. A block diagram of the respiration analysis subsystem is shown in Fig. 5-2. A non-rebreathing valve at the face mask draws inspired air from the left

and expels expired air to the right. Static and timed lung volumes can be obtained by integrating the upstream and downstream flow measurements. Alternatively, the spirometer can be used to make these measurements.

For evaluation of pulmonary function, it is proposed to use the velocity-volume ($\dot{V}$ -V) loop of Bartlett. A $\dot{V}$ -V loop is constructed by simultaneously plotting values for respiration velocity and volume in a two-dimensional plot. Residual lung volume is measured by setting the valves to allow pure O_2 to be inspired. The volume expired is obtained by integrating the downstream flow meters for 7 min. Concurrently with this, the mass spectrometer measures the pN_2 concentrations; from the mean pN_2 and the 7-min volume, the lung volume can be computed based on the point in the respiration cycle (determined from the flow meter) where the measurement began.

Airway resistance is measured with the downstream flow meter, pressure transducer, and shutter. The four-way valve is set so that the subject exhales through the flow meter and shutter. The shutter rapidly interrupts the expired gas flow and the resultant pressure rise, along with the flow, is used to compute airway resistance.

Oxygen consumption is measured by rebreathing O_2 from one spirometer. The water and carbon dioxide are scrubbed from the expired air, which is returned to the spirometer. As oxygen is consumed from one spirometer, it is periodically replenished by an accurately measured quantity from the other spirometer.

Cardiac output measured by the CO_2 rebreathing technique requires three pCO_2 measurements. Carbon dioxide production and pCO_2 at the end of a maximum exhalation are measured by the mass spectrometer. Volumes are measured with the spirometer. The spirometer is then loaded with an O_2 and CO_2 mixture and this gas is rebreathed until pCO_2 equilibrium is obtained. The three carbon dioxide measurements are used with the Fick equation to give cardiac output.

Esophageal pressure is measured by an esophageal pressure transducer mounted on a catheter. Equipment requirements other than those displayed on the panel layout are

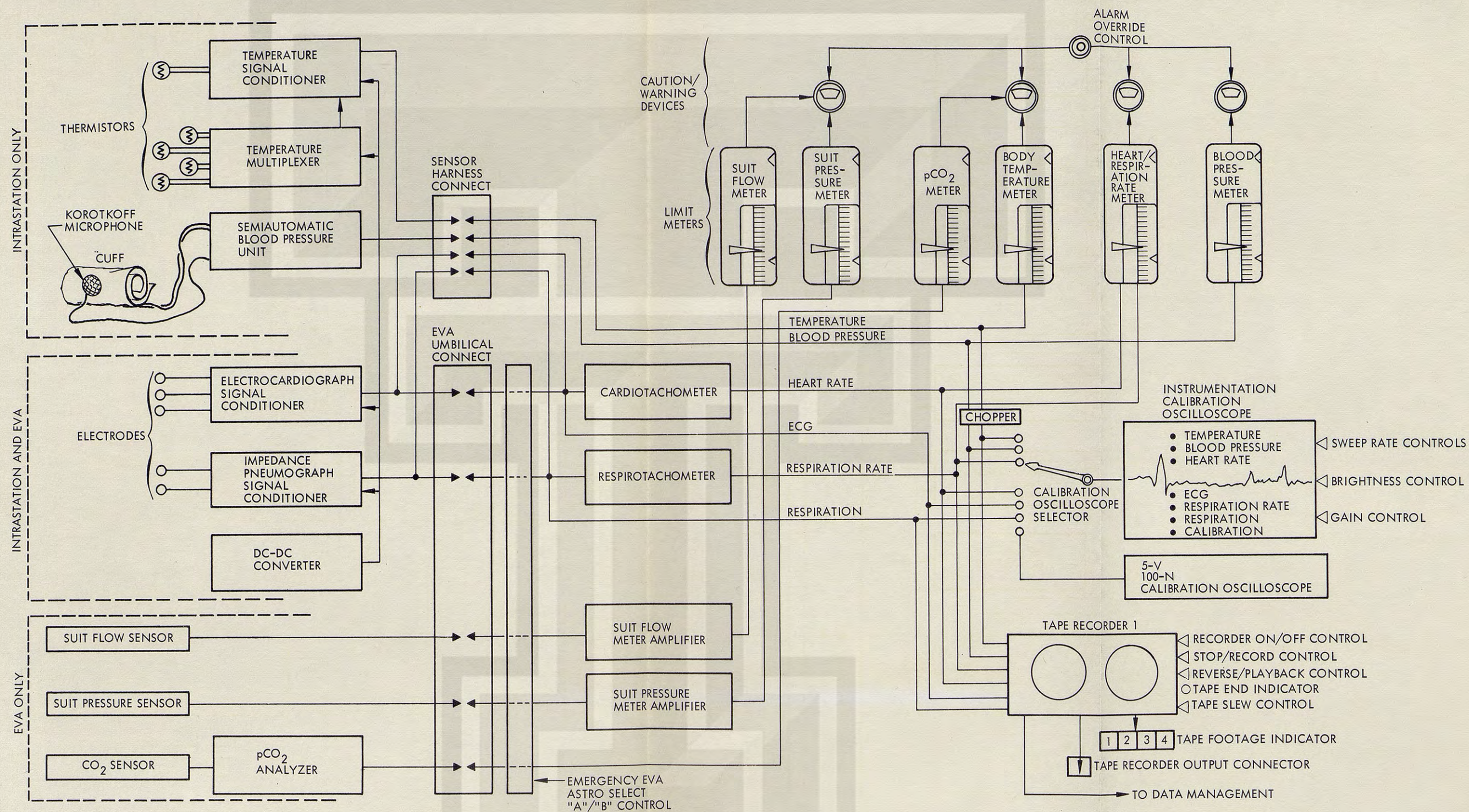


Fig. 7-3 Dynamic Physiologic Equipment Diagram

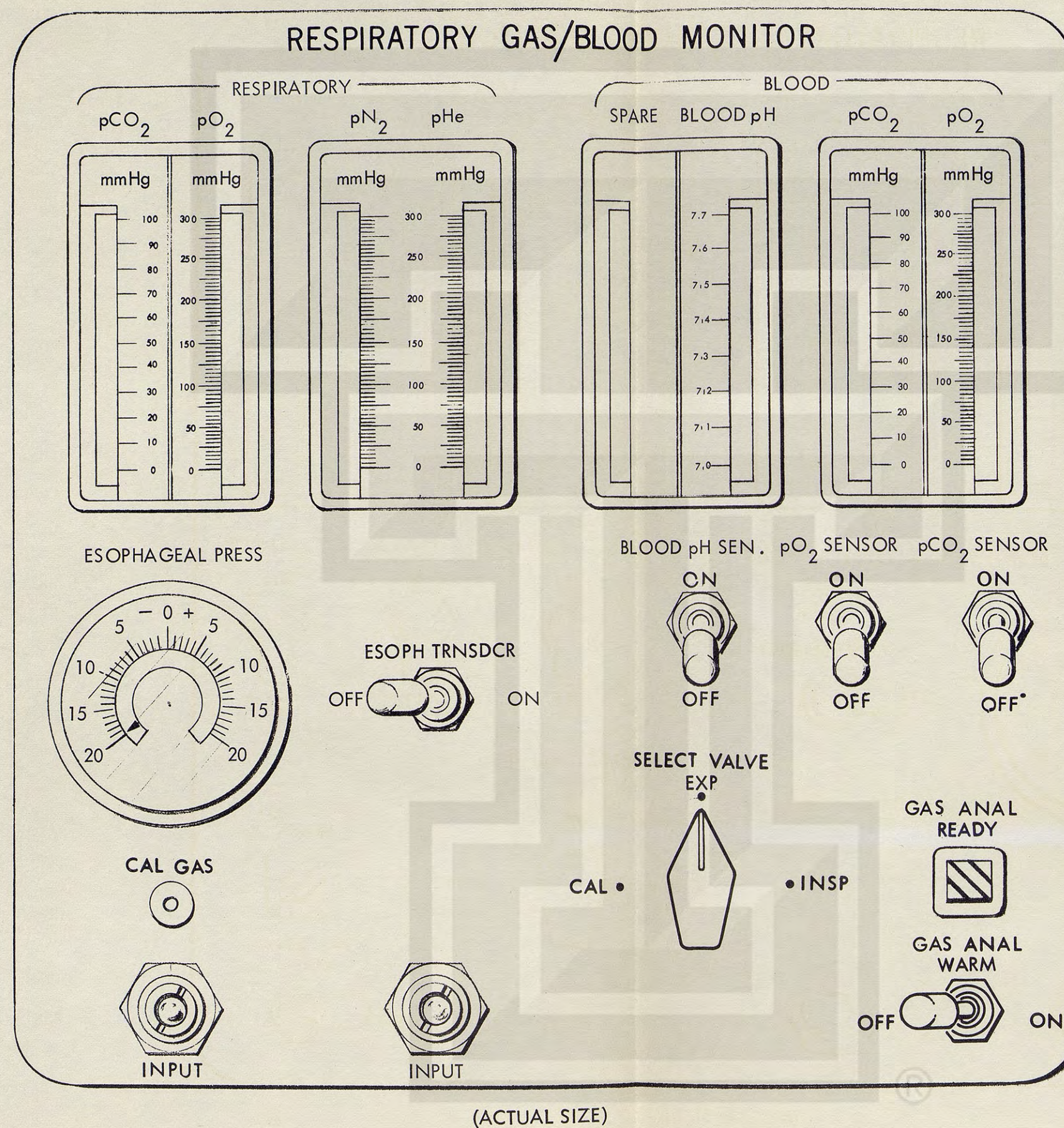


Fig. 7-4 Respiratory Gas/Blood Monitor

flow meters, servospirometers, plumbing, canisters, valves, mass spectrometer, and calibration gases.

7.2.3 Vascular Dynamics Monitor (Fig. 7-5)

The vascular dynamics module is structured primarily to support peripheral measurements requiring relatively large equipment – such as the LBNP, ergometer, and countermeasure devices – and to support associated measurements being taken while using this equipment. Timers have been provided for measurements requiring specific measurement time periods.

All controls and monitoring of the measurements are regulated by an observer because of the stress level imposed on the subject. For those measurements requiring a vacuum source such as the LBNP, hose connections are provided at this panel. Individual coaxial connectors are shown for some of the associated measurements such as impedance plethysmograph and venous pressure. Consideration will be given to integrating these into a common umbilical if detailed studies indicate that the measurement will not be compromised.

Equipment requirements other than those displayed on the panel layout are plumbing and electrical circuits.

Figure 7-6 is an equipment block diagram of the vascular dynamics module. In addition to showing the major operating elements of the module, the diagram shows the external peripheral units that may be plugged into the module panel. All major paths of information may be followed through their control and processing elements to the appropriate display devices. All functional elements are shown, including data flow paths, signal processors, control devices, and display units, thus permitting full visualization of the operation of the panel in conjunction with the peripheral equipment.

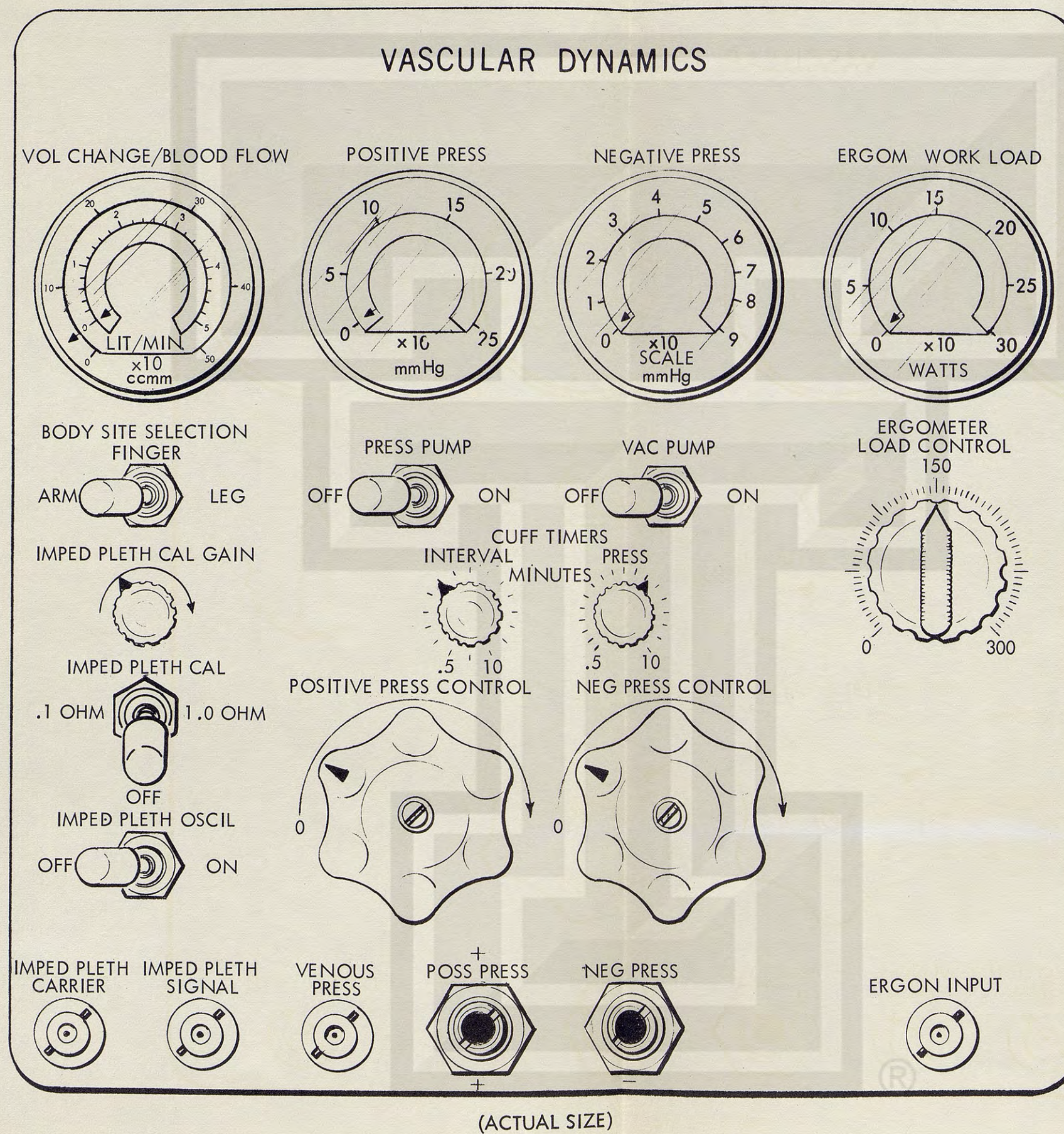


Fig. 7-5 Vascular Dynamics Monitor

7-17

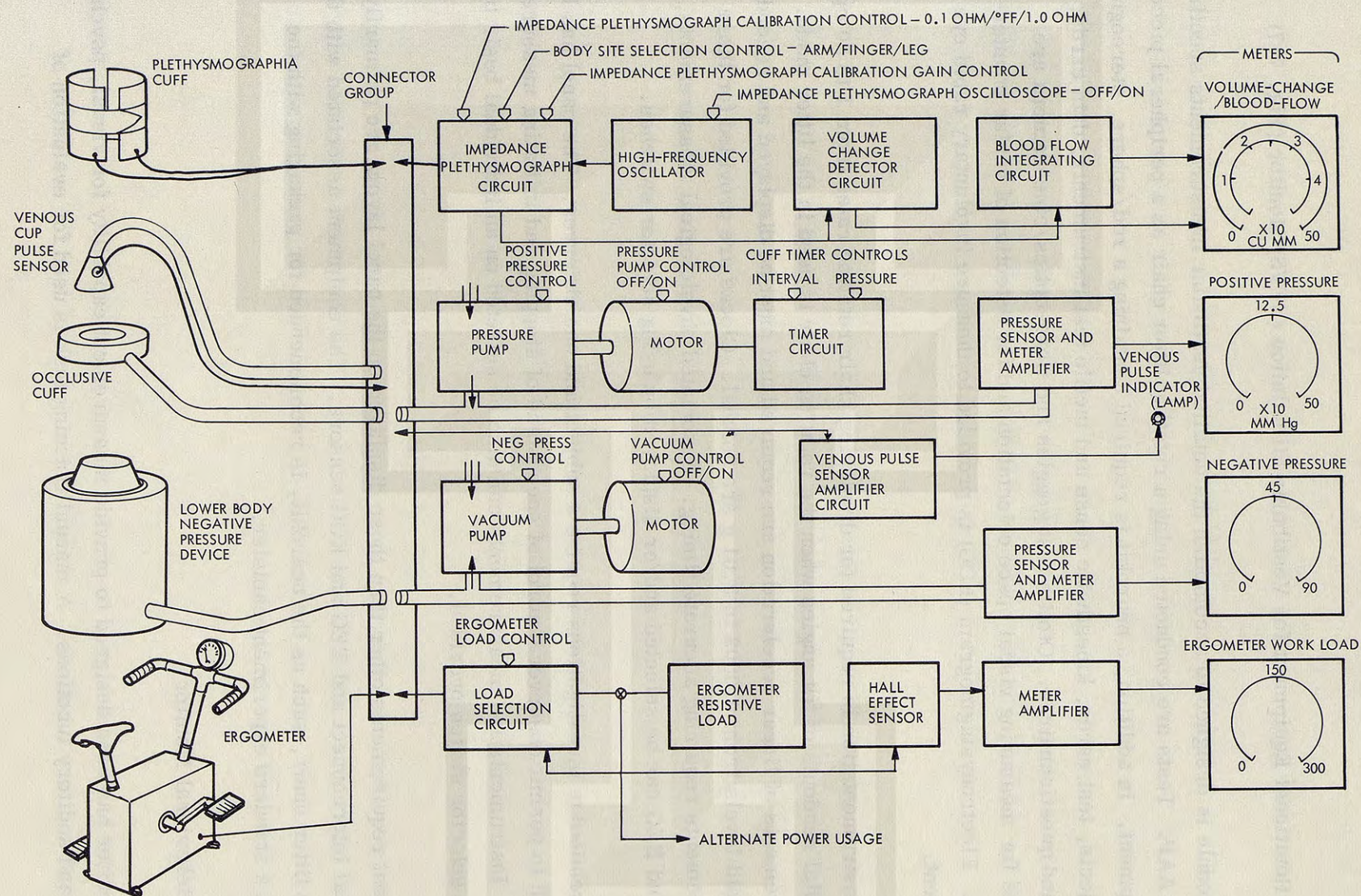


Fig. 7-6 Vascular Dynamics Equipment Diagram

T-30-67-1

7.2.4 Rotational Equipment for Vestibular Stimulation (REVS) Monitor (Fig. 7-7)

This module is designed to accomplish the detailed vestibular measurements specified for the AAP. Tests are conducted using a rotating litter chair as a peripheral piece of equipment. In addition, a neurokit is required containing a rod/sphere, stereognosis test objects, test cards, kinesthetic sense and tactile test instruments, data cards, pens, and questionnaires. Otolith test goggles and fibre-optics/cine-camera are required for measuring visual space orientation and for detection of ocular counter-rolling. Electronystagmogram (EOG) is provided to measure involuntary rapid eye movement.

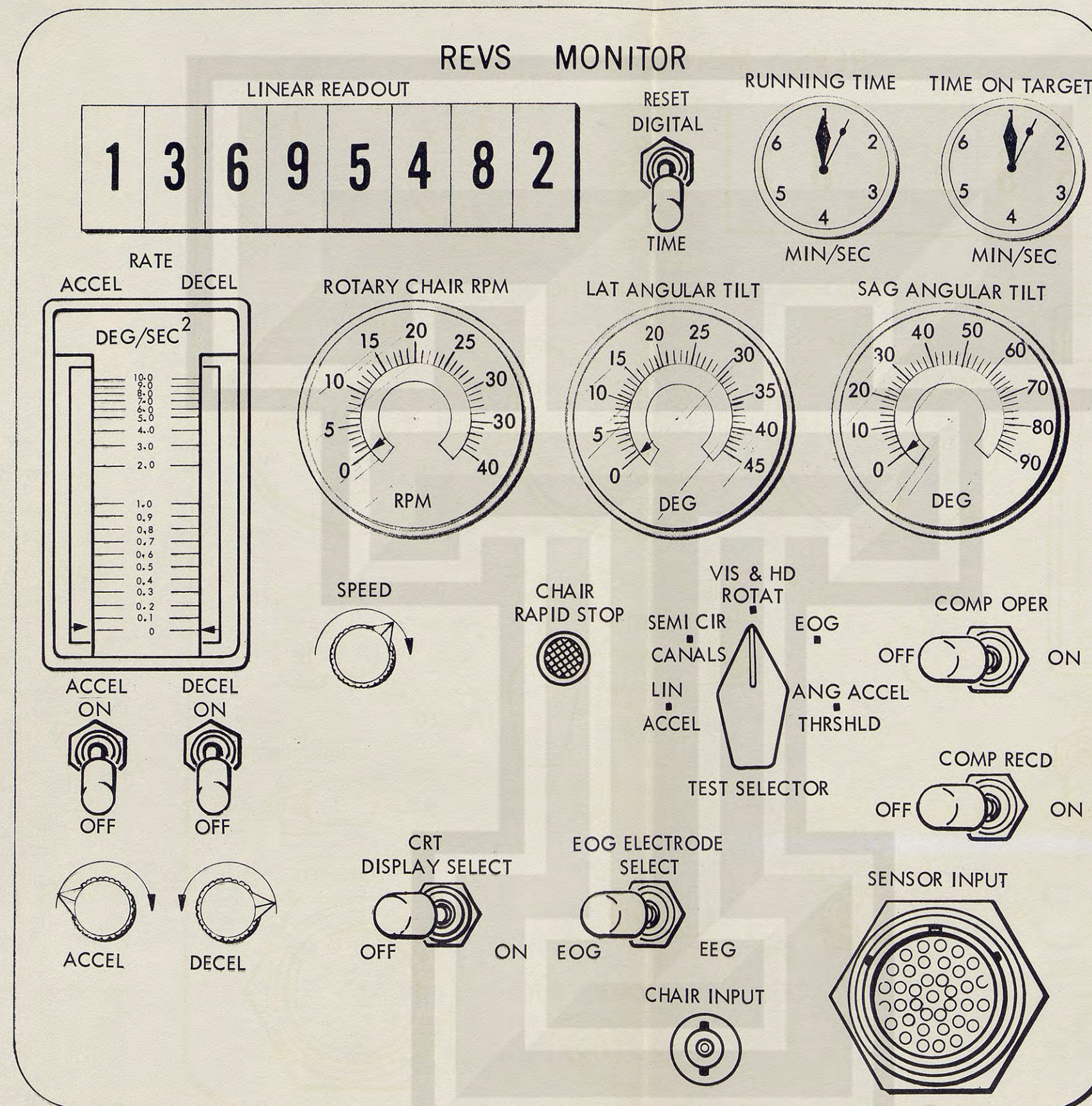
Panel instrumentation is required for displaying chair rotation rates from 1 to 30 rpm and digital readouts of tilt angles when the rotating chair is used in the litter mode. Measurements of linear acceleration are required and must be displayed and recorded. Threshold levels from 0.0003 to 0.01 g are normal. Clocks are provided for those measurements requiring accurate timing. Associated physiological measurements, EOG, and EEG can be selected and/or displayed by using selector switches.

These vestibular investigations require a subject and one observer. The panel has been designed to permit observer control of speeds and of stopping and initiating measurements. Instrumentation measurements can also be selected on an individual basis by the test selector switch provided.

Equipment requirements other than those displayed on the panel layout are primarily electrical interconnect and EEG and EOG sensors. The equipment associated with the rotating litter chair, such as the neurokit, is recommended for packaging with the chair in a standard experiment canister.

7.2.5 Behavioral Monitor

This monitor has been designed to provide measurement capability for visual, psychomotor, and auditory functions. A manual tracking task is used for evaluation of



(ACTUAL SIZE)

Fig. 7-7 REVS Monitor

combined visual and psychometer capabilities. The task display appears on a cathode ray tube housed in one of the data management modules. Figure 7-8 illustrates the module, which uses the separately located CRT for tracking tasks. This module approach is preferred because of the versatility of the CRT for tracking task presentations.

An alternate candidate, presented in Fig. 7-9, uses tracking displays mounted on the panel for the tracking task. This approach is somewhat less versatile because only meters are used for tracking tasks. The subject manually corrects the observed tracking error by manipulation of a two-dimensional hand controller. The task requires two-dimensional compensatory tracking with an acceleration control. The target path is generated with a digital processor. A vision tester housed in a storage compartment at the behavioral monitor is used to test visual acuity, depth perception, and phoria. The vision tester is a device resembling an orthorater, modified to permit the insertion of new stimulus material. The tester will be removed from its storage position to be centrally located on the work table in front of the data keyboard. A hood to eliminate extraneous light, and a head rest for maintaining head position, are required. Subjects enter their responses using a thumbwheel dial switch.

The sensitivity of the subject to auditory stimuli is measured with a prerecorded tape containing pure tone signals at various frequencies and intensities. The subject's responses are entered on an audio memo tape recorder. Temporal orientation testing is provided by means of the same audio tape. The subject's task is to judge the duration of the second of a series of pairs of tones relative to the first tone, which has a fixed duration. Responses are entered on the thumbwheel dial switch used for the visual entries.

Psychomotor functioning is evaluated using a hand-steadiness tester and processor-controlled indicator lights, which serve as test stimuli for reaction-time measurement. The subject's task for hand-steadiness evaluation is to insert a metal stylus in small circular holes drilled in a metal panel. Restraints are provided to maintain the subject's

arm and shoulder in a fixed position relative to the panel. A digital code is recorded directly on magnetic tape each time the stylus touches the edge of a hole during a fixed interval of time. Processor-controlled indicator lights serve as test stimuli for reaction-time measurements. A single light is used for the measurement of simple reaction time, whereas several adjacent lights serve as the test stimuli for measurement of complex reaction times involving the identification of the particular stimulus that was presented.

Responses are entered using the thumbwheel dial switch. The encoded switch signals are transmitted to the processor, which, in conjunction with its real-time clock, generates the series of test stimuli, measures response times, and records the measurements on magnetic tape. The processor also displays measured response times on a four-unit digital display for the benefit of an on-board observer, or for the test subject himself.

Required equipment other than that displayed on the panel layout are the processor interface circuitry, the electrical system, and the stowed vision tester, tracking control stick, and hand-steadiness tester.

7.2.6 Stowage Modules (Fig. 7-10)

Three stowage modules are provided. They contain physiological sensors, harnesses, etc., that are required in making measurements concerned with respiratory and dynamic physiology. They also contain equipment supporting vascular dynamics and provide the housing for the TV-microscope. The equipment items are as follows: sensor harness and signal conditioners, body sensors, thermal harness, impedance cardiac harness, pulse contour sensor, electrode attach kit, integrating pneumotachograph, esophageal pressure transducer, plethysmograph, TV-microscope, venous cup, occlusive cuff, sphygmomanometer cuff, and carotid stimulus device.

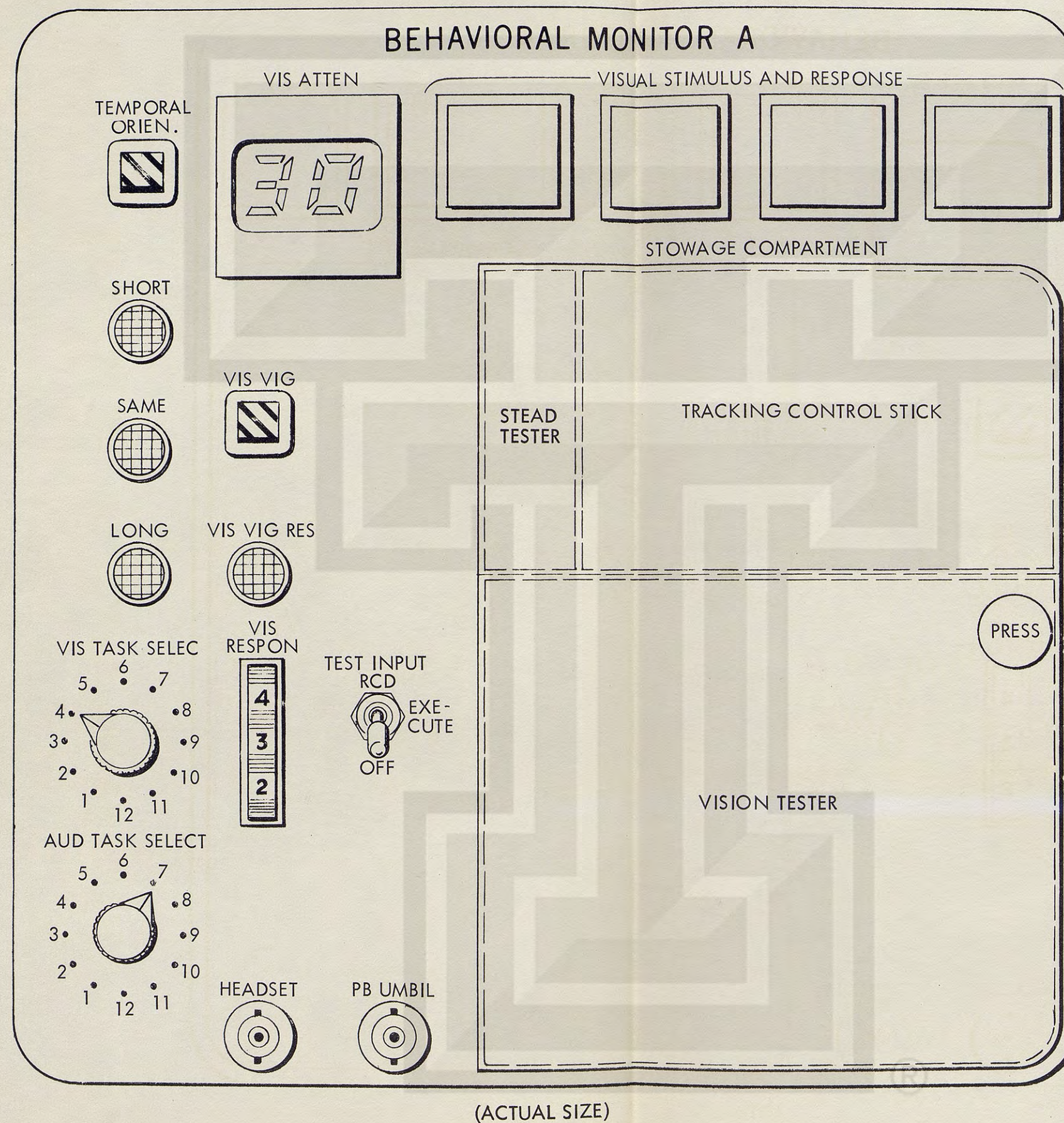


Fig. 7-8 Behavioral Monitor - Ancillary CRT Presentation

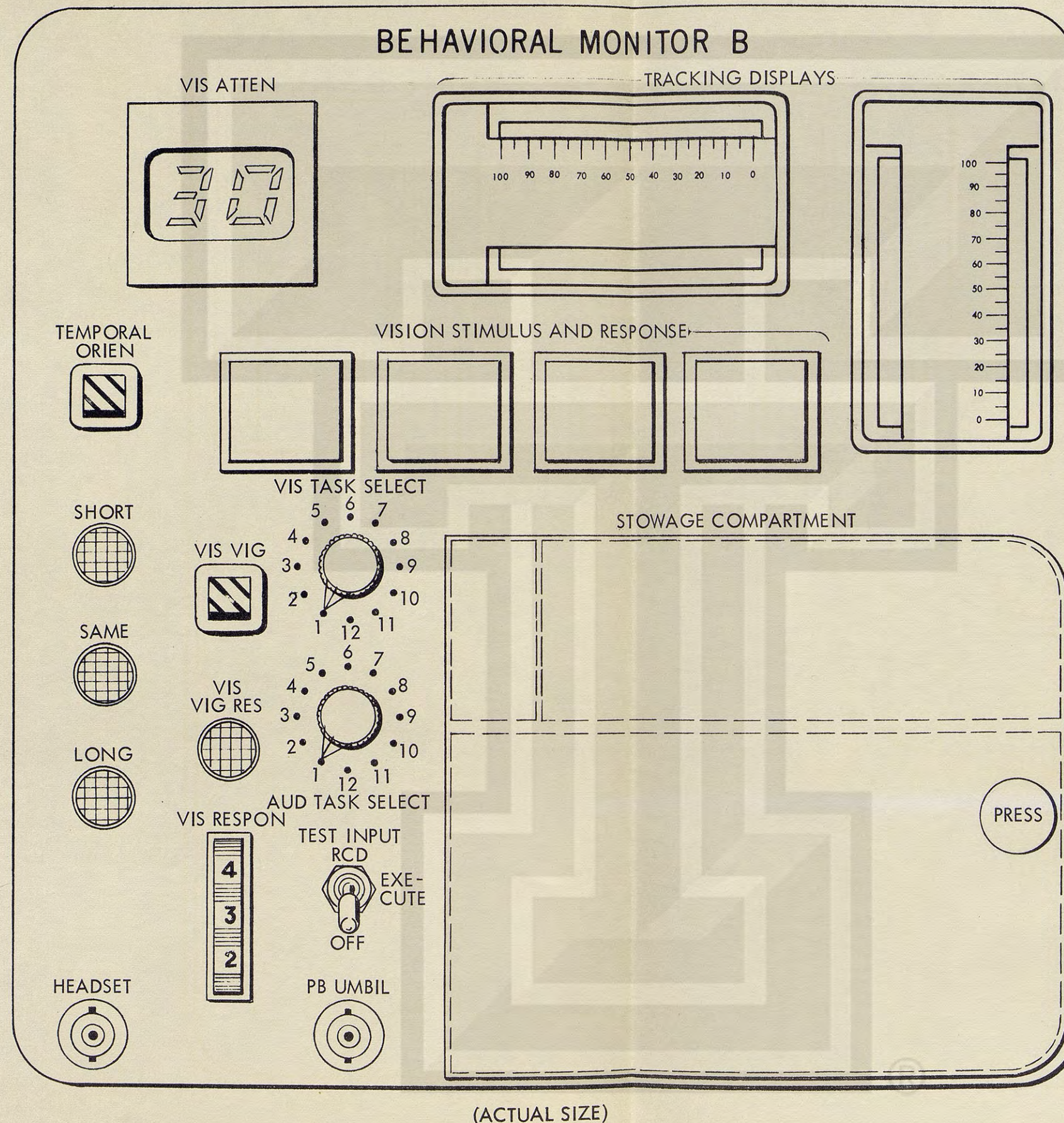


Fig. 7-9 Behavioral Monitor - Meter Display for Tracking Task

PHYSIOLOGY SUPPORT EQUIPMENT STOWAGE

SENSOR HARNESS & SIGNAL CONDITIONERS
SENSORS - BODY WORN
8 THERMAL LEAD HARNESS
IMPEDANCE CARDIAC HARNESS
ELECTRODE ATTACHMENT KIT
PULSE CONTOUR SENSOR
EAR OXIMETER
INTEGRATING PNEUMOTACHOGRAPH
ESOPH PRESSURE TRANSDUCER

PRESS

(ACTUAL SIZE)

PHYSIOLOGY SUPPORT EQUIPMENT STOWAGE

TV CAMERA
MICROSCOPE
VENOUS CUP
OCCLUSIVE CLIFF
SPHYGMOMANOMETER CUFF
CAROTID STIMULUS DEVICE

PRESS

(ACTUAL SIZE)

PHYSIOLOGY SUPPORT EQUIPMENT STOWAGE

PRESS

(ACTUAL SIZE)

Fig. 7-10 Stowage Modules

7.2.7 Data Management Modules

Four data management modules are illustrated in Fig. 7-1: video and display monitor; numerical data entry and printer; processor; and data management control. These modules are described and illustrated in detail in Section 6. This section summarizes the equipment requirements.

7.2.7.1 Video and Display Monitor. This monitor contains two major items: the CRT monitor and its associated controls, and the controls for the video recorder. The CRT has a combined capability of video image presentation and oscillographic display. The latter capability is used for presenting analog information, including the $\dot{V}$ -V loop by CRT image reintensification, and for presenting vectorcardiogram data using Z-axis modulation.

7.2.7.2 Numerical Data Entry and Printer. This module contains a printer that provides hard copy printout before actual recording. It can print out computations occurring in the IMBLMS processor and also ground (up-link) instructions, etc. Copy is obtained by swinging back a plastic lid for access to tape. The panel shows digit dial switches that provide for entry of numerical data.

7.2.7.3 Data Management Processor. This module contains the necessary controls and displays for astronaut communication with the processor. The panel shows a recessed Apollo-type keyboard and display.

7.2.7.4 Data Management Control Module. This module provides remote control of the carriers' real-time and delayed-time-transmitted controls and inputs for the TV camera, a mission cumulative time-and-event timer, manual control of the four channel inputs to the video and display monitor, and controls and displays for the memo recorder.

7.3 BIOCHEMICAL STATION

The biochemical station furnishes a centralized facility for storing and operating the equipment for in-flight measurements. In addition, it provides the facility for collecting, handling, and preserving biospecimens either for transmittal to ground via a TV-microscope or for transporting frozen samples to ground during a resupply mode. It is conceptually designed to provide maximum capability for performing biochemical analysis with a minimum of astronaut handling and interpretation. The design of the station modules are based on the following design criteria:

- Majority of experimental procedures to be performed at the station
- Majority of experimental procedures to be performed with minimal use of multiple devices
- Manual use of buttons and switches, and manual insertion of specimens into measurement devices
- Recording and transmitting of logged data to be performed at PBDM station
- Transmittal of TV-microscopy scheduled for PBDM station
- Filtered compartment used wherever gas/liquid is involved

The design of the station is based on the biochemical analyzer module because of the requirements of the determinations. Instrument readout sensors and support instruments required to monitor the different modalities are grouped at this module. Other major modules are the following: freezer, incubator, isotope, canister, waste storage, and four supporting stowage modules. Figure 7-11 illustrates the grouping of the modules.

7.3.1 Biochemical Analyzer Module (Fig. 7-12)

The major equipment located in this module comprises colorimeter, electrophoresis unit, electronic hematocrit, and the ion-specific electrode measurement unit. Dual indicator dials permit reading quantitative data on K, Na, Cl, O₂, CO₂, and pH.

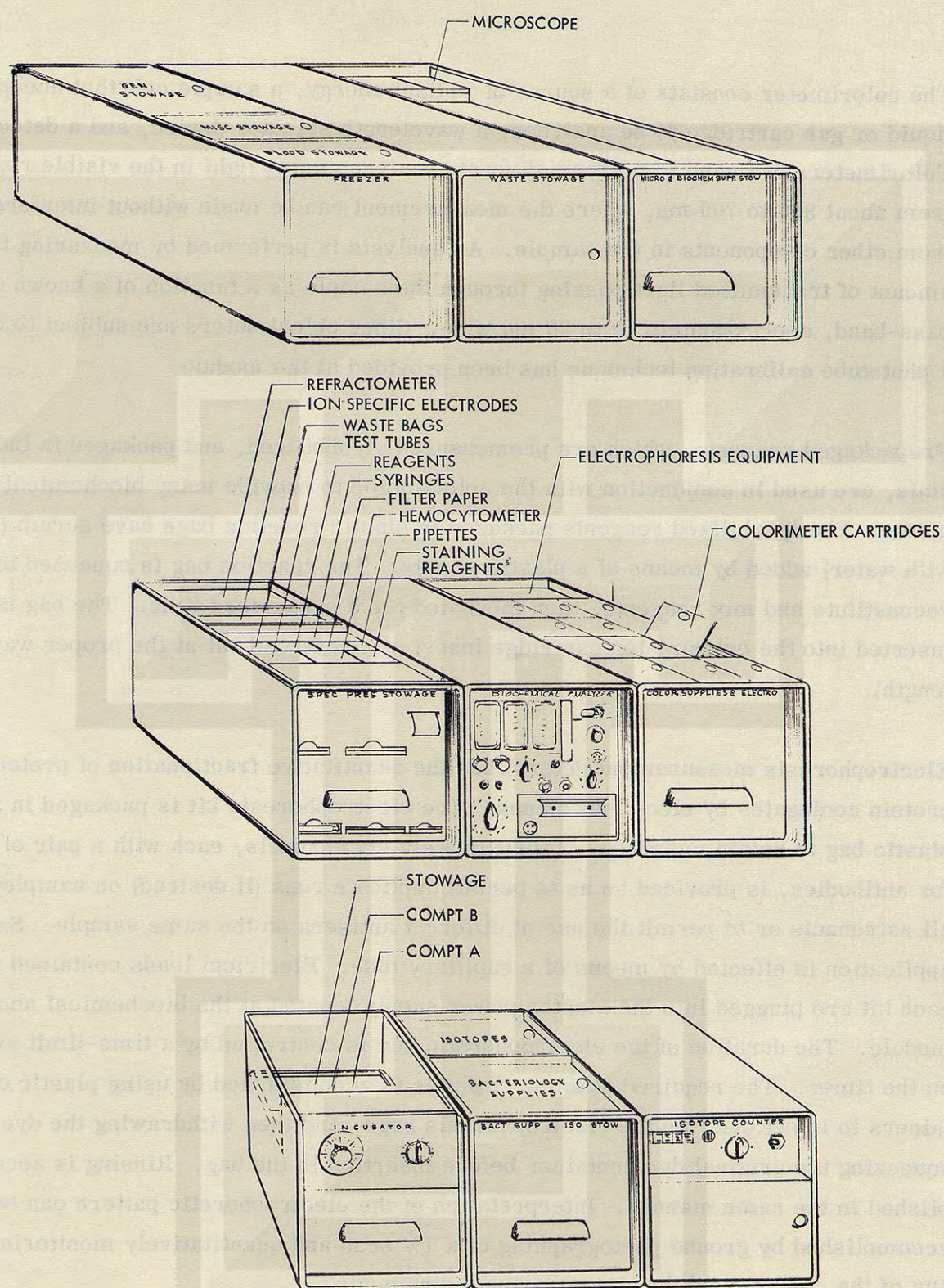


Fig. 7-11 Biochemical Station

The colorimeter consists of a source of radiant energy, a sample cell that accepts the liquid or gas cartridge to be analyzed, a wavelength selector device, and a detector. Colorimeters are used to perform discrete analyses using light in the visible region from about 360 to 700 $m\mu$, where the measurement can be made without interference from other components in the sample. An analysis is performed by measuring the amount of transmitted light passing through the sample as a function of a known optical pass-band, approximately 10 to 20 $m\mu$ wide. Since colorimeters are subject to drift, a phototube calibration technique has been provided at the module.

Prepackaged reagents, which are premeasured, lyophilized, and packaged in individual vials, are used in conjunction with the colorimeter to provide many biochemical measurements. The lyophilized reagents packaged in plastic reaction bags have serum (diluted with water) added by means of a plastic pipette. The reaction bag is squeezed to reconstitute and mix reagents, then incubated for a prescribed time. The bag is then inserted into the colorimeter cartridge insert slot and read out at the proper wave length.

Electrophoresis measurement determines the quantitative fractionation of proteins and protein conjugates by electrical means. The electrophoresis kit is packaged in a plastic bag to retain moisture. Approximately six channels, each with a pair of slots for antibodies, is provided so as to permit duplicate runs (if desired) on samples from all astronauts or to permit the use of different antisera on the same sample. Sample application is effected by means of a capillary tube. Electrical leads contained in each kit are plugged into the master power supply located at the biochemical analyzer module. The duration of the electrophoretic run is controlled by a time-limit switch on the timer. The required staining of plates is accomplished by using plastic containers to inject dye into the electrophoresis bags, and then withdrawing the dye by squeezing the original dye container before insertion in the bag. Rinsing is accomplished in the same manner. Interpretation of the electrophoretic pattern can be accomplished by ground photographing of a TV scan and quantitatively monitoring by any of the commercial density scanning instruments.

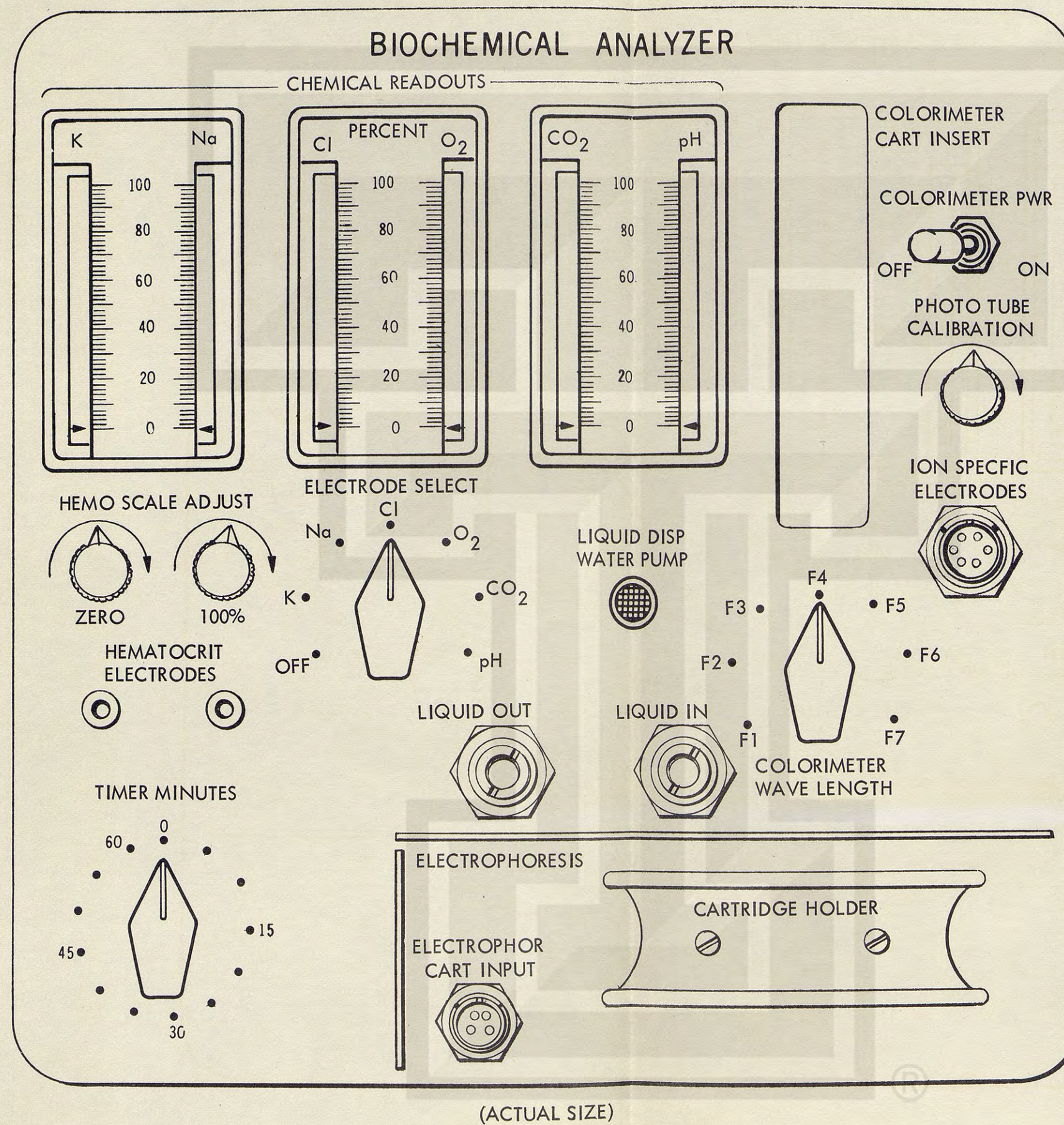


Fig. 7-12 Biochemical Analyzer Monitor

The electronic hematocrit (Model 30 Electronic Micro Hematocrit) is an accepted method of determining hematocrit. The determination is based upon a measurement of the electrolytic conductivity of whole or heparinized blood. Since the specific conductance of all ions is temperature-dependent, the conductivity cell must be compensated for temperature variations. The Model 30 Electronic Micro Hematocrit, marketed by the Yellow Springs Instrument Company, appears to be well-suited to the present application.

Determinations by ion-specific electrode use electrode syringes (pH, pCl, Na, K, pO_2 and pCO_2) to measure the specified concentrations in the biological materials sampled. The electrodes also monitor the concentration changes and levels during the preparatory step in various determinations. The electrodes are positioned in the plungers of the various syringes and thus readily allow transfer of the sample to and from the measuring device. A cable at the end of a syringe provides contact at the module, and appropriate chemical readout is made on a selector switch.

Equipment stowed in an adjacent module but used in performing measurements at this module comprises ion-specific electrodes, reagents, syringes, pipettes, staining reagents, electrophoresis bags, colorimeter cartridges, and miscellaneous collection and handling equipment for blood and urine.

7.3.2 Freezer Module (Fig. 7-13)

The requirement for storing body and waste fluids for on-board or postflight analysis can be achieved by a cryogenic freezer. One technique uses high-pressure gas or cryogenic fluid in a freezer unit. The fluid or gas, which fills all the void space around the specimen containers, is solidified by being subjected to a vacuum before launch. The temperature of the solidified gas is controlled by vapor pressure with a pressure relief valve.

Insulation is provided over the surface of the unit. Associated equipment to be used with the freezer unit is the Arde urine-volume measurement system modified to permit extraction of aliquots of urine. A liquid-gas phase separator, and a transfer system, must also be used to transfer samples to freezer, reagent bags, or slides.

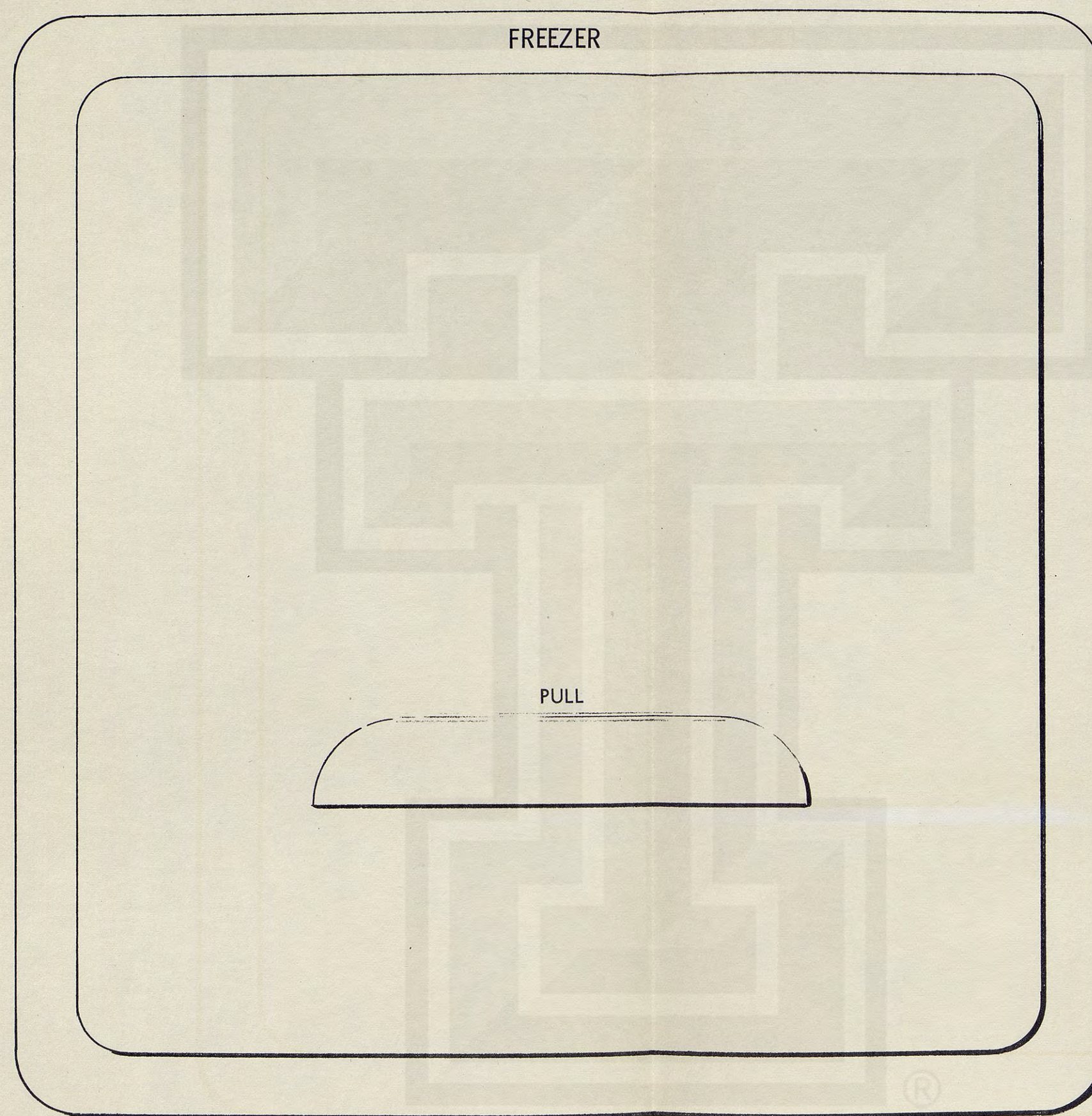
7.3.3 Incubator Module (Fig. 7-14)

Temperature blocks are used to facilitate the incubation of sample and/or reagent syringes at manually set temperatures as prescribed for the various measurements being performed. The temperature blocks are designed for rapid temperature equilibration to eliminate, as much as possible, prolonged stabilization periods. Temperature control and readout are included on the module face. A section of the incubator has been provided for the cytological determinations requiring the incubation of stains, cultures, or bacteria. The oven is designed for running multiple, individual incubations with a temperature range from ambient to 40 °C above ambient. The interior accommodates several of the special cytological devices.

7.3.4 Isotope Monitor (Fig. 7-15)

This module houses a scintillation counter used in radioisotope tracer determinations of body fluids compartments. A well crystal and spectrometer are used in determining equilibrium concentrations of chromium 51 and iodine 125.* The Cr-51 is used to find red blood cell mass, the I-125-tagged human serum albumin to monitor blood plasma volume. Measuring these two directly avoids possible error in obtaining total blood volume from venous hematocrits and correction factors. Further, by measuring RBC Cr-51 activity over the course of several weeks, RBC mean lifetime can be determined. Water tagged by tritium (hydrogen 3)* is used to study total body water. A urine sample is measured with a liquid scintillator, and the count is totaled, using a photomultiplier tube.

*If used for IMBLMS.



(ACTUAL SIZE)

Fig. 7-13 Freezer

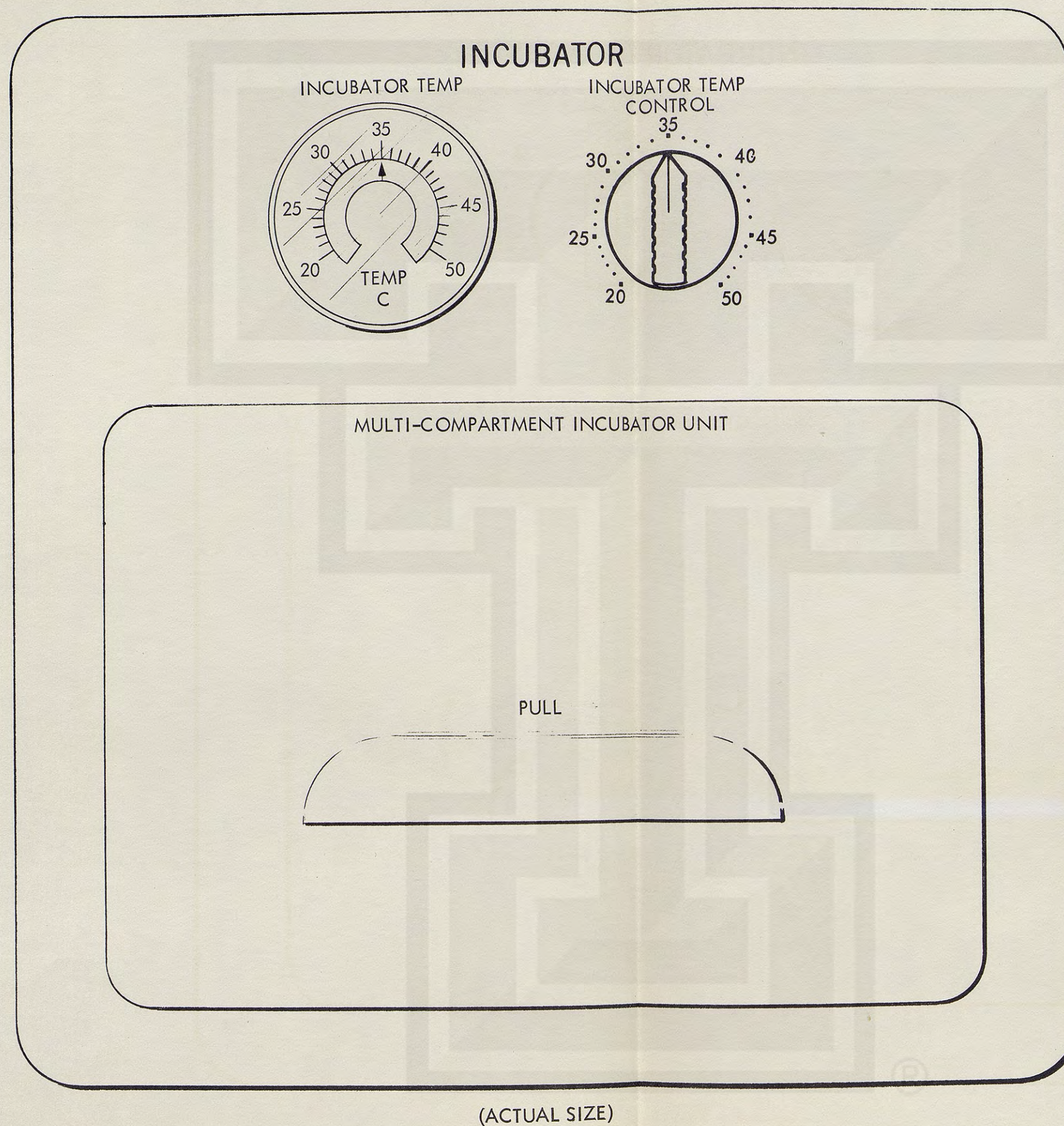


Fig. 7-14 Incubator

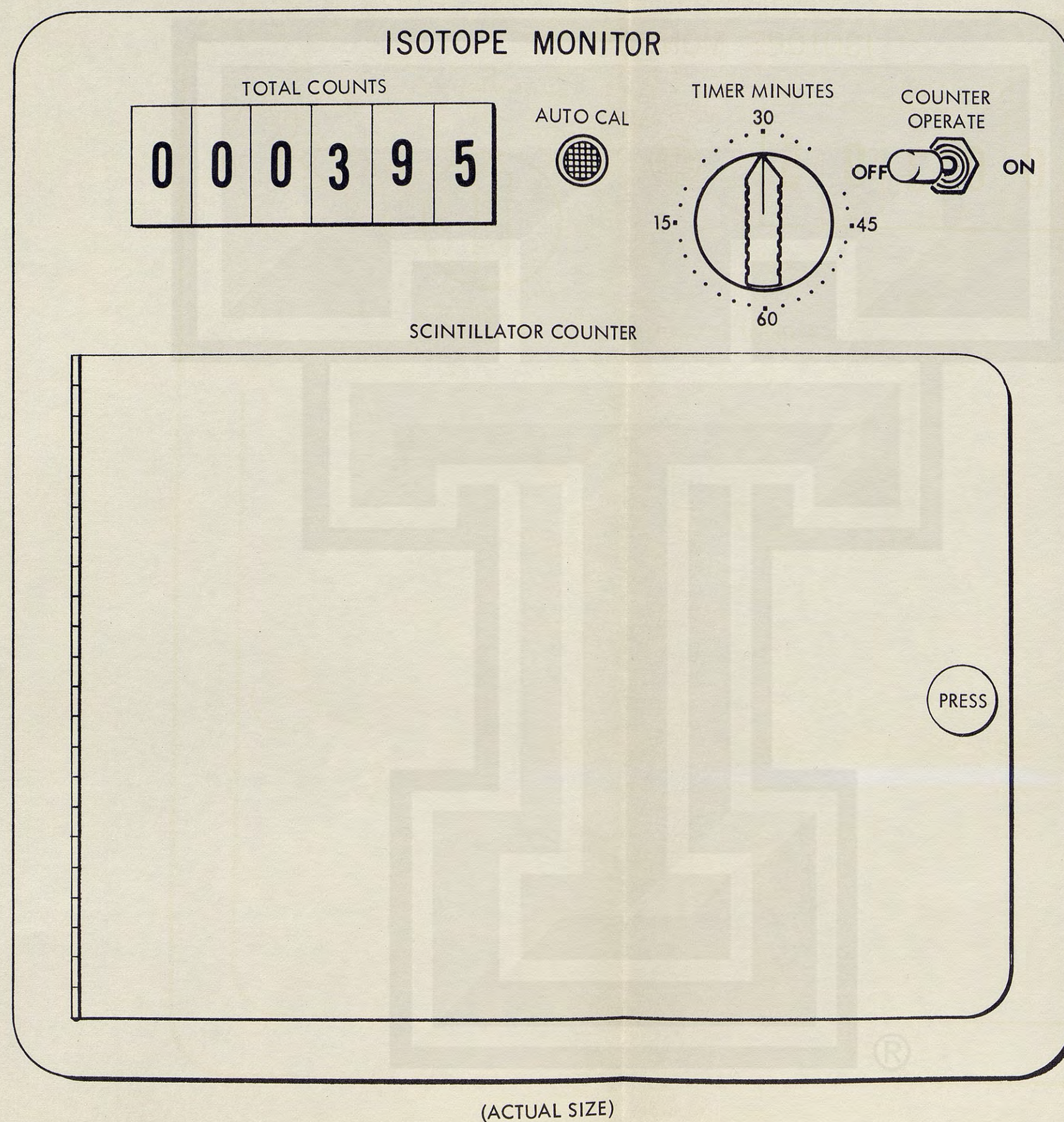


Fig. 7-15 Isotope Monitor

7.3.5 Biochemical Waste Collection Compartment (Fig. 7-16)

Waste products – including used reagent, water, urine, and blood – must be flushed from measuring devices and stored in the waste storage area. Plastic bags will be used, with desiccants if required.

7.3.6 Biochemical Supplies and Stowage (Fig. 7-17)

Four supporting stowage modules are required to house peripheral measuring equipment, reagents, syringes, refractometer (used for urine specific gravity), test tubes, pipettes, staining reagents, staining slide apparatus, urine-volume measurement equipment, and miscellaneous biochemical supplies. A microscope is stored for ancillary microscope work. This microscope can also act as a spare for the one integrated in the TV-microscope system at the PBDM station.

7.3.7 Operational Considerations

It is recommended that any measurement involving the taking of liquid samples be carried out at the filtered biochemical station. Experimental data will be logged in a standard log book. Encoding and transmittal of this data to ground are scheduled for the PBDM station. In the preparation of blood and urine slides, the initial operation will take place at the biochemical station; however, since the TV-microscope system is located at the PBDM station, the slides will have to be carried to that area for data transmittal to ground.

7.4 MAJOR PERIPHERAL MEASUREMENT EQUIPMENT

Major peripheral measurement equipment is categorized as any equipment that, because of its physical size or its use in the measurement, can be located remotely from the two identified stations. This equipment has been identified as lower body negative pressure device (LBNP), ergometer, total body exercise system, mass measurement

system (specimen and body), rotating chair and its associated equipment, maintenance equipment, and the helmet used in pulmonary evaluations.

LMSC considers integration of this equipment an important aspect of the total IMBLMS concept. The numerous interface problems associated with physical location, electrical connections, display requirements, and data management control must be considered. An equally important aspect of the problem is packaging and storing this peripheral equipment properly. The design of common experiment canisters suitable for withstanding ascent loads and other environmental conditions is considered within the scope of the IMBLMS. By proper design the canister can be an integral part of the equipment, as illustrated in Fig. 4-10 and discussed in Section 4. For example, the canister for LBNP can form the bottom panel of the LBNP, thereby reducing the overall weight of the system and, in addition, providing a more satisfactory seal. The ergometer canister can form the base plate and be a part of the ergometer structure.

7.5 SUMMARY OF IMBLMS EQUIPMENT

Based on the preliminary design concept of the IMBLMS and taking into consideration approved biomedical experiments on AAP, a preliminary equipment list (Table 7-1) has been developed. This list shows that a comprehensive biomedical measurement system requires 777 lb of equipment. This list will be subject to further detailed analysis and refinement during the final Phase B study effort.

Four categories were established to summarize the state of development of IMBLMS equipment: (1) off-the-shelf, (2) under development, (3) laboratory state-of-the-art, and (4) conceptual/research. In general, it can be stated that physiological measuring equipment has been developed to the space-qualified status in many areas; behavioral equipment is fairly well defined but extensive modification and development effort must be expended; and biochemical equipment is the least defined and requires extensive



Fig. 7-16 Biochemical Waste Collection Compartment

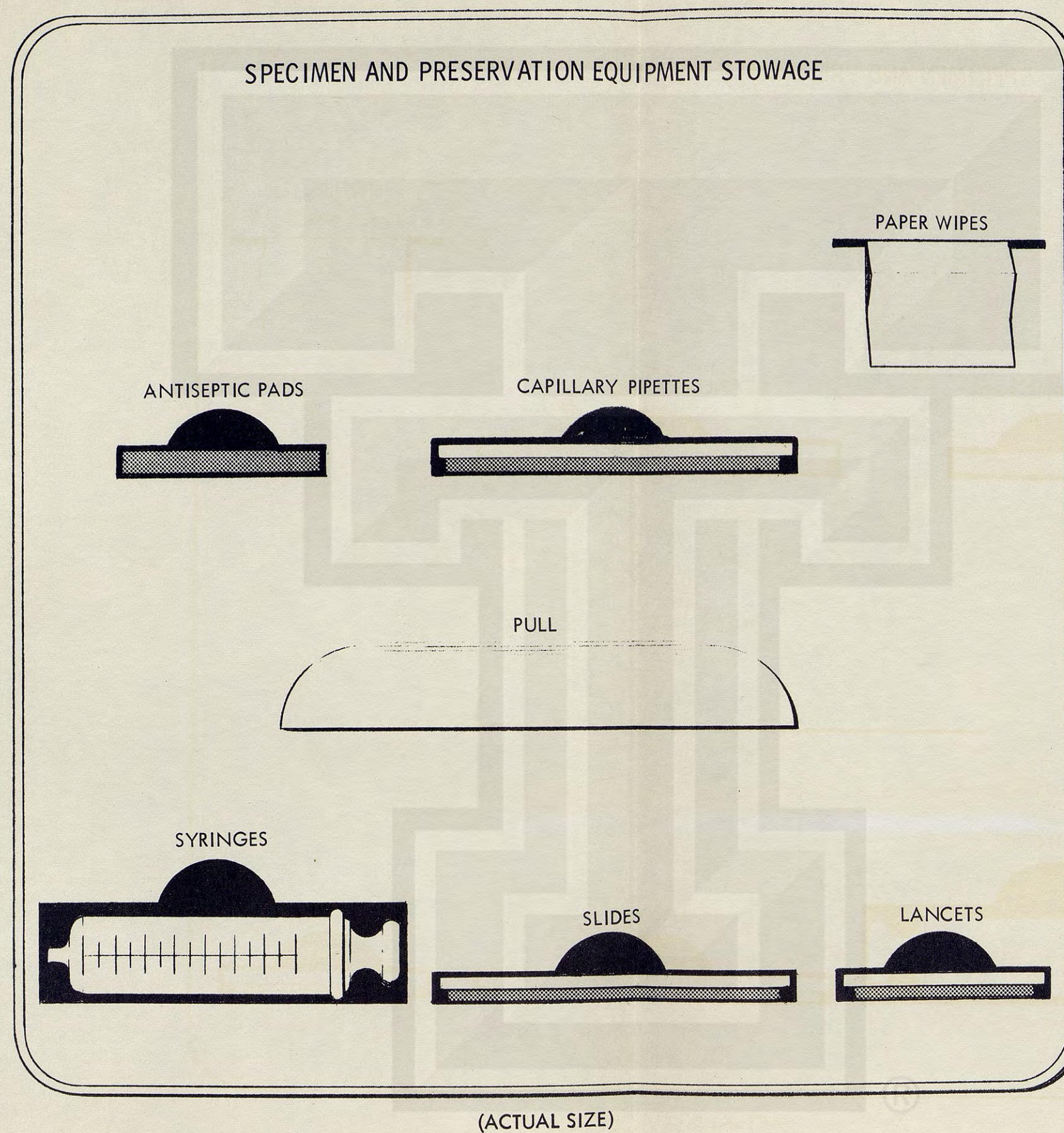


Fig. 7-17 Specimen and Preservation
Equipment Stowage

Table 7-1
PRELIMINARY WEIGHT SUMMARY

Item	Weight (lb)
PHYSIOLOGICAL/BEHAVIORAL/DATA MANAGEMENT STATION	
Dynamic Physiological Monitor	49
Respiratory Gas/Blood Monitor	77
Vascular Dynamics Monitor	26
REVS Monitor	36
Behavioral Monitor	18
Stowage Modules, Including Stowed Equipment (3)	56
Video and Display Monitor	56
Numerical Data Entry and Printer	11
Data Management Processor	32
Data Management Control Module	21
BIOCHEMICAL STATION	
Biochemical Analyzer Module	23
Freezer Module	22
Incubator Module	8
Isotope Monitor	36
Waste Storage Module	7
Stowage Modules (4)	50
EXPERIMENT CANISTERS (7)	65
MAJOR PERIPHERAL EQUIPMENT	
LBNP	15
Ergometer	20
Total Body Exercise System	35
Body Mass Measurement System	38
Specimen Mass Measurement System	20
Rotating Chair	56
TOTAL	777

research and development. Data-management display equipment is well-defined and much of it is available. Primary recording equipment has been developed and flight-tested but most of it is not directly applicable to IMBLMS requirements and will require additional development.

A preliminary survey has indicated that, of the approximately 300 equipment items identified, 90 items can be purchased off-the-shelf. These items include physiological sensors and signal conditioners, as well as display and control equipment. Approximately 12 major equipment items are under development, including the ergometer, LBNP, body exercise system, mass spectrometer, and the rotating litter chair. Relatively few equipment items are in the conceptual/research category (e.g., body volume measurement, and isotope scintillator counter). Although major modifications are required for most of the clinical biochemical equipment, most IMBLMS equipment is in the state-of-the-art category. Techniques are well known, and further engineering development is required - e.g., the TV-microscope concept. Low-frame-rate TV units have been developed for the Surveyor and Mariner, but IMBLMS requirements may demand extensive modifications. Although compact rugged microscopes have been developed for general field work, the unique requirements imposed by the space environment will demand engineering development.

Identification of the equipment development needs and a realistic appraisal of the development time and cost constitute an important aspect of IMBLMS and will be reviewed thoroughly during the course of the Phase B study.

7.6 PRELIMINARY DESIGN CONCEPT TASKS TO BE PERFORMED

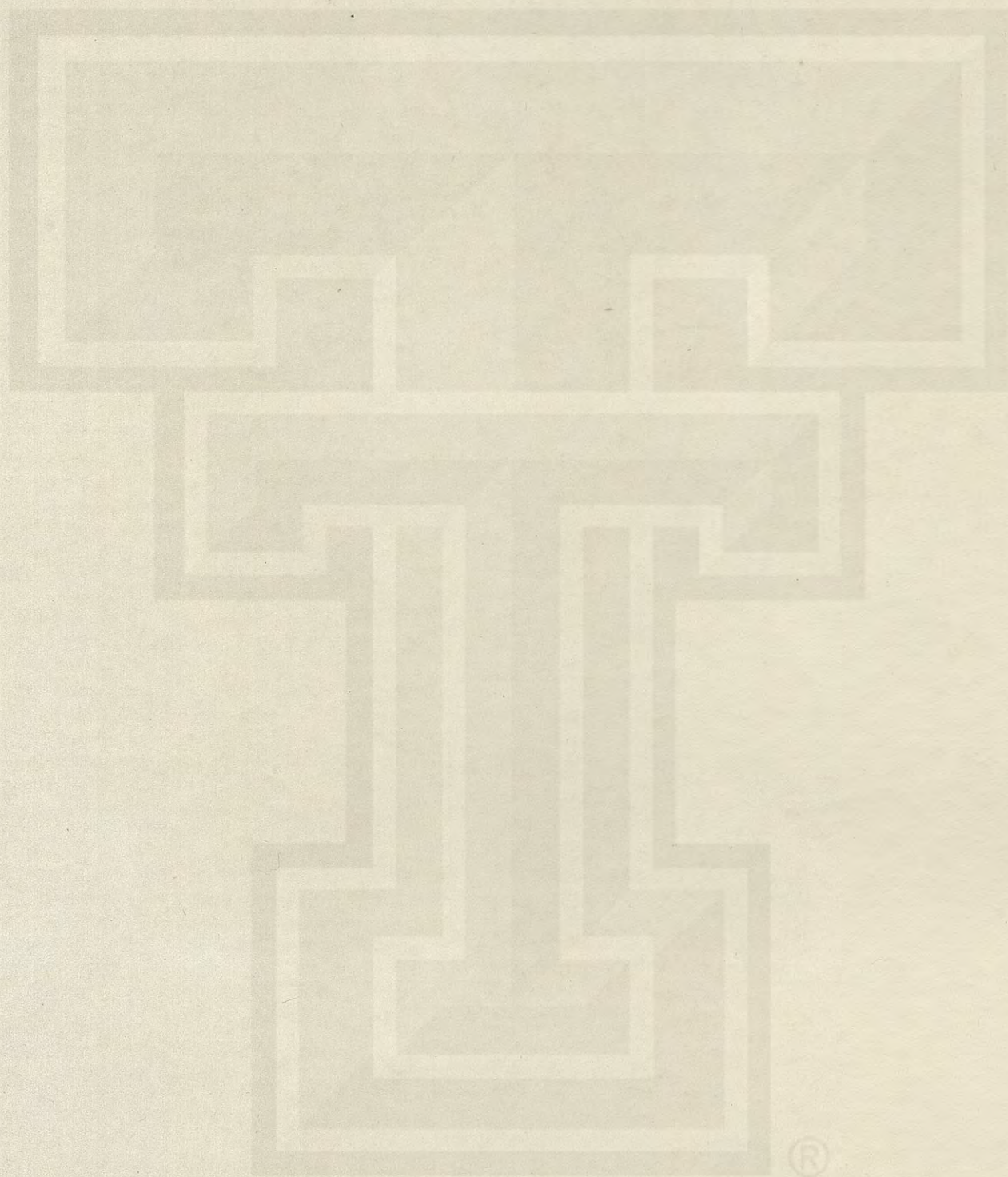
Additional technical effort during Phase B is to be directed toward the following engineering tasks:

- Prepare preliminary block diagram schematics for each module and overall system interfaces.

- Evaluate internal volumetric requirements of IMBLMS modules.
- Reexamine parts placement, density, and thermal considerations, and investigate further harness/cable/connector interfaces.
- Review each candidate IMBLMS in terms of weight, power, and size.
- Reevaluate stowage volume allotment based on IMBLMS candidate design.
- Review need for data compression as a tool to reduce video bandwidth and minimize quantity of data on downlinks.
- Analyze EMI requirements and consider solutions such as box shielding, special harness shielding, and filtering.
- Investigate problem area of RF radiation within spacecraft when operating near field telemetry.
- Perform preliminary analysis of an automatic pulmonary function evaluation program for on-board processor.

Determination of the resource requirements for Phase D - Development and Operations is a subtask to be defined during the Phase B effort. Items to be specifically covered are equipment availability and qualifications.

Two major tasks (H, Development of Preliminary Program Plans for Phase C Effort; and I, Definitive Statement of Work and Cost Proposal for Phase C) are scheduled for completion during Phase B and will be included as sections of the final report.



®

Section 8
REFERENCES

- 1-1. National Aeronautics and Space Administration, Design and Development of an Integrated Medical and Behavioral Laboratory Measurement System, NASA RFP 10-1243, Washington, D. C., 27 Dec 1966
- 2-1. A. Graybiel, "The Oculogravic Illusion," A.M.A. Arch. Ophthal., Vol. 48, 1952, p. 605
- 2-2. B. J. Loret, "Optimization of Space Vehicle Design with Respect to Artificial Gravity," Aerosp. Med., Vol. 34, 1963, p. 430
- 2-3. A. A. J. van Egmond, J. J. Goren, and L. B. Jongkees, "The Function of the Vestibular Organ," Pract. Otorhinolaryng, Vol. 14, Suppl. 2, 1952, p. 1
- 2-4. B. F. McCabe, "Nystagmus Response of the Otolith Organs," Laryngoscope, Vol. 74, 1964, p. 372
- 2-5. A. Graybiel and H. Hupp, "The Oculogyral Illusion," J. Aviat. Med., Vol. 17, 1946, p. 3
- 2-6. U. S. Army Medical Research Laboratory, Adaptation to Bizarre Stimulation of the Semicircular Canals as Indicated by the Oculogyral Illusion, by A. Graybiel, F. Guedry, and W. Johnson, Report No. 464, Fort Knox, 1964
- 2-7. R. Lorente de No', "Vestibulo-ocular Reflex Arc," Arch. Neurol. Psychiat., Vol. 30, 1933, p. 245
- 2-8. A. A. J. van Egmond, J. J. Groen, and L. B. Jongkees, "The Mechanisms of the Semicircular Canal," J. Physiol., Vol. 110, 1949, p. 1
- 2-9. U. S. N. School of Aviation Medicine, A Signal Conditioner and Electrode Technique for Nystagmus Measurements, by W. Carroll Hixson and J. J. Niven, Project MR005.13-6001, 1963

- 2-10. R. S. Weaver, "Theoretical Aspects of the Role of Angular Acceleration in Vestibular Stimulation," Acta Oto-Laryng., Suppl. 205, 1965, p. 1
- 2-11. R. L. Maulsby, "Electroencephalogram during Orbital Flight," Aerosp. Med., Vol. 37, 1966, p. 1022
- 2-12. R. Patterson, W. F. Kubicek, E. Kinnen, and D. Witsoe, "Development of an Electrical Impedance Plethysmography System to Monitor Cardiac Output," Proc. of First Annual Rocky Mountain Bioengineering Symposium, 1964, p. 56
- 2-13. J. G. Defares, M. E. Wise, and J. W. Duyff, "New Indirect Fick Procedure for the Determination of Cardiac Output," Nature, Vol. 192, 1961, p. 760
- 2-14. O. T. Garza, "Measurement of Cardiac Output in Man, at Rest and During Exercise, by an Indirect Fick CO₂ Method," master's thesis, University of New Mexico, 1963
- 2-15. K. Klausen, "Comparison of CO₂ Rebreathing and Acetylene Methods for Cardiac Output," J. Appl. Physiol., Vol. 20, 1965, p. 763
- 2-16. J. H. Comroe, Jr., R. E. Forster II, A. B. Dubois, W. A. Briscoe, and E. Carlsen, The Lung: Clinical Physiology and Pulmonary Function Tests, 2nd edition, Year Book Publishers, Inc., 1962
- 2-17. R. C. Darling, A. Cournand, and D. W. Richards, Jr., "Studies on the Intrapulmonary Mixtures of Gases. III. Open Circuit Method for Measuring Residual Air," J. Clin. Invest., Vol. 19, 1940, p. 609
- 2-18. R. G. Bartlett, Jr., and N. E. Phillips, "The Velocity-Volume Loop; A Composite Pulmonary Function Test," Dis. Chest, Vol. 42, 1962, p. 482
- 2-19. K. von Neergard and K. Wirz, "Die Messung der Strömungswiderstände, in den Atemwegen des Menschen Insbesondere bei Asthma und Emphysem," Z. Klin. Med., Vol. 105, 1927, p. 51
- 2-20. J. Mead and J. L. Whittenberger, "Physical Properties of Human Lungs Measured During Spontaneous Respiration," J. Appl. Physiol., Vol. 5, 1953, p. 779
- 2-21. J. Mead, M. B. McIlroy, N. J. Selverstone, and B. C. Kriete, "Measurement of Intraesophageal Pressure," J. Appl. Physiol., Vol. 7, 1955, p. 491

- 2-22. K. von Neergard and K. Wirz, "Über eine Methode zur Messung der Lungenelastizität am lebendigen Menschen, Insbesondere beim Emphysem," Z. Klin. Med., Vol. 105, 1927, p. 105
- 2-23. W. S. Fowler, E. R. Cornish, Jr., and S. S. Kety, "Lung Function Studies: Analysis of Alveolar Ventilation by Pulmonary Nitrogen Clearance Curves," J. Clin. Invest., Vol. 31, 1952, p. 40
- 2-24. J. H. Comroe, Jr., and E. H. Wood, "Measurement of Oxygen Saturation of Blood by Filter Photometers (Oximeters)," Methods in Med. Res., Vol. 2, 1950, p. 144
- 2-25. E. H. Wood and J. E. Geraci, "Photoelectric Determination of Arterial Oxygen Saturation in Man," J. Lab. Clin. Med., Vol. 34, 1949, p. 387
- 2-26. George Wertheim, personal communication
- 2-27. Dunlap and Associates, Adaptive Simulation, Final Report, by Charles R. Kelley, Contract Nonr-4986(00), Design Applications of Self-Adjusting Simulators, 15 Aug 1966
- 2-28. R. H. Okada, IRE Trans. Med. Elec., Vol. 7, 1966, p. 188
- 2-29. Gradwohl, Clinical Laboratory Methods and Diagnosis, S. Frankel and S. Reitman, eds., 6th edition, C. V. Mosby Co., Inc., St. Louis, 1963
- 2-30. D. Danon, J. Clin. Path., Vol. 16, 1963, p. 377
- 2-31. I. Davidsohn and B. J. Wells, eds., Clinical Diagnosis by Laboratory Methods, 13th edition, Todd-Sanford, 1963
- 2-32. Gradwohl, Clinical Laboratory Methods and Diagnosis, Vol. 2, C. V. Mosby Co., Inc., St. Louis, 1963
- 2-33. Abbott Laboratories, Triosorb T-3 Diagnostic Kit, Abbott Radio-Pharmaceuticals Brochure 97-0152/R4-20-Rev., Nov 1965
- 2-34. J. H. Fellman, et al., Am. J. Clin. Path., Vol. 38, 1962, p. 651
- 2-35. P. Di Giulio et al., J. Lab. Clin. Med., Vol. 63, 1964, p. 864

- 2-36. S. Burnjes et al., Clin. Chem., Vol. 10, 1964, p. 1
- 2-37. H. E. Harrison, Yale J. Biol. & Med., Vol. 38, 1966, p. 393
- 2-38. G. W. Asheroft, Clin. Chem. Acta, Vol. 9, 1964, p. 364
- 2-39. C. R. Berrett et al., Clin. Chem., Vol. 12, 1966, p. 399
- 2-40. H. Jacobson, Anal. Chem., Vol. 38, 1966, p. 1951
- 2-41. B. A. Butcher et al., Aerospace Med., Vol. 36, 1965, p. 1032
- 2-42. General Dynamics Report ERR AN415, by A. Wolgin and G. J. Goble, 1963
- 2-43. E. J. Miller and K. A. Piez, Anal. Biochem., Vol. 16, 1966, p. 320
- 2-44. F. Hutterer and E. J. Singer, Anal. Chem., Vol. 32, 1960, p. 556
- 2-45. V. Hawkinson et al., J.A.M.A., Vol. 128, 1945, p. 514
- 2-46. O. Wrong et al., Clin. Sci., Vol. 28, 1965, p. 357
- 2-47. R. L. Searcy et al., Clin. Chem., Vol. 11, 1965, p. 786, and Am. J. Clin.
Vol. 46, 1966, p. 582
- 2-48. M. Mager and G. Farese, Techn. Bull. Reg. Med. Techn., Vol. 35, 1965,
p. 104
- 2-49. H. G. Goslar, Acta Histochem. Suppl., Vol. 4, 1965, p. 317
- 2-50. R. J. Henry et al., Am. J. Clin. Path., Vol. 23, 1953, p. 841
- 2-51. Gradwohl, Clinical Laboratory Methods and Diagnosis, 6th edition, C. V. Mosby
Co., St. Louis, 1963
- 2-52. S. H. Jackson, Clin. Chem., Vol. 11, 1965, p. 1051
- 2-53. K. Cramer et al., Scand. J. Clin. Lab. Invest., Vol. 11, 1959, p. 213
- 2-54. D. Seligson et al., Clin. Chem., Vol. 4, 1958, p. 159
- 2-55. G. M. Martin and L. Siebel, Cann. Med. Assn. J., Vol. 83, 1960, p. 1214
- 2-56. Miles Lab, Inc., Br. Pat. No. 922655, 3 Apr 1963
- 2-57. A. Ness, Clin. Chem. Acta, Vol. 13, 1966, p. 532

- 2-58. K. Lorentz, Clin. Chem. Acta, Vol. 13, 1966, p. 660
- 2-59. L. A. Carlson, Acta Soc. Med. Upsalien., Vol 64, 1959, p. 208, and Clin. Chem. Acta, Vol. 4, 1959, p. 197
- 2-60. B. Klein et al., Clin. Chem., Vol. 6, 1960, p. 269
- 2-61. F. Wroblewski and J. S. La Due, Proc. Soc. Exp. Biol. Med., Vol. 90, 1955, p. 210
- 2-62. R. J. Henry et al., Am. J. Clin. Path., Vol 34, 1960, p. 381
- 2-63. L. Fishman and J. Doubilet, J.A.M.A., Vol. 157, 1955, p. 908
- 2-64. A. J. Karmen, J. Clin. Invest., Vol. 34, 1955, p. 131
- 2-65. K. S. Henley and H. M. Pollard, Lab. Clin. Med., Vol. 46, 1955, p. 785
- 2-66. B. J. Friis-Hansen et al., Pediat., Vol. 7, 1951, p. 321
- 2-67. B. B. Brodie et al., J. Biol. Chem., Vol. 179, 1949, p. 25
- 2-68. M. J. Gregerson, J. Lab. and Clin. Med., Vol. 29, 1944, p. 1266
- 2-69. S. L. Shapiro, Science, Vol. 114, 1951, p. 73
- 2-70. W. O. Caster et al., J. Lab. and Clin. Med., Vol. 42, 1953, p. 493
- 3-1. National Aeronautics and Space Administration, Office of Manned Space Flight, Apollo Applications Program, Baseline Configuration Definition AAP-1A Through AAP-5, 1 Jun 1967
- 3-2. -----, Program Directive No. 3B, Flight Mission Directive for AAP-1/AAP-2, 19 Jun 1967
- 3-3. -----, Program Directive (Preliminary), Flight Mission Directive for AAP-3/AAP-4, undated
- 3-4. Lockheed Missiles & Space Company, Data Return Capsule System Feasibility Study for the Cluster A Mission, LMSC-A842144, 1967
- 4-1. -----, Biological Measurement of Man in Space, Vols. I-VI, NASA Contract NASw-1071, Report M-61-64-1, 1964-1967

- 4-2. Lockheed Missiles & Space Company, Biological Measurement of Man in Space, Vol. VI, "Time-Line and Feasibility Analysis for AAP Biomedical Experiment Program, Final Report," NASA Contract NASw-1071 Modification 3, Report M-61-64-1-VI, Jan 1966
- 4-3. National Aeronautics and Space Administration, Marshall Space Flight Center, Systems Engineering Branch, R-P&VE-VA, S-IVB Orbital Workshop Astronaut Walkthrough Final Report, 28 Jun 1967
- 5-1. -----, Orbital Workshop Experiment Requirements, NASA General Working Paper No. 10,065
- 5-2. -----, Marshall Space Flight Center, Environmental Design and Qualification Test Criteria for ATM, 50M02408, Huntsville, Ala., 31 Jan 1967
- 5-3. -----, Manned Space Center, Apollo Spacecraft Parts and Material Program, MSC-A-D-66-7, Houston, Tex., 14 Nov 1966
- 5-4. -----, Manned Spacecraft Center, Procedures and Requirements for the Evaluation of Spacecraft Nonmetallic Materials, MSC-A-D-66-3, Houston, Tex., 5 Jun 1967
- 5-5. -----, Reliability Program Provisions for Space Systems Contractors, NPC 250-1, Jul 1963
- 5-6. -----, Quality Provisions for Space System Contractors, NPC 200-2, Apr 1962
- 5-7. -----, Inspection System Provisions for Suppliers of Space Materials, Components, and Services, NPC-200-3, Apr 1962