FINAL REPORT TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PART II INTERFACE DOCUMENT

RESEARCH CONTRACT NASA NSR 05-007-158

"PHYSIOLOGY OF CHIMPANZEES IN ORBIT"

JULY 8, 1968 through FEBRUARY 28, 1971

Dr. W. Ross Adey
Space Biology Laboratory
Brain Research Institute
University of California, Los Angeles

April 10, 1972

FINAL REPORT TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PART II INTERFACE DOCUMENT

RESEARCH CONTRACT NASA NSR 05-007-158

"PHYSIOLOGY OF CHIMPANZEES IN ORBIT"

JULY 8, 1968 trough FEBRUARY 28, 1971

Dr. W. Ross Adey
Space Biology Laboratory
Brain Research Institute
University of California, Los Angeles

April 10, 1972

PHYSIOLOGY OF CHIMPANZEES IN ORBIT INTERFACE DOCUMENT

THIS DOCUMENT WAS PREPARED UNDER CONTRACT NSR 05-007-158
BY THE SPACE BIOLOGY LABORATORY, BRAIN RESEARCH INSTITUTE,
UNIVERSITY OF CALIFORNIA, LOS ANGELES, CALIFORNIA 90024.

PREPARED BY: Allen Firstenberg
Project Engineer

APPROVED BY: Pierre M. Hahn

Pierre M. Hahn
Research Manager

W.R. Adey

W.Ross Adey, M.D.
Principal Investigator

Final Revision:

POCO-04-071-006

December, 1971

TABLE OF CONTENTS

			Page
I.	Introduction		1
II.	Primate Interface		
	A.	Introduction	2
	B.	Food	3
	C.	Water	6
		C.1 Water Budget	6
		C.2 Potable Water	7
	D.	Atmosphere	9
		D.1 Primate Gas, Vapor and Heat Loads	10
		D.2 Primate Effluent Gas Production	11
	E.	Behavioral Tasks	12
		E.1 Reinforcement Button Task	13
		E.2 One Sample, One Choice Random Task	18
		E.3 Two Sample, Two Choice Random, MSS Behavior Task	25
		E.4 Multiple Symbol Random, MSS Behavior Task	30
		E.5 Primate Environmental Control	30
		E.6 Task Presentation Criteria	34
		E.7 Training Protocol	48
	F.	Implanted Telemetry	60
		F.1 Data Acquisition Requirements	60
		F.2 Automatic Electroencephalogram Analysis	68
	G.	Waste Production	74
		G.1 Fluids	74
		G.2 Solids	74

TABLE OF CONTENTS (con't)

		Page
H.	Orientation Considerations	76
I.	Acoustic Considerations	77
J.	Lighting	78
	J.1 House Lighting	78
K.	Primate Configuration	79
L.	Acceptable Limits of Environment	87
	L.1 Acceleration	87
	L.2 Vibration	87
	L.3 Shock	90
	L.4 Guidance and Control	90
	L.5 Primate Launch Support Equipment	90
M.	Drug Administration	93
III.	Experiment Interface	95
A.	Introduction	95
B.	Pellet Feeder	96
	B.1 Description	96
	B.2 Concept	96
	B.3 Specifications	99
C.	Water Dispenser	100
	C.1 Concept	100
	C.2 Specifications	102
D.	Gas Management System	105
	D.1 Concept	105

TABLE OF CONTENTS (con't)

		Page
E.	Behavioral Task Display	113
	E.1 Description	113
	E.2 Concept	113
	E.3 Specifications	118
F.	Local Telemetry	120
	F.1 Description	120
	F.2 Specifications	128
	F.3 Power Considerations	131
G.	Waste Removal System	132
	G.1 Concept	132
H.	Orientation Sensing System	150
	H.1 Concept	150
I.	Camera Subsystem	157
	I.1 Operations	157
J.	House Lighting	158
	J.1 Concept	158
	J.2 Specifications	159
K.	Primate Life Cell	161
	K.1 Concept	162
	K.2 Specifications	165
	K.3 Life Cell Wall Segment Disposition	167
L.	Behavioral Electronics	169
M.	Mission Sequence	170
N.	Five Year Plan for POCO Development	174

TABLE OF CONTENTS (con't)

Appendix A: POCO Primary Training Protocol

Appendix B: Primate Inserted System Test Specifications

LIST OF ILLUSTRATIONS

No.	Description	Page
1	Behavioral Display Panel	15
2	Reinforcement Button Task Flow Diagram	16
3	Reinforcement Button Task Time Chart	17
4	One Sample Random Task Flow Diagram	20
5	One Sample Random Task Time Chart	21
6	Two Sample MSS Task Flow Chart	27
7	Two Sample MSS Task Flow Chart	28
8a	Three Symbol MSS Time Chart	31
8b	Four Symbol MSS Time Chart	32
8c	Five Symbol MSS Time Chart	33
9	Primary Behavioral Display Panel	52
10	MSS Training Behavioral Panel	54
11	Flight Configuration Behavioral Panel	55
12	Environmental Control Display Switch Location	59
13	Pleural Cavity Telemetry Unit	61
14	Telemetry Units Area of Implantation	62
15	Telemetry Units Area of Implantation	63
16	Typical Electrode Locations	64
17	EEG Sleep Stages in Chimpanzee	69
18	Automatic EEG Analyzer Block Diagram	73
19	Primate Configuration - Straight Measurements	83
20	Primate Configuration - Straight Measurements	84
21	Primate Configuration - Straight Measurements	85

LIST OF ILLUSTRATIONS (con't)

No.	Description	Page
22	Primate Configuration - Circumferential Measurements	86
23	Available Paylod Envelope	88
24	Acceleration-Time History	89
25	Random Vibration Amplitude-Frequency-Time History	91
26	Pellet Dispenser	97
27	Water Dispensation - Block Diagram	101
28	Demand Regulator	103
29	GMS Block Diagram	106
30	Behavioral Display Panel Mounting Locations	114
31	Telemetry Allocation	121
32	Telemetry System Block Diagram	122
33	EEG Amplifier Schematic	124
34	PAM Multiplexer Schematic	125
35	Transmitter Schematic	127
36	Thick Film Hybrid Package Eight Amplifiers Plus Multiplexer	129
37	Waste Receptacle	133
38	Excretion Sensing Electrodes	135
39	Backpack	136
40	Harness, Front View	138
41	Harness, Back View	139
42	Water Jet Concept	141
43	Water Jet Cleaner Support Shaft	142

LIST OF ILLUSTRATIONS (con't)

No.	Description	Page
44	Water Jet Outer Bearing Plate	143
45	Water Jet Rotor	144
46	Water Jet Support Frame	145
47	Wiper Blade Configuration	148
48	Typical Servo Electro-optical Tracking System	151
49	Sampling Type Tracking System	153
50	Incandescent Lighting	160
51	Triangular Shaped Wall Segment	163
52	Relative Position of Triangular Segment in Respect to Sphere and Cylinders	164
53	Molded Polycarbonite Triangular Spherical Segment	166
54	Mission Sequence - One Trimester	172
55	System Block Diagram	173
56	5 Year Flow Chart for POCO Development	175

LIST OF ILLUSTRATIONS (con't)

No.	Description	Page
44	Water Jet Outer Bearing Plate	143
45	Water Jet Rotor	144
46	Water Jet Support Frame	145
47	Wiper Blade Configuration	148
48	Typical Servo Electro-optical Tracking System	151
49		

LIST OF TABLES

No.	Description	Page
1	Nomenclature	34
2	Task Presentation Criterion	40
3	Implanted Telemetry Channel Disposition	65
4	Capsule Generated Physiological Telemetry Channel Disposition	66
5	Chimpanzee Flight Configuration Straight Measurements	79
6	Chimpanzee Flight Configuration Circumferential Measurements	81
7	Primate Launch Support Equipment	92
8	Pharmaceutical Administration	93
9	Summary of Conatminant Control	110
10	Symbol Presentation Array	117
11	Wall Segment Disposition	167
12	Major Milestone Schedule	177
13	Primate Test Summary	178

I. INTRODUCTION

This document presents the interface requirements for the design and development of an earth orbiting experiment to be known as POCO, Physiology of Chimpanzees in Orbit.

It is separated into the two major sections: "Primate Interface," and "Experiment Interface." Section II, entitled Primate Interface, defines the requirements of each subsystem necessary to support the physiological and psychological needs of the primate as well as to establish the specified experimental conditions. Section III, entitled Experiment Interface, offers the design and specifications of hardware necessary to support the mission requirements described in Section II.

It is to be understood by the reader that the design concepts presented herein are not considered final by this laboratory and in fact, are undergoing continual re-evaluation and improvement. Also of importance is that the details of the experiment are still within the stage of formulation. Controls on the experimental subject, the types and quantities of physiological data to be monitored and the behavioral task definition are but a few of the mission specifications undergoing refinement.

The POCO experiment may be designed to operate within an orbiting space station (provided artificial gravity measures are not employed), a Saturn IV-B workshop, an Apollo Command Module, or service module, a Saturn-1B spacecraft LM adapter, or aboard one of the presently conceived appendages connected by an umbilical to a space station.

It is the purpose of this document to set forth the experiment definition and requirements and to describe the hardware under development to accomplish these objectives as they are realized at this date.

II PRIMATE INTERFACE

A. INTRODUCTION

Section II of this report presents the primate interface; that is, the interface between the primate and its supporting equipment. The requirements imposed on each subsystem as well as on the overall system and spacecraft design by the primate's physiological and psychological needs and by the experimental conditions to be imposed upon the primate are included herein.

II. PRIMATE INTERFACE

B. FOOD

There shall be a singular solid diet formulation supplied in the form of dry pellets to the primate. At the successful completion of each behavioral task trial, one pellet shall be dispensed to the primate. The diet selected is a vitamin fortified modification to Purina Monkey Chow. It considers the somewhat specialized needs of the juvenile (growing) chimpanzee as opposed to other diets which provide proper maintenance only for adult animals. Formulations similar to this diet have been used successfully on chimpanzees as the sole solid diet for periods of years. Its formulation is shown below:

DIET FORMULATION

NUTRIENTS	% BY WEIGHT*
1. Protein	25.9
Arginine	1.7
Glycine	1.2
Lysine	1.6
Methionine	0.45
Tryptophan	0.32
Cystine	0.40
Histidine	0.73
Leveine	2.3
Isoleucine	1.5
Phenylalanine	1.3

*Water Content: Approximately 9% by Weight

		% BY WEIGHT
Threonine		1.1
Valine		1.4
Other Amino Acids (By Difference)		11.9
2. Fat		4.9
3. Fiber		2.7
4. Nitrogen Free Extract		49.5
5. Ash		7.3
Calcium		1.30
Phosphorus		0.94
Potassium		1.03
Magnesium		0.26
Sodium		0.22
Chlorine		0.27
Other (By Difference)		3.28
Iron (ppm)	244	
Zinc (ppm)	21.0	
Manganese (ppm)	40.5	
Copper (ppm)	13.4	
Cobalt (ppm)	0.25	
Iodine (ppm)	0.81	
6. Vitamins		0.7
Thiamin (ppm)	17.7	
Riboflavin (ppm)	10.0	
Niacin (ppm)	100.3	
Pantothenic Acid (ppm)	67.3	
Choline (ppm)	2403	

	% BY WEIGHT
Folic Acid (ppm)	5.9
Pyridoxine (ppm)	14.1
Biotin (ppm)	0.34
B-12 (μgm/gm)	.0225
Vit-A (IU/gm)	5.0
Vit-D (IU/gm)	10.0
Alpha-Biocopherol (IU/gm)	13500
Ascorbic Acid (mg/gm)	0.50

DIET CHARACTERISTICS

1. Total Digestable Nutrients: 80%
2. Gross Energy: 4.31 Kcal/gm

INGREDIENTS

Dehydrated alfalfa meal, ground yellow corn, dried skimmed milk, soybean meal, fish meal, animal fat preserved with butylated hydroxyanisole, brewer's dried yeast, vit-B_{12} supplement, riboflavin supplement, calcium pantothenate, niacin, folic acid, pyridoxine hydrochloride, thiamin, ascorbic acid, vit-A supplement, D activated animal sterol (source of vit-D_3), steamed bone meal, vit-E supplement, calcium carbonate, defluorinated phosphate, iodized salt, iron oxide, iron sulfate, manganese sulfate, manganese oxide, cobalt carbonate, zinc oxide.

The pellets shall be procured in lots, each lot being enclosed in an individual water-tight container marked with such pertinent information as batch designation, date of manufacture, weight of lot, number of pellets of lot and diet title. The diet shall be certified to be free of <u>Salmonella</u> and <u>Shigella</u>; it shall contain vitamin fortification exceeding the standard commercially available product; potency maintenance shall exceed commercial standards; animal fat shall not be derived from reclaimed sources; calcium and phosphorus shall be derived from steamed bone meal, certified wholesome; and all manufacturing methods must meet the minimum standards for wholesomeness provided for in contemporary human consumption by USDA.

The food dispenser shall be loaded from a single lot for flight and primate inserted tests. A 2% sample of each lot used for flight and primate inserted tests shall be analyzed for caloric content, hardness, water content, and micro-organism count. The handling and storage of pellets must be rigidly defined to minimize caloric breakdown as a function of time.

Each pellet shall conform to the following specifications:

weight	1.55 ± 0.7 gms
caloric content	6.67 ± 0.3 kcal
dimensions	1.7 ± 0.17 cm diameter, spherical configuration

To satisfy the requirements of the countdown phase and the 180 day mission, a total of 48,000 pellets is required on board. A force of not more than five pounds must be necessary to actuate the feeder mechanism. After actuation is complete the pellet must protrude from the feeder no less than 1.1 cm with a force no more than 200 gms necessary to detach the pellet from the feeder.

A separate supply of drug incorporated pellets, fresh fruit and other forms of pharmaceuticals shall be stored on board and dispensed to the primate for medicinal purposes as described in Section II M.

C. WATER

C.1 WATER BUDGET

The only liquid to be available for primate consumption during the flight shall be water. The average water requirement of a 17.5 kg chimpanzee is 800 cc per day; however, to insure water presentation on an *ad lib* basis, the following limits of the amount of water available to the primate shall be programmed:

80 cc ± 2 cc per hr - day cycle

80 cc ± 2 cc per 3 hr - night cycle

Provision shall be made for command to allow dispensing of 80 cc/hr during the night cycle or for dispensing on a completely *ad lib* basis.

The temperature of the water delivered to the primate shall be between 55°F and 80°F. The suction required for operation of the water dispenser by the primate shall be between 22 torrs and 40 torrs. The maximum suction a primate can apply will be 150 torrs. The water flow rate over the range of allowable suctions will be no less than 0.2 cc/sec and no more than 0.7 cc/sec.

The water dispenser shall be provided with a metering system to measure the amount of water dispensed to the primate. An emergency override system shall be provided to permit filling of the water dispenser upon receipt of ground command. The portion of the water dispenser which contacts the primate's mouth shall be fabricated of 304 stainless steel (same material as implant electrodes), shall be isolated from spacecraft ground by at least 80 MΩ, and shall conform to the following dimensions: Outside diameter: 1 cm.

C.2 POTABLE WATER

Potable water to be supplied to the primate shall conform to the following contamination limitations:

CONTAMINANT	LIMIT	CONTAMINANT	LIMIT
Total Solids	1000 ppm	Mg	50 ppm
Total Organics	200 ppm	K	10 ppm
Phenols	0.001 ppm	Na	25 ppm
ABS	0.5 ppm	Ag	0.05 ppm
As	0.05 ppm	Sulfate	250 ppm
Cd	0.01 ppm	Cyanide	0.2 ppm
Cr (Cr^6)	0.05 ppm	F	3 ppm
Cu	1.0 ppm	Ti	10 ppm
Pb	0.05 ppm	P	10 ppm
Fe	0.30 ppm	Cl	250 ppm
Mn	0.05 ppm	Silica	100 ppm

Ph	6 - 9
Odor Threshold* Number	6
Conductivity	750 micro mhos/cm
Particles	Must meet total solids requirement and the specific requirements of the following table

PARTICLE SIZE, MICRONS	MAXIMUM QUANTITY OF METALLIC PARTICLES ALLOWABLE	MAXIMUM QUANTITY OF NONMETALLIC PARTICLES ALLOWABLE
Under 25	Total solids requirement only	Total solids requirement only
20 - 50	20	300
51 - 100	10	100
101- 150	None	15
Over 150	None	None

* Described in "Standard Methods for the Examination of Water and Waste Water", American Public Health Association, 11th Edition.

Viable material - 200 counts per cc maximum.

Coliform bacteria - 2.2 organisms per 100 cc maximum.

II. PRIMATE INTERFACE

D. ATMOSPHERE

The primate shall be enclosed in a controlled environment. The environmental control shall provide a habitable closed capsule environment for a period of not less than 6 months and 10 days. The environmental control functions shall include oxygen, nitrogen, carbon dioxide, noxious and toxic gas content, capsule pressure, capsule temperature, relative humidity and particulate matter concentration. The environmental control limits shall be as follows:

1. Capsule pressure (PSIA): 14.7 ± 0.75

2. Rate of change of total pressure (PSI/min): 0.25 max

3. O_2 partial pressure (torrs): 135 to 165

4. CO_2 partial pressure:

   Maximum (torrs): 16

   Minimum (torrs): 4

5. N_2 partial pressure (torrs): remainder to achieve specified capsule pressure

6. Relative humidity (%): 35 to 70

7. Temperature in capsule (°F): $76° \, {}^{+5}_{-1}$ *

8. Particulate matter (microns): 100

9. Noxious and toxic gases, maximum allowable limits:

Carbon monoxide (ppm)	20
Ammonia (ppm)	50
Hydrogen sulfide (ppm)	20
Ozone (ppm)	10
Formaldehyde (ppm)	10
Ethylene oxide (ppm)	5
Ketones (ppm)	5
Methane (ppm)	5
Phenols (ppm)	5
Fluorine (ppm)	5

10. Gas flow rate into life cell: To be determined

*Capsule temperature control by the primate is being considered in which case the temperature limits would be extended to 76°F ± 5°F.

11. Temperature variation across primate (°F) maximum: 3

D.1 PRIMATE GAS, VAPOR AND HEAT LOADS

1. O_2 Consumption

peak (liters/hr)	32
average (liters/day)	223
minimum (liters/day)	124

2. CO_2 Production

peak (liters/hr)	27
average (liters/day)	185
minimum (liters/day)	100

3. H_2O Vapor Production

peak (grams/day)	143
average (grams/day)	540
minimum (grams/day)	52

4. Total Metabolic Heat Production

peak (BTU/hr)	437
average (BTU/hr)	174
minimum (BTU/hr)	96

D.2 PRIMATE EFFLUENT GAS PRODUCTION

The typical sources of noxious and toxic gases and their associated gases are shown in the table below:

Source	Gas
Expired Air	Methane, Hydrogen, Carbon Dioxide, Nitrogen, Hydrogen Sulfide
Flatus	Hydrogen, Hydrogen Sulfide, Nitrogen, Methane, Indole, Skatole, Ammonia, Amines, Mercaptan
Feces	Ammonia, Methane, Hydrogen Sulfide, Methylmercaptan, Indole, Skatole, Paracresol
Urine	Ammonia, Hippuric Acid, Phenols
Perspiration	Iodine, Flourine, Bromine, Nitrogen, Ammonia, Phenol

II. PRIMATE INTERFACE

E. BEHAVIORAL TASKS

Description

A variety of behavioral tasks will be presented to the primate of varying degrees of difficulty. The purpose of the dynamics of the behavioral task progression is to lay down an experimental environment which will mirror the gamut of drives and capabilities of the unrestrained chimpanzee throughout extended stresses. In prolonged orbital flight the tasks and options will test:

1) The ability of the primate to maneuver and orient in weightlessness;
2) The ability to attend to and orient to sustained sequential response requirements;
3) The ability to make correct judgments of recognition;
4) The primate's motivation to perform by offering session or trial self-select options;
5) The motivation to select day/night cycles;
6) The change in performance as a function of continuous light;
7) The motivation to select life cell temperature;
8) The motivation to perform for auditory reinforcement.

Successful completion of a behavioral task is rewarded by dispensing a pellet for primate consumption.* Incorrect responses by the primate initiate a buzzer indicating failure to the primate and no food reward is dispensed. No response to a behavioral task presentation is also considered a failure (no play); however, no buzzer is imposed upon the primate for failure to respond.

---

*Being considered is the addition of chimpanzee colony sounds as a reward for successful completion of the more difficult behavioral tasks with the duration of the colony sounds dependent upon task difficulty.

Primate depression of non-excited display switches does not constitute an incorrect response and does not represent a switch depression to the behavioral logic. The interval between successive trials within a behavioral task session is identical for each of the behavioral tasks and shall be set at 10 to 60 sec (controllable by real time command in 10 sec increments).

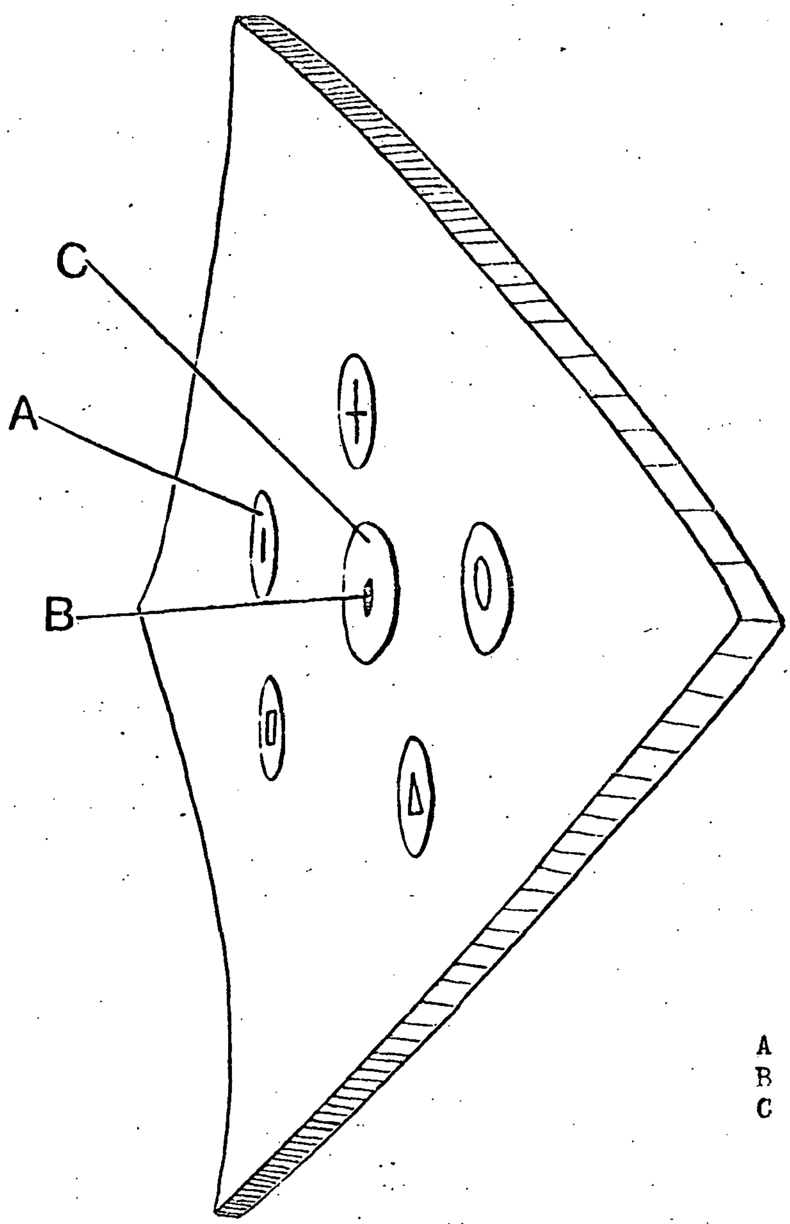
The behavioral tasks, in the order of their difficulty are presented below:

E.1 REINFORCEMENT BUTTON TASK

The reinforcement button task represents the simplest behavioral task to be presented to the primate. Its primary purpose is to test the primate's ability to locomote in the weightless state. It consists merely of a button press response to an orientation cue. At task initiation, a reinforcement switch lights up (see Fig 1) and a simultaneous audio tone (200 Hz) is sounded. The audio tone and light cue remain on for a specific duration, set initially as 60 sec. The arming of the reinforcement switches from the different sextants of the sphere will signal availability of food. Availability will occur randomly to impose orienting requirements upon the primate.

Depression of the reinforcement switch by the primate within the allotted 60 sec represents a success. Button depression extinguishes the light and audio tone and causes a pellet to be dispensed in the reinforcement light's associated feeder for primate consumption. No button press within the allotted time constitutes a failure wherein no food reward is dispensed. The inter-trial interval is defined as that time between button press or presentation timeout and subsequent trial initiation. A flow diagram and time chart of this behavioral task is presented in Fig 2 and 3 respectively.

The Event I duration of the reinforcement button task will initially be set at 60 sec. Subsequent durations of this event will be contingent upon the animal's response latency history. The Event I duration will be titrated from 60 sec to 10 sec, as described in the task progression criteria section, E.6.



A Display switch
B Pellot dispenser
C Reinforcement switch

Behavioral Display Panel

FIGURE 1

Reinforcement Button Switch On

200 Hz Audio Tone On

Event 1 - Orientation Cue

Reinforcement switch not depressed within allotted time.

Reinforcement switch depressed within allowable response time of 10, 20, 30, 40, 50 or 60 seconds.

Reinforcement light and tone extinguishes after allotted time has elapsed. Initiate inter-trial interval.

Reinforcement light and audio tone are extinguished; Dispense pellet; initiate inter-trial interval

FIGURE 2

REINFORCEMENT BUTTON

Behavioral Task
Flow Diagram

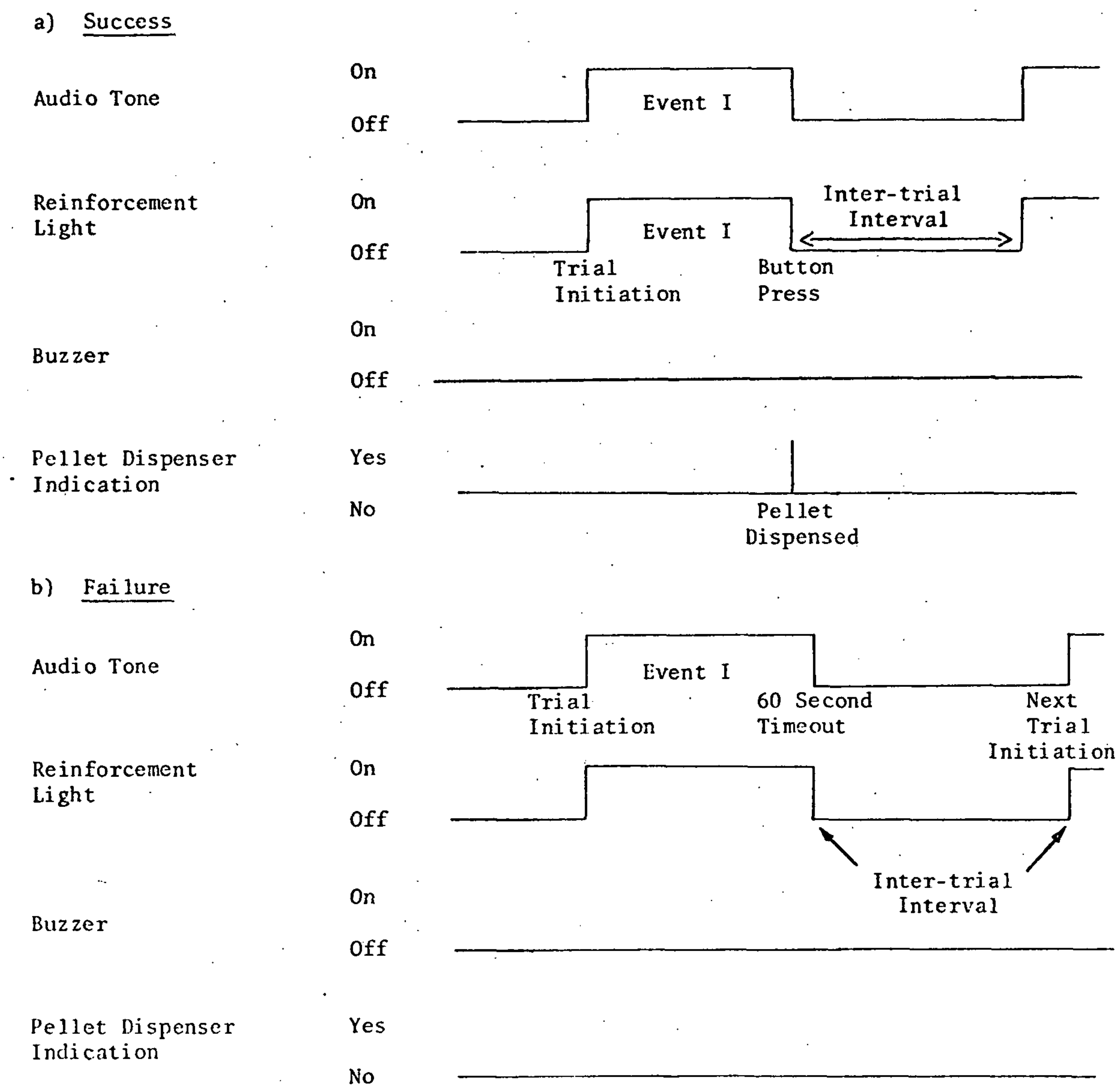


FIGURE 3

REINFORCEMENT BUTTON

Behavioral Task
Time Chart

E.2 ONE SAMPLE, ONE CHOICE RANDOM TASK

The next step in task difficulty will be the requirement to respond successively to a single sample, then to its matching choice symbol appearing on the same behavioral display. This task tests the critical integrity of vestibular function to mediate multiple press responses over a sustained trial duration.

The one sample random behavioral task requires three successive button presses for successful completion of the task. A trial is initiated by a one sec duration audio and visual orientation cue emitted from one of the six behavioral panels present in the life cell. At the completion of the orientation cue, one of five symbols is selected randomly and presented in a random window of the randomly selected behavioral display panel. The primate has a specified time to depress the switch located directly in front of the excited symbol. The allowable response time, X, is to be determined in flight by the primate's performance on the reinforcement button behavioral task. The criteria by which this response time is determined is presented in the following section of this report. Failure of the primate to depress the switch within the allotted time constitutes a failure whereby the symbol is extinguished and the inter-trial interval begins.

Primate button depression within the allotted time extinguishes the symbol and initiates a delay period initially set between 0 and 1 sec. Following the delay period, a one sec orientation tone is presented to cue the onset of the choice phase of the trial. At the completion of the orientation cue, the same symbol reappears in a randomly selected window of the identical behavioral display panel. The primate must respond within the allotted response time by button depression. Failure to do so initiates the inter-trial interval. Successful button depression results in a simultaneous third orientation cue whereby the reinforcement switch lights up simultaneously with a tone. The remainder of the task is identical to the reinforcement button task. A flow diagram and time chart are shown in Fig 4 and 5 respectively.

The delayed matching to one symbol task is expanded in subsequent behavioral sessions to incorporate multiple symbols (5 maximum) during the choice phase of the trial. The one sample, two choice task, through the one sample, five choice task are identical to the task just described with the exception that multiple symbols will appear randomly on the switches of the behavioral panel during the choice time of the trial. Reinforcement contingencies are dependent upon the subject selecting the switch on which is displayed the sample symbol whereas a response to any other illuminated symbol constitutes a failure, terminating the trial with a one sec duration buzzer sound.

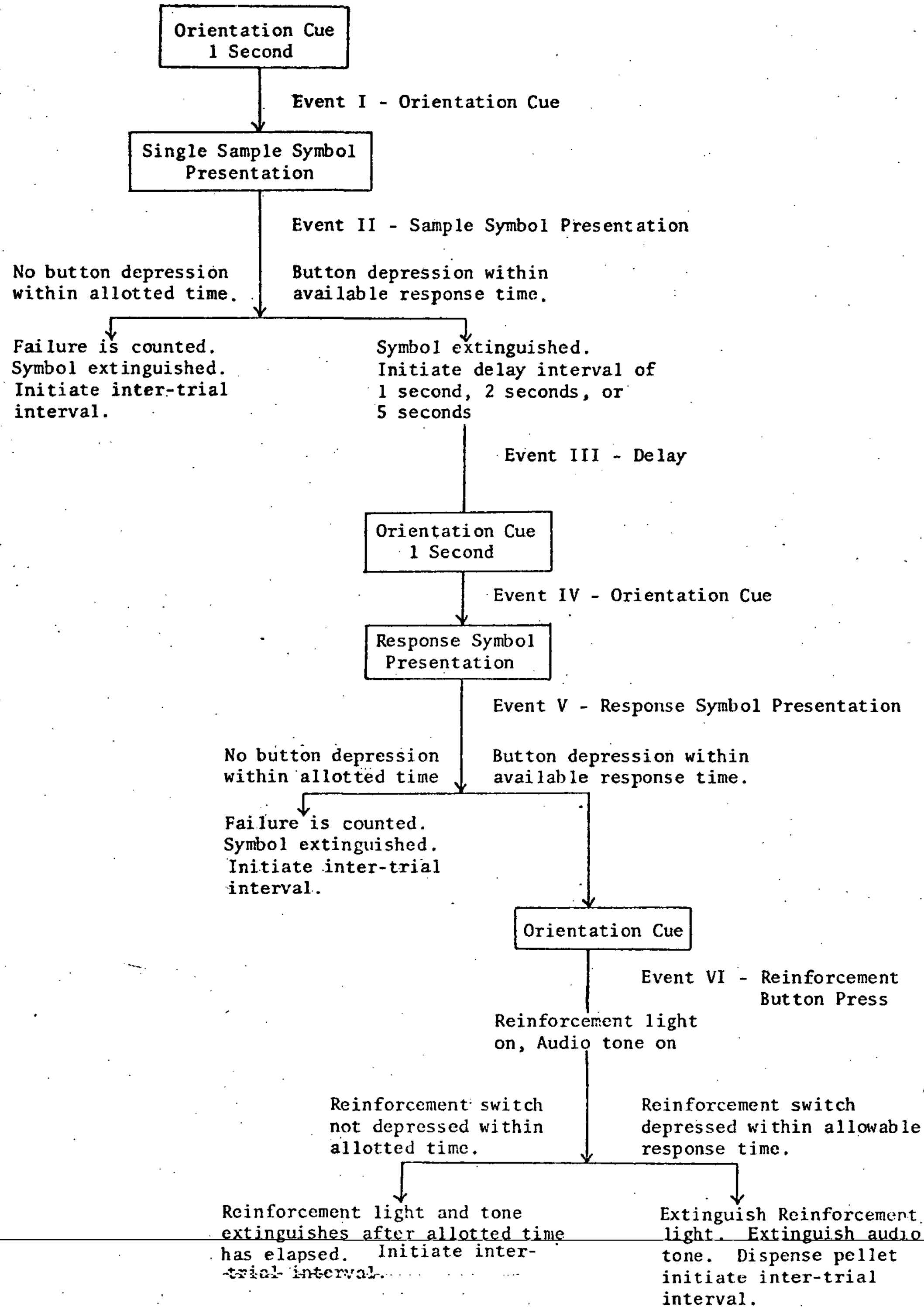


FIGURE 4

ONE SAMPLE, ONE CHOICE RANDOM
BEHAVIORAL TASK FLOW DIAGRAM

a) Failure in Event II
No Sample Symbol Switch Depression

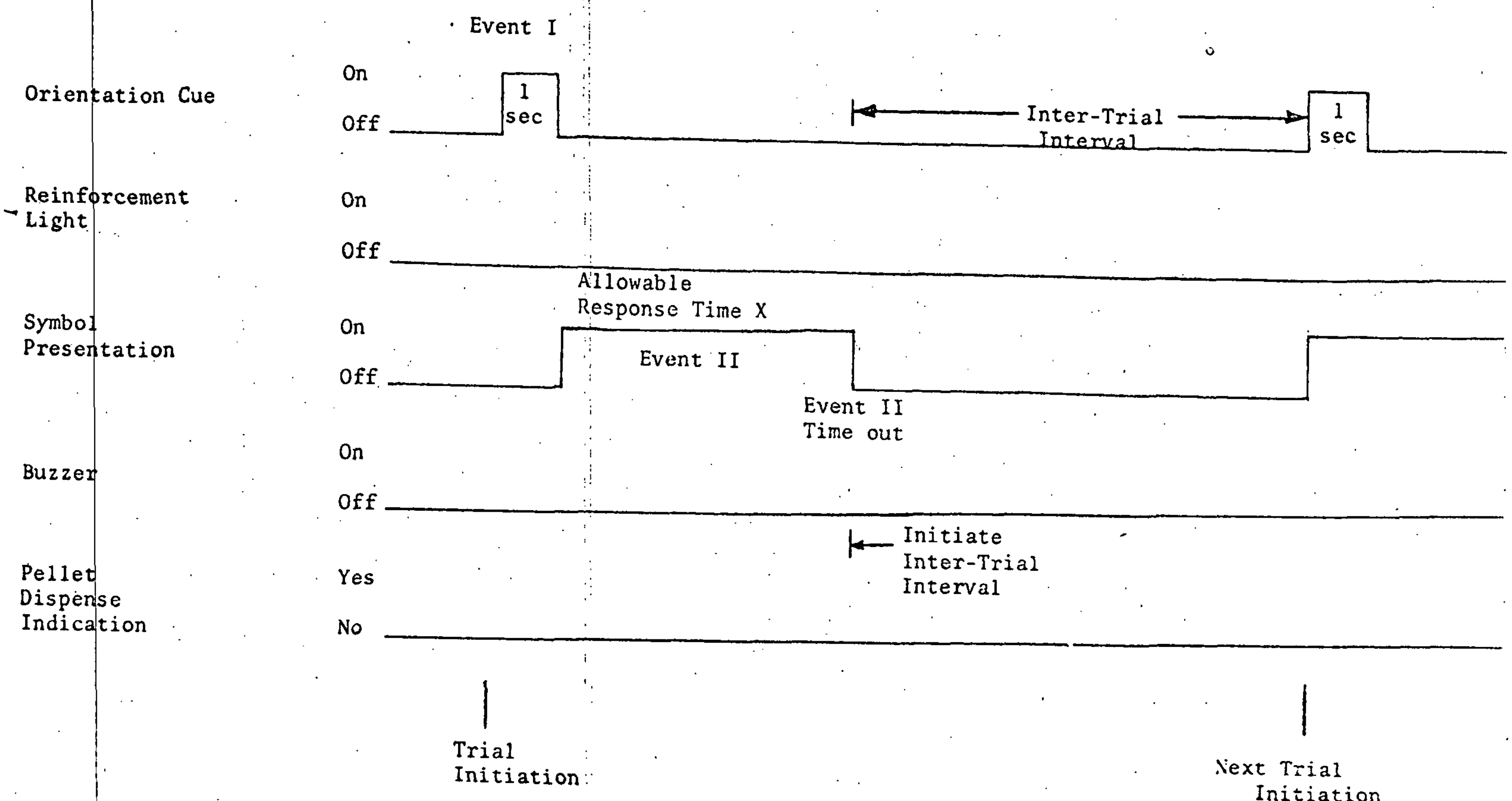


FIGURE 5a

ONE SAMPLE, ONE CHOICE RANDOM
BEHAVIORAL TASK TIME CHART

b) Failure in Event V
No Response Symbol Switch Depression

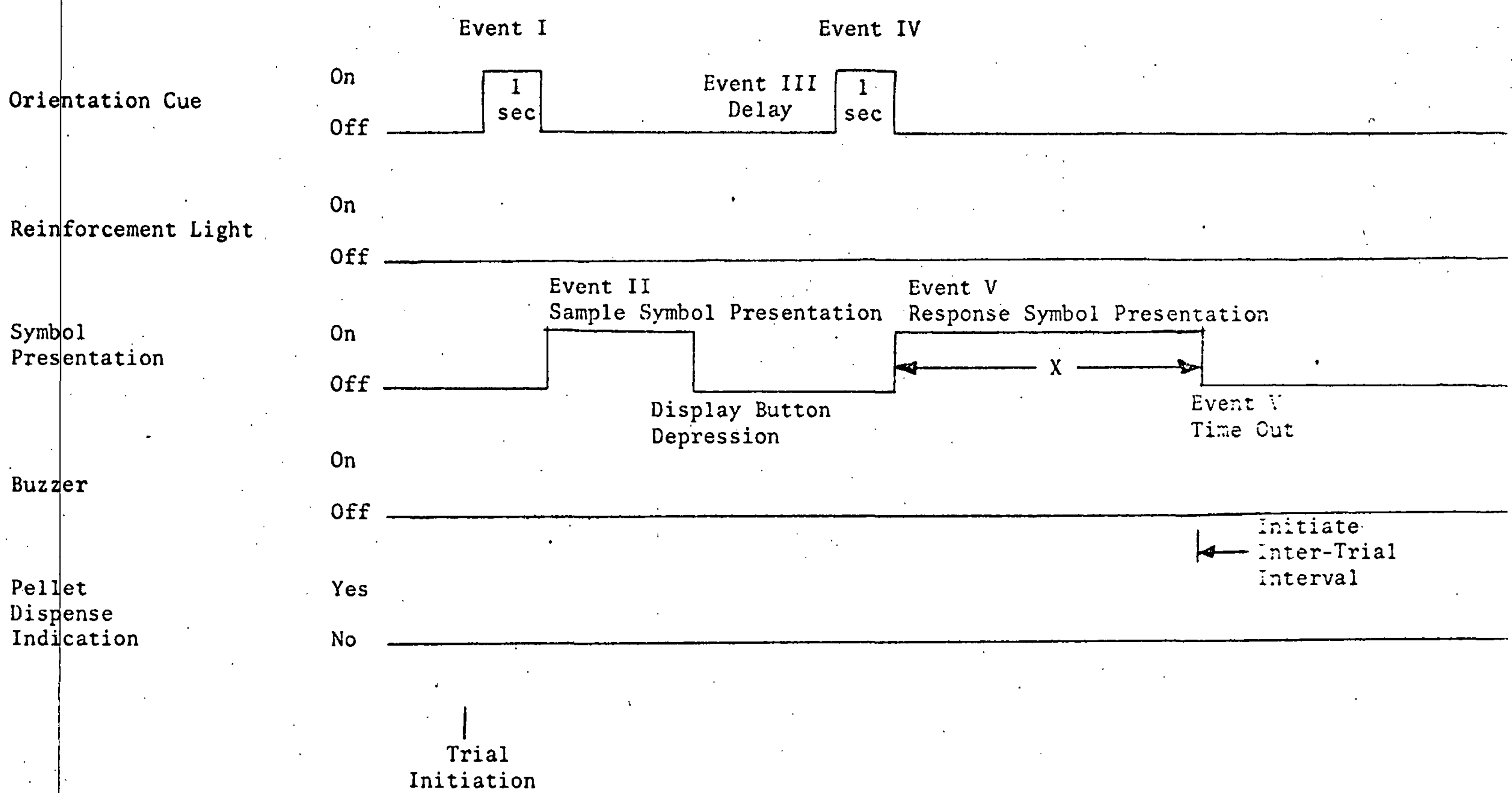


FIGURE 5b

ONE SAMPLE, ONE CHOICE RANDOM
BEHAVIORAL TASK TIME CHART

c) Failure in Event VI
No Reinforcement Button Depression

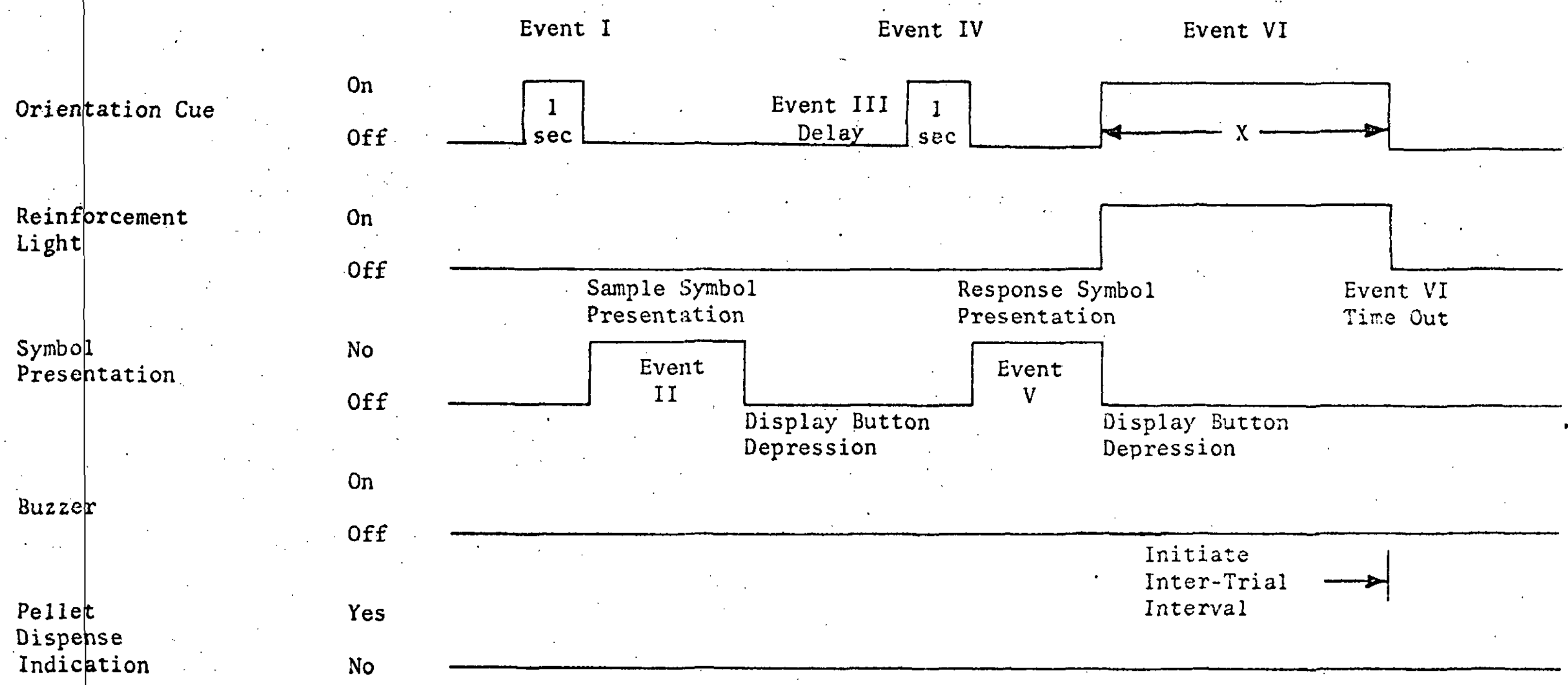


FIGURE 5c

ONE SAMPLE, ONE CHOICE RANDOM
BEHAVIORAL TASK TIME CHART

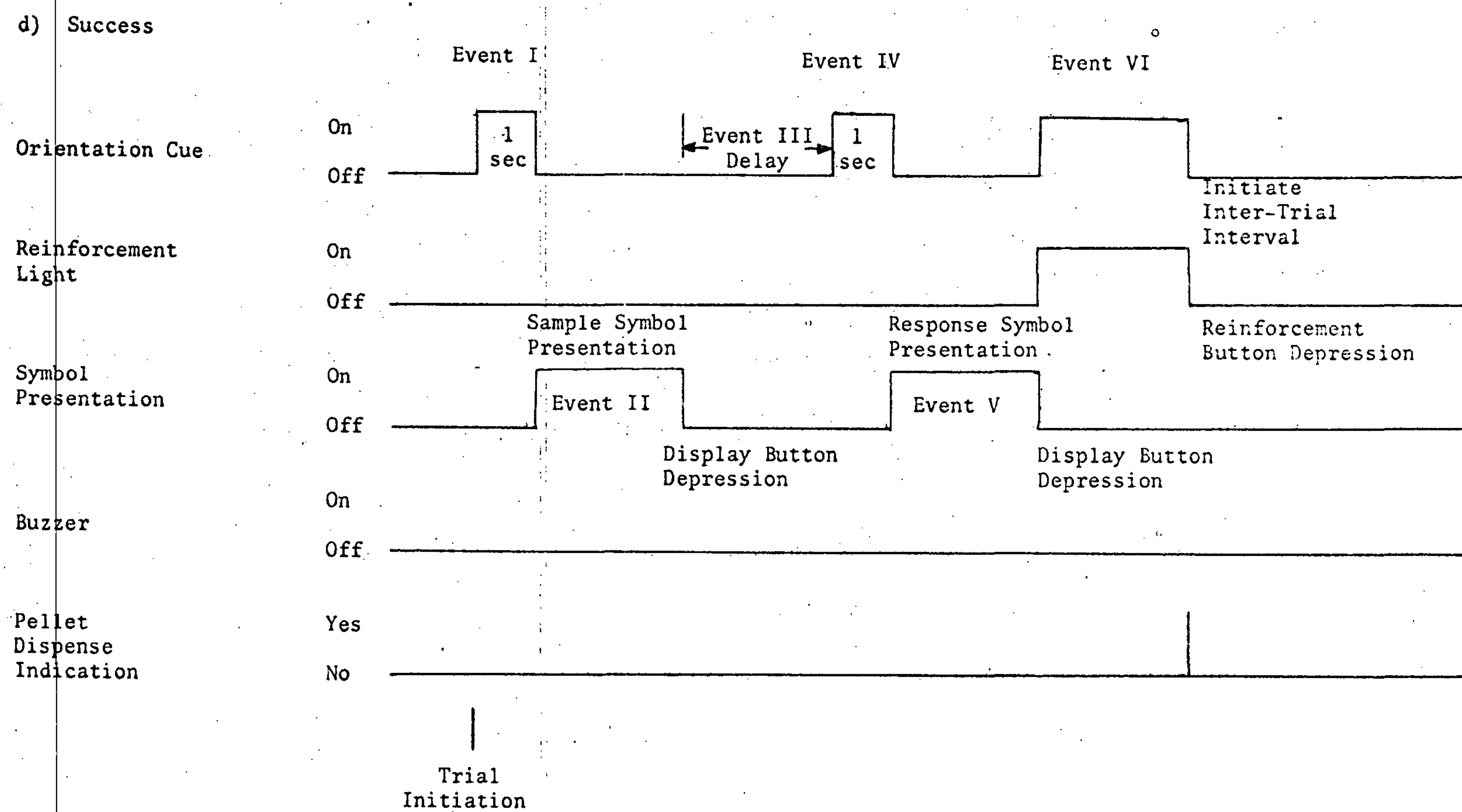


FIGURE 5d

ONE SAMPLE, ONE CHOICE RANDOM

BEHAVIORAL TASK TIME CHART

E.3 TWO SAMPLE, TWO CHOICE RANDOM, MATCHING TO SUCCESSIVE SAMPLING BEHAVIORAL TASK

The delayed matching to successive sample (MSS) tasks will test the primate's ability to perform sustained recognition of symbol sequences through memory.

The two sample, two choice random MSS behavioral task is initiated by a one sec in duration orientation cue. At the completion of the orientation cue, one of five possible symbols is selected randomly and presented in a random window of one of the six behavioral display panels also to be selected randomly. The primate has a specified response time, X, to depress the symbol's associated display switch. Depression of the switch within the allotted time initiates a delay period referred to as the intersample interval. The inter-sample interval will be 0, 0.5 or 1 sec in duration. Following the inter-sample interval, one of the remaining four symbols is selected randomly and presented in a randomly selected display switch of the same behavioral display panel. The primate has a specified response time, X, to depress the illuminated display switch. No switch depression within the time limitation constitutes a failure, whereby the symbol is extinguished and the inter-trial interval is initiated. Successful switch depression of the second sample symbol initiates a delay of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 sec after which a second orientation cue of 1 sec duration is generated. At the completion of this orientation cue, the same two symbols that were previously presented to the primate reappear simultaneously as choice symbols in two of the five display switches chosen randomly. The primate is now given a total time of 2X (no. of symbols times the response time for each particular switch depression) to extinguish the symbols by depressing their associated display switch in the identical sequence as they were originally presented as samples. No switch depression within the time limitation constitues a failure, extinguishing all symbols and initiating the inter-trial interval. Out of sequence switch depressions constitutes a failure, extinguishing all symbols and causing the one sec buzzer to sound. At the completion of the one sec buzzer, the inter-trial interval begins. Correct sequential response within the time constraints results in a third orientation cue whereby the reinforcement switch lights up simultaneously with a tone. The remainder of the task is identical to the reinforcement button task previously discussed. A flow diagram and time chart are shown in Fig 6 and 7 respectively.

The delayed matching to two samples task is expanded in subsequent behavioral ~~symbols~~ SESSIONS. The trial progression is identical to that just described with the only exception being the number of symbols illuminated during choice time.

a)

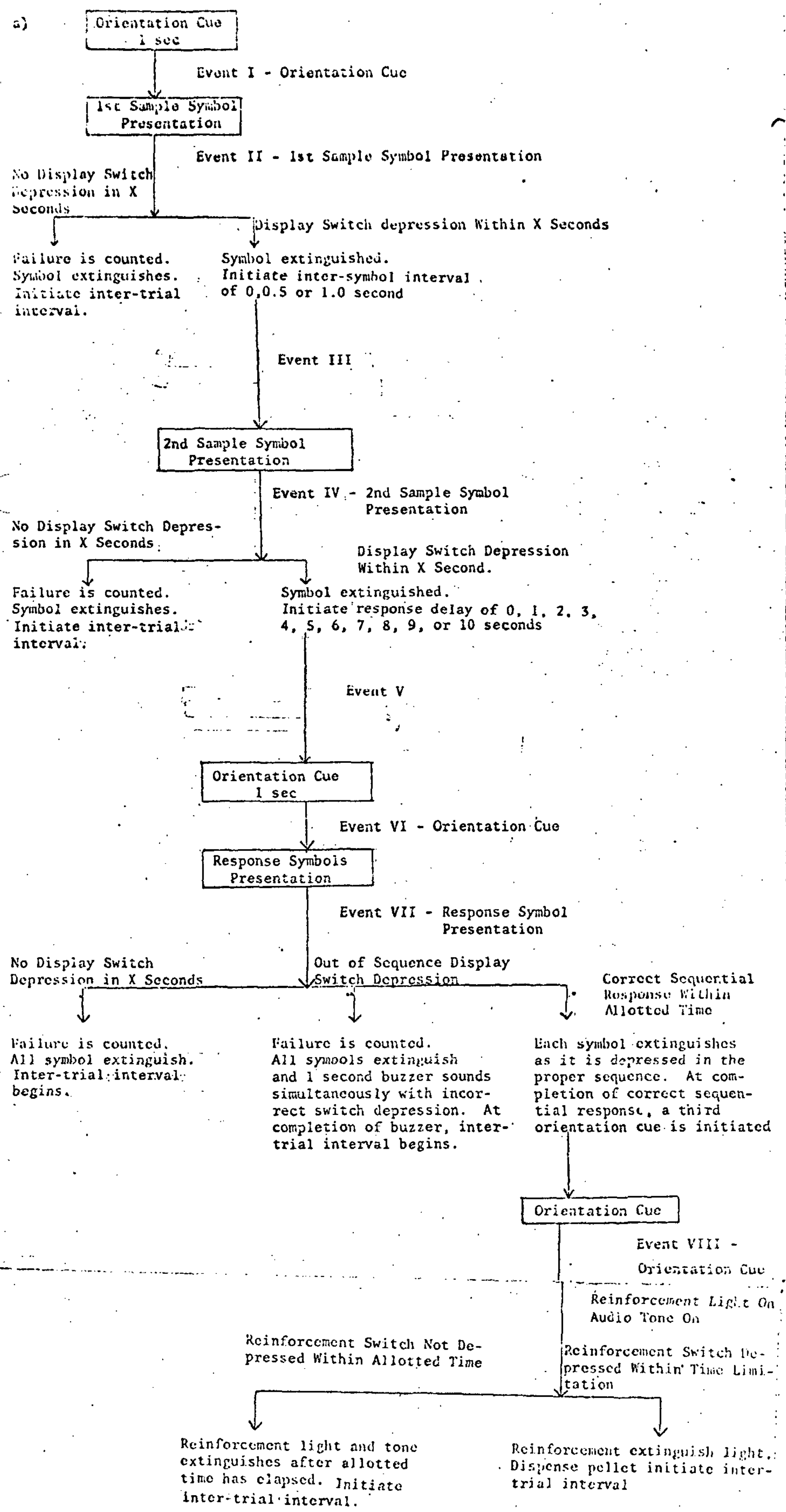


FIGURE 6

TWO SAMPLE, TWO CHOICE RANDOM, MSS BEHAVIORAL TASK FLOW CHART

a) Failure in Event VII
1st Display Switch Depression not in Proper Sequence

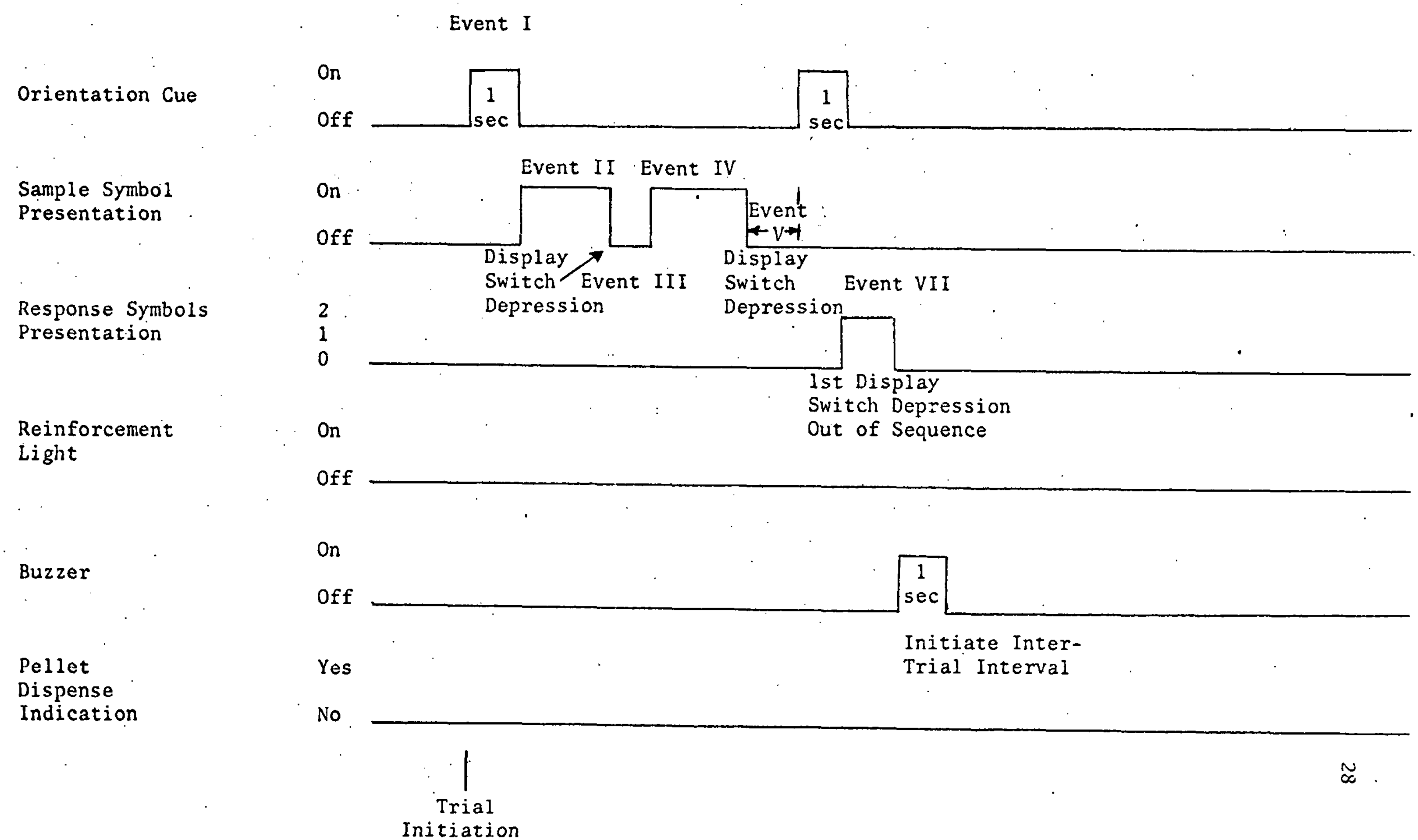


FIGURE 7a

TWO SAMPLE, TWO CHOICE RANDOM, MSS BEHAVIORAL TASK FLOW-CHART

b) Success

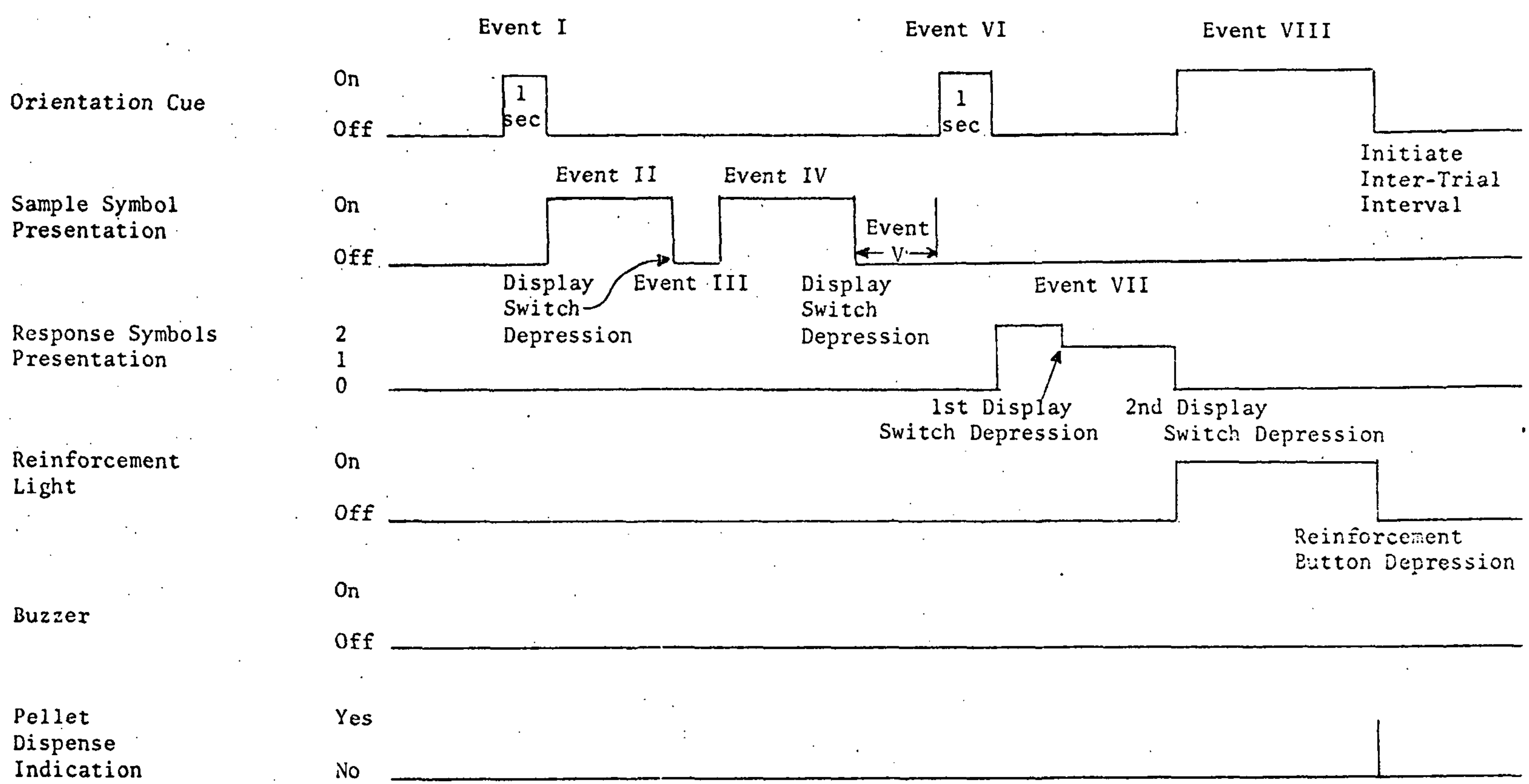


FIGURE 7b

TWO SAMPLE, TWO CHOICE RANDOM, MSS
BEHAVIORAL TASK FLOW CHART

E.4 MULTIPLE SYMBOL RANDOM, MATCHING TO SUCCESSIVE SAMPLE BEHAVIORAL TASK

An extension of the two symbol MSS task to three symbol, four symbol and five symbol random MSS behavioral tasks will be presented to the primate. These behavioral tasks are merely a logical extension of the task described in the previous paragraph and do not warrant additional detailed discussion; however, a time chart of the successful completion of each of these tasks is included in Figure 8.

E.5 PRIMATE ENVIRONMENTAL CONTROL

Environmental or operant task self-select options are desirable from an experimental standpoint to investigate the subject's drive for light, dark or particular task presentations during periods where the option is available.

Opportunities to initiate a behavioral session (or trial) will be made available by color-code illumination of switches. The availability of task options will be timed according to the flight trimester schedule.

Opportunities to select light/dark cycles shall be offered also at select periods during the flight and shall be specified by the trimester schedule. The option switches shall be color-coded and will correlate with light or dark states. Also, under consideration is primate control of the life cell temperature within the specified controlled limits of 71°F to 81°F.

a) Success - Three Symbol MSS Task

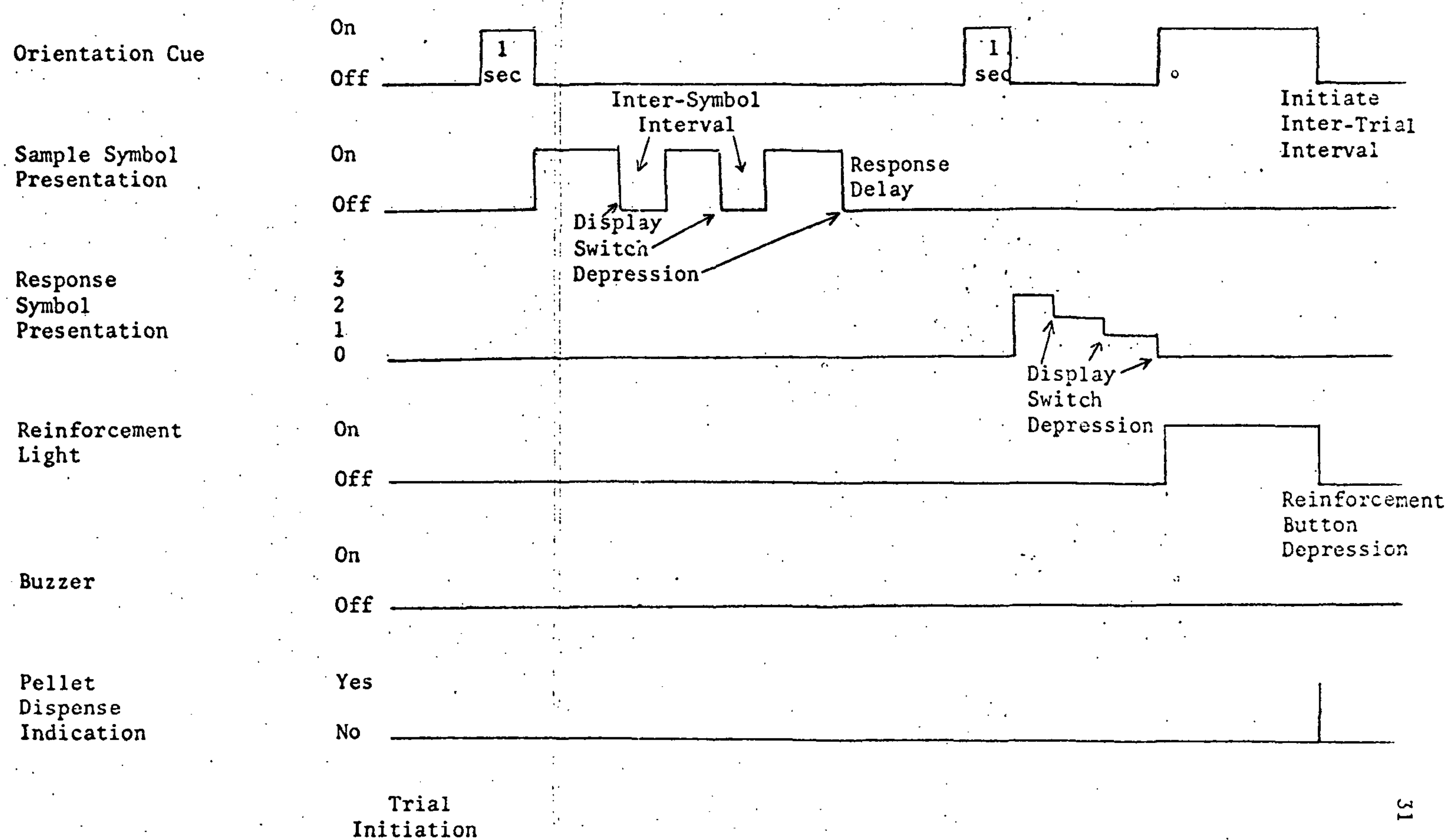


FIGURE 8a

THREE SYMBOL MSS TIME CHART

b) Success - Four Symbol MSS Task

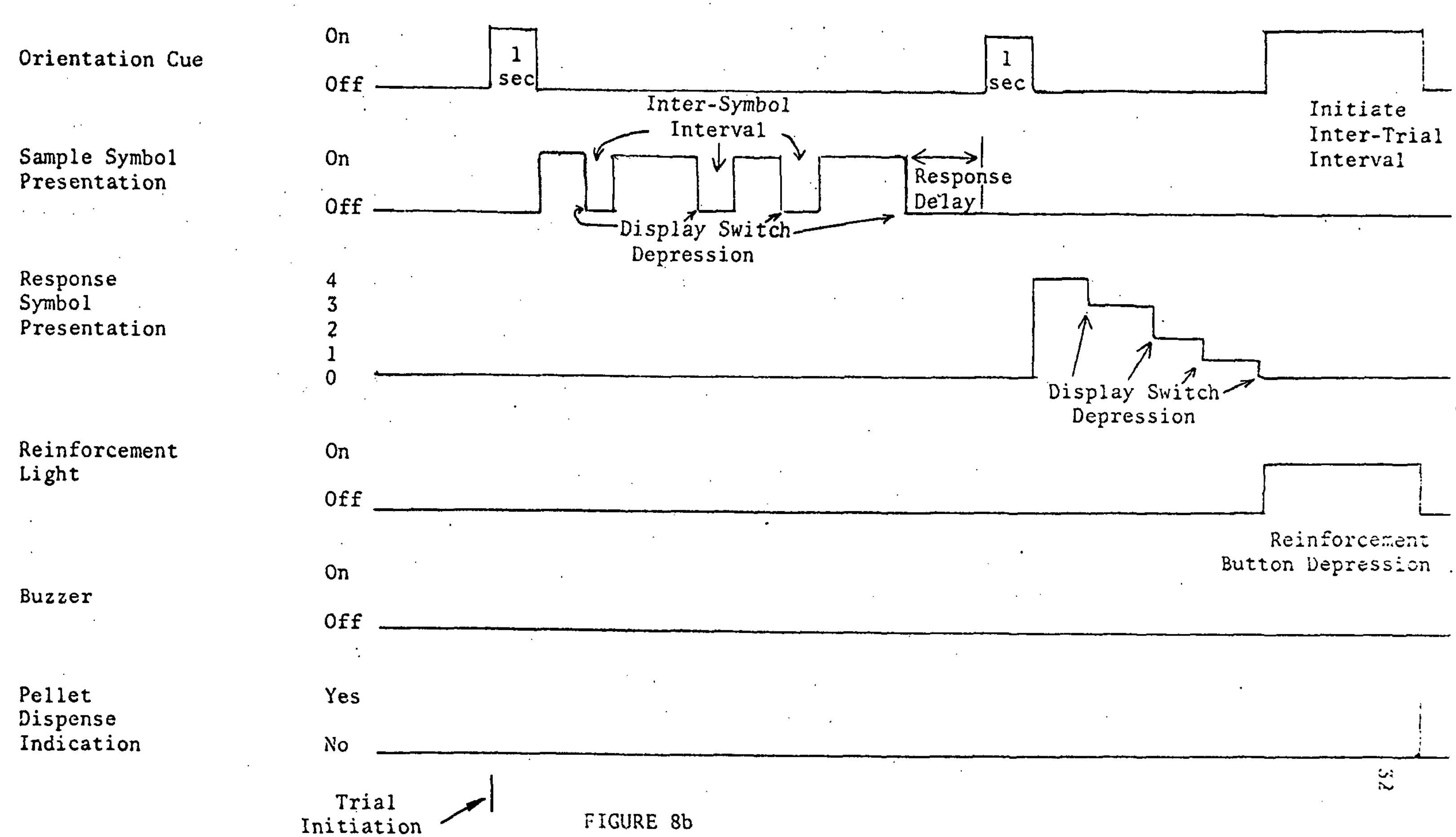


FIGURE 8b

FOUR SYMBOL MSS TIME CHART

c) Success - Five Symbol MSS Task

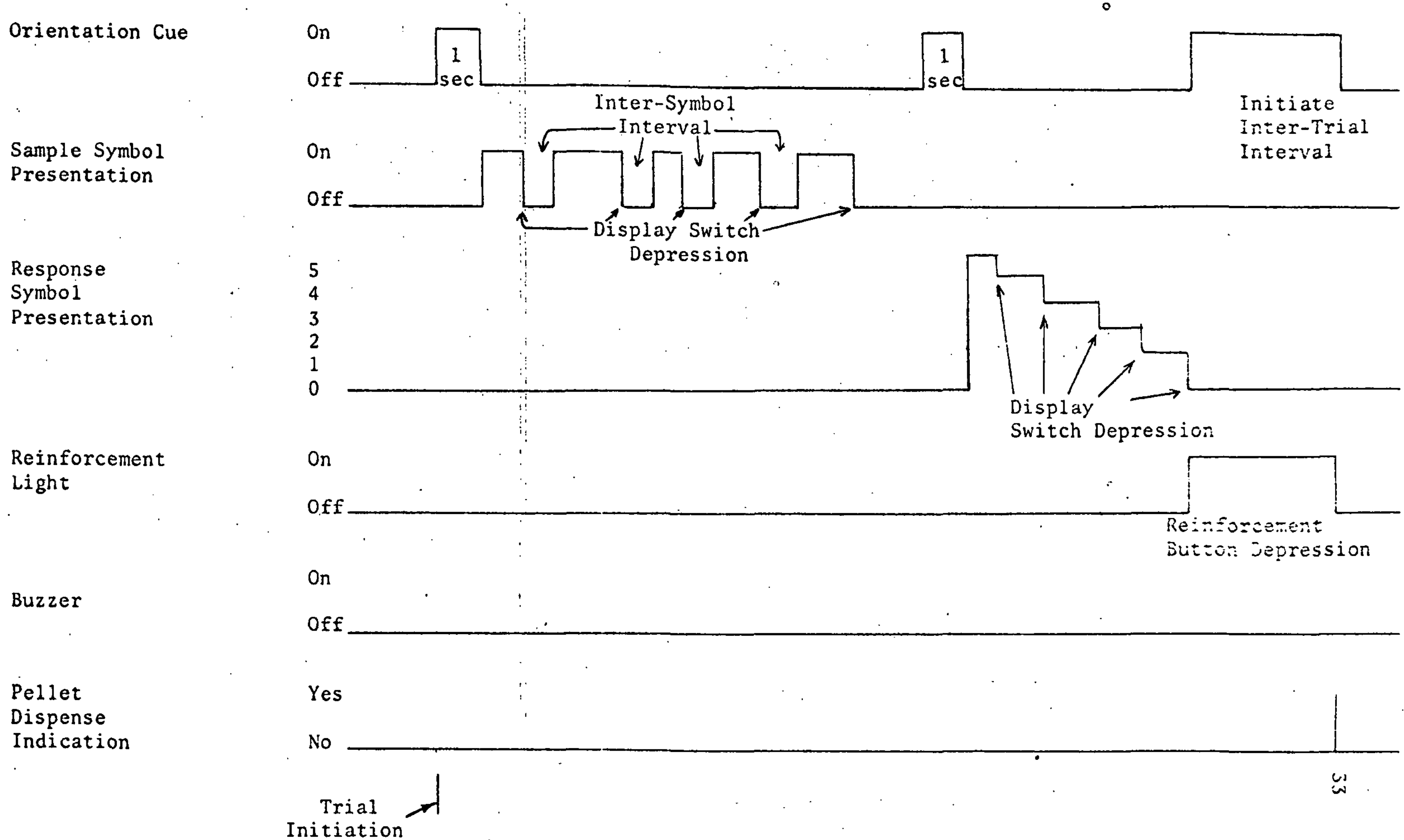


FIGURE 8c

FIVE SYMBOL MSS TIME CHART

II. PRIMATE INTERFACE

E.6 BEHAVIORAL TASK

TASK PRESENTATION CRITERIA

The behavioral tasks are to be presented in a meaningful progression which is dependent on past primate performance. The following section defines the performance criteria required from the primate as a prerequisite for behavioral task progression. Each behavioral task session will be comprised of 100 identical trials. The primate performance in a behavioral task session will be automatically compared with the criteria set forth in this section to determine the particular behavioral task to be presented in the following behavioral task session.

Table 1 contains the nomenclature utilized throughout this report in reference to particular behavioral tasks.

TABLE 1

Nomenclature	Description
R1	Reinforcement Button Task: Event I Duration = 60 sec
R2	Reinforcement Button Task: Event I Duration = 50 sec
R3	Reinforcement Button Task: Event I Duration = 40 sec
R4	Reinforcement Button Task: Event I Duration = 30 sec
R5	Reinforcement Button Task: Event I Duration = 20 sec
R6	Reinforcement Button Task: Event I Duration = 10 sec
OS1C1	One Sample, One Choice Random Task: Event III Duration = 1 sec
OS1C2	One Sample, One Choice Random Task: Event III Duration = 2 sec
OS1C3	One Sample, One Choice Random Task: Event III Duration = 5 sec

TABLE 1 (cont)

Nomenclature	Description
OS2C1	One Sample, Two Choice Random Task: Event III Duration = 1 sec
OS2C2	One Sample, Two Choice Random Task: Event III Duration = 2 secs
OS2C3	One Sample, Two Choice Random Task: Event III Duration = 5 secs
OS3C*	One Sample, Three Choice Random Task
OS4C*	One Sample, Four Choice Random Task
OS5C*	One Sample, Five Choice Random Task
TWS2C1	Two Sample, Two Choice Random, Matching to Successive Sample Task: Intersymbol Interval = 0 sec; Delay Between Sample Presentation "OFF" and Response Orientation Cue = 0 sec
TWS2C2	Intersample Interval = 0.5 sec; Delay = 0.5 sec
TWS2C3	Intersample Interval = 1.0 sec; Delay = 1.0 sec
TWS2C4	Intersample Interval = 1.0 sec; Delay = 2.0 sec
TWS2C5	Intersample Interval = 1.0 sec; Delay = 3.0 sec
TWS2C6	Intersample Interval = 1.0 sec; Delay = 4.0 sec
TWS2C7	Intersample Interval = 1.0 sec; Delay = 5.0 sec
TWS2C8	Intersample Interval = 1.0 sec; Delay = 6.0 sec
TWS2C9	Intersample Interval = 1.0 sec; Delay = 7.0 sec
TWS2C10	Intersample Interval = 1.0 sec; Delay = 8.0 sec
TWS2C11	Intersample Interval = 1.0 sec; Delay = 9.0 sec
TWS2C12	Intersample Interval = 1.0 sec; Delay = 10.0 sec

* The number (1, 2 or 3) following this notation specifies the Event III duration. 1 = 1 sec, 2 = 2 secs, and 3 = 5 secs.

TABLE 1 (cont)

Nomenclature	Description
TWS3C*	Two Sample, Three Choice, Matching to Successive Sample Task
TWS4C*	Two Sample, Four Choice, Matching to Successive Sample Task
TWS5C*	Two Sample, Five Choice, Matching to Successive Sample Task
THS3C1	Three Sample, Three Choice Random, Matching to Successive Sample Task: Intersample Interval = 0 secs; Delay Between Sample Presentation "OFF" and Response Orientation Cue = 0 secs
THS3C2	Intersample Interval = 0.5 sec; Delay = 0.5 sec
THS3C3	Intersample Interval = 1.0 sec; Delay = 1.0 sec
THS3C4	Intersample Interval = 1.0 sec; Delay = 2.0 sec
THS3C5	Intersample Interval = 1.0 sec; Delay = 3.0 sec
THS3C6	Intersample Interval = 1.0 sec; Delay = 4.0 sec
THS3C7	Intersample Interval = 1.0 sec; Delay = 5.0 sec
THS3C8	Intersample Interval = 1.0 sec; Delay = 6.0 sec
THS3C9	Intersample Interval = 1.0 sec; Delay = 7.0 sec
THS3C10	Intersample Interval = 1.0 sec; Delay = 8.0 sec
THS3C11	Intersample Interval = 1.0 sec; Delay = 9.0 sec
THS3C12	Intersample Interval = 1.0 sec; Delay = 10.0 sec
THS4C**	Three Sample, Four Choice Random, Matching to Successive Sample Task
THS5C**	Three Sample, Five Choice Random, Matching to Successive Sample Task

* The number (1 through 12) following this notation specifies the intersample interval and delay identically as presented for the TWS2C task.

** The number (1 through 12) following this notation specifies the intersample interval and delay identically as presented for the THS3C task.

TABLE 1 (cont)

Nomenclature	Description
FOS4C1	Four Sample, Four Choice Random, Matching to Successive Sample Task: Intersample Interval = 0 secs; Delay Between Sample Presentation "OFF" and Response Orientation Cue = 0 secs
FOS4C2	Intersample Interval = 0.5 sec; Delay = 0.5 sec
FOS4C3	Intersample Interval = 1.0 sec; Delay = 1.0 sec
FOS4C4	Intersample Interval = 1.0 sec; Delay = 2.0 sec
FOS4C5	Intersample Interval = 1.0 sec; Delay = 3.0 sec
FOS4C6	Intersample Interval = 1.0 sec; Delay = 4.0 sec
FOS4C7	Intersample Interval = 1.0 sec; Delay = 5.0 sec
FOS4C8	Intersample Interval = 1.0 sec; Delay = 6.0 sec
FOS4C9	Intersample Interval = 1.0 sec; Delay = 7.0 sec
FOS4C10	Intersample Interval = 1.0 sec; Delay = 8.0 sec
FOS4C11	Intersample Interval = 1.0 sec; Delay = 9.0 sec
FOS4C12	Intersample Interval = 1.0 sec; Delay = 10.0 sec
FOS5C*	Four Sample, Five Choice, Matching to Successive Sample Task
FIS5C1	Five Sample, Five Choice Random, Matching to Successive Sample Task: Intersample Interval = 0 sec; Delay Between Sample Presentation "OFF" and Response Orientation Cue = 0 sec
FIS5C2	Intersample Interval = 0.5 sec; Delay = 0.5 sec
FIS5C3	Intersample Interval = 1.0 sec; Delay = 1.0 sec
FIS5C4	Intersample Interval = 1.0 sec; Delay = 2.0 sec
FIS5C5	Intersample Interval = 1.0 sec; Delay = 3.0 sec

* The number (1 through 12) following this notation specifies the intersample interval and delay identically as presented for the FOS4C task.

TABLE 1 (cont)

Nomenclature	Description
FIS5C6	Intersample Interval = 1.0 sec; Delay = 4.0 sec
FIS5C7	Intersample Interval = 1.0 sec; Delay = 5.0 sec
FIS5C8	Intersample Interval = 1.0 sec; Delay = 6.0 sec
FIS5C9	Intersample Interval = 1.0 sec; Delay = 7.0 sec
FIS5C10	Intersample Interval = 1.0 sec; Delay = 8.0 sec
FIS5C11	Intersample Interval = 1.0 sec; Delay = 9.0 sec
FIS5C12	Intersample Interval = 1.0 sec; Delay = 10.0 sec

1. Behavioral Task Presentation Criteria

The first behavioral task presented to the primate at the start of each phase of the test is the reinforcement button press task (R1). The task progression from task R1 through R6 to OS1C1 will be contingent upon the primate's response latency scores, defined as the time from trial onset to reinforcement switch depression. During the initial bank of trials, task R1 will be presented to the primate (Event I, duration = 60 sec). The criteria for determining the subsequent tasks are as follows:

a. If the primate performs successfully (latency scores equal to or less than Event I duration) on 22 or more of the 25 trials, he shall advance to the reinforcement task that has an Event I duration within which have occurred no less than 15 of 25 of his response latency scores.

b. If on any given R task the primate successfully performs on 15 to 21 of 25 trials, then the same R task will be presented on the subsequent bank of trials.

c. If the primate performs successfully on less than 15 of 25 trials for any R task, R2 through R6, then on the next bank of trials, he shall revert to an R task that has an Event I duration 10 sec longer than the previous R task. (60 sec is maximum Event I duration, 10 sec is the minimum Event I duration).

d. The performance criterion to advance the task to OS1C1 with a switch depression opportunity time of 10 sec will be 12 successive banks of 25 trials where the animal has averaged greater than 90 percent successful responses to the reinforcement switch on task R6. If the subject does not meet the above criterion within 108 banks then he will be presented successive banks of task R5. The subject will advance to task OS1C1 with a switch depression opportunity time of 20 sec only if he averages on 12 successive banks greater than 90 percent successful responses and that his latency scores on 75 percent of the trials of the banks are equal to or less than 10 sec. The subject will remain on task R5 until criterion is reached or unless performance is such to warrant the presentation of task R4 to R1. After criterion is reached, the subject advances to the OS1C1 task.

TABLE 2 - TASK PRESENTATION CRITERION

Behavioral Task	Performance - Subsequent Behavioral Task 22/25	17 to 21/25	0 to 16/25
OS1C1	OS1C2	OS1C1	OS1C1
OS1C2	OS1C3	OS1C2	OS1C1
OS1C3	OS5C1	OS1C3	OS1C2
OS2C1	OS2C2	OS2C1	OS1C3
OS2C2	OS2C3	OS2C2	OS2C1
OS2C3	OS5C1	OS2C3	OS2C2
OS5C1	OS5C2	OS5C1	OS2C1
OS5C2	OS5C3	OS5C2	OS5C1
OS5C3	TWS2C1	OS5C3	OS5C2

Behavioral Task	Performance - Subsequent Behavioral Task 21/25	16 to 20/25	0 to 15/25
TWS2C1	TWS2C3	TWS2C1	OS5C3
TWS2C2	TWS2C3	TWS2C2	TWS2C1
TWS2C3	TWS2C5	TWS2C3	TWS2C2
TWS2C4	TWS2C5	TWS2C4	TWS2C3
TWS2C5	TWS2C7	TWS2C5	TWS2C4
TWS2C6	TWS2C7	TWS2C6	TWS2C5
TWS2C7	TWS2C9	TWS2C7	TWS2C6
TWS2C8	TWS2C9	TWS2C8	TWS2C7
TWS2C9	TWS2C12	TWS2C9	TWS2C8
TWS2C10	TWS2C11	TWS2C10	TWS2C9
TWS2C11	TWS2C12	TWS2C11	TWS2C10
TWS2C12	TWS5C1	TWS2C12	TWS2C11
TWS3C1	TWS3C3	TWS3C1	TWS2C12
TWS3C2	TWS3C3	TWS3C2	TWS3C1
TWS3C3	TWS3C5	TWS3C3	TWS3C2
TWS3C4	TWS3C5	TWS3C4	TWS3C3
TWS3C5	TWS3C7	TWS3C5	TWS3C4
TWS3C6	TWS3C7	TWS3C6	TWS3C5
TWS3C7	TWS3C9	TWS3C7	TWS3C6
TWS3C8	TWS3C9	TWS3C8	TWS3C7
TWS3C9	TWS3C12	TWS3C9	TWS3C8
TWS3C10	TWS3C11	TWS3C10	TWS3C9

Behavioral Task	Performance - Subsequent Behavioral Task 21/25	16 to 20/25	0 to 15/25
TWS3C11	TWS3C12	TWS3C11	TWS3C10
TWS3C12	TWS5C1	TWS3C12	TWS3C11
TWS5C1	TWS5C3	TWS5C1	TWS3C12
TWS5C2	TWS5C3	TWS5C2	TWS5C1
TWS5C3	TWS5C5	TWS5C3	TWS5C2
TWS5C4	TWS5C5	TWS5C4	TWS5C3
TWS5C5	TWS5C7	TWS5C5	TWS5C4
TWS5C6	TWS5C7	TWS5C6	TWS5C5
TWS5C7	TWS5C9	TWS5C7	TWS5C6
TWS5C8	TWS5C9	TWS5C8	TWS5C7
TWS5C9	TWS5C12	TWS5C9	TWS5C8
TWS5C10	TWS5C11	TWS5C10	TWS5C9
TWS5C11	TWS5C12	TWS5C11	TWS5C10
TWS5C12	TWS3C1	TWS5C12	TWS5C11

Behavioral Task	Performance - Subsequent Behavioral Task 19/25	14 to 18/25	0 to 13/25
THS3C1	THS3C3	THS3C1	TWS5C12
THS3C2	THS3C3	THS3C2	THS3C1
THS3C3	THS3C5	THS3C3	THS3C2
THS3C4	THS3C5	THS3C4	THS3C3
THS3C5	THS3C7	THS3C5	THS3C4
THS3C6	THS3C7	THS3C6	THS3C5
THS3C7	THS3C9	THS3C7	THS3C6
THS3C8	THS3C9	THS3C8	THS3C7
THS3C9	THS3C12	THS3C9	THS3C8
THS3C10	THS3C11	THS3C10	THS3C9
THS3C11	THS3C12	THS3C11	THS3C10
THS3C12	THS5C1	THS3C12	THS3C11
THS4C1	THS4C3	THS4C1	THS3C12
THS4C2	THS4C3	THS4C2	THS4C1
THS4C3	THS4C5	THS4C3	THS4C2
THS4C4	THS4C5	THS4C4	THS4C3
THS4C5	THS4C7	THS4C5	THS4C4
THS4C6	THS4C7	THS4C6	THS4C5
THS4C7	THS4C9	THS4C7	THS4C6
THS4C8	THS4C9	THS4C8	THS4C7
THS4C9	THS4C12	THS4C9	THS4C8
THS4C10	THS4C11	THS4C10	THS4C9

Behavioral Task	Performance - Subsequent Behavioral Task 19/25	14 to 18/25	0 to 13/25
THS4C11	THS4C12	THS4C11	THS4C10
THS4C12	THS5C1	THS4C12	THS4C11
THS5C1	THS5C3	THS5C1	THS4C12
THS5C2	THS5C3	THS5C2	THS5C1
THS5C3	THS5C5	THS5C3	THS5C2
THS5C4	THS5C5	THS5C4	THS5C3
THS5C5	THS5C7	THS5C5	THS5C4
THS5C6	THS5C7	THS5C6	THS5C5
THS5C7	THS5C9	THS5C7	THS5C6
THS5C8	THS5C9	THS5C8	THS5C7
THS5C9	THS5C12	THS5C9	THS5C8
THS5C10	THS5C11	THS5C10	THS5C9
THS5C11	THS5C12	THS5C11	THS5C10
THS5C12	FOS4C1	THS5C12	THS5C11

Behavioral Task	Performance - Subsequent Behavioral Task 16/25	10 to 15/25	0 to 9/25
FOS4C1	FOS4C3	FOS4C1	THS5C12
FOS4C2	FOS4C3	FOS4C2	FOS4C1
FOS4C3	FOS4C5	FOS4C3	FOS4C2
FOS4C4	FOS4C5	FOS4C4	FOS4C3
FOS4C5	FOS4C7	FOS4C5	FOS4C4
FOS4C6	FOS4C7	FOS4C6	FOS4C5
FOS4C7	FOS4C9	FOS4C7	FOS4C6
FOS4C8	FOS4C9	FOS4C8	FOS4C7
FOS4C9	FOS4C12	FOS4C9	FOS4C8
FOS4C10	FOS4C11	FOS4C10	FOS4C9
FOS4C11	FOS4C12	FOS4C11	FOS4C10
FOS4C12	FOS5C1	FOS4C12	FOS4C11
FOS5C1	FOS5C3	FOS5C1	FOS4C12
FOS5C2	FOS5C3	FOS5C2	FOS5C1
FOS5C3	FOS5C5	FOS5C3	FOS5C2
FOS5C4	FOS5C5	FOS5C4	FOS5C3
FOS5C5	FOS5C7	FOS5C5	FOS5C4
FOS5C6	FOS5C7	FOS5C6	FOS5C5
FOS5C7	FOS5C9	FOS5C7	FOS5C6
FOS5C8	FOS5C9	FOS5C8	FOS5C7
FOS5C9	FOS5C12	FOS5C9	FOS5C8
FOS5C10	FOS5C11	FOS5C10	FOS5C9
FOS5C11	FOS5C12	FOS5C11	FOS5C10
FOS5C12	FIS5C1	FOS5C12	FOS5C11

Behavioral Task	Performance - Subsequent Behavioral Task 12/25	6 to 11/25	0 to 5/25
FIS5C1	FIS5C3	FIS5C1	FOS5C12
FIS5C2	FIS5C3	FIS5C2	FIS5C1
FIS5C3	FIS5C5	FIS5C3	FIS5C2
FIS5C4	FIS5C5	FIS5C4	FIS5C3
FIS5C5	FIS5C7	FIS5C5	FIS5C4
FIS5C6	FIS5C7	FIS5C6	FIS5C5
FIS5C7	FIS5C9	FIS5C7	FIS5C6
FIS5C8	FIS5C9	FIS5C8	FIS5C7
FIS5C9	FIS5C12	FIS5C9	FIS5C8
FIS5C10	FIS5C11	FIS5C10	FIS5C9
FIS5C11	FIS5C12	FIS5C11	FIS5C10
FIS5C12	FIS5C12	FIS5C12	FIS5C11

At the completion of each mission phase, the behavioral task program will recycle and start again at task R1. The automatic task progression criteria will be supplemented by an overriding capability via ground command to initiate any of the 57 alternate tasks. Ground command capabilities will be such that any particular behavioral task may be initiated at the receipt of a real time command, or at the next behavioral session, either scheduled or self initiated. When a ground command is utilized to alter the automatic progression schedule, the progression criteria will continue as previously defined from that task on, with the only exception begin the overriding capability of additional ground commands.

II. PRIMATE INTERFACE

E.7 BEHAVIORAL TASK

TRAINING PROTOCOL

a. DOMESTICATION AND TRAINING

When preadolescent male chimpanzees have been found acceptable under criteria of size, health, and coordination by the experimenter, they will be subject to customary quarantine procedures. Following this, a domestication and handling procedure will commence.

1. The candidates will be observed individually by the animal trainers during and following isolation. The purpose here is to estimate natural dominance, submissiveness, agility and native resourcefulness.

2. Each trainer will participate in the domestication and training of all candidates.

   a. Training here consists of daily exposure to progressive amounts of handling and gentle restraining.

   b. Once the confidence of handling and leading has been established, verbal commands and obedience training can begin. This consists mainly of simple verbal commands urging the primate to sit and stay on a chair, or to return to his home cage. Frequent food rewards given during this process may facilitate it.

   c. The next necessary phase to accomplish is to induce the acceptability of the primate for injection. This may take slightly longer than to train chair-sitting, but when accomplished, minimizes future trauma when blood testing or sedation is required. There is a specific in-house protocol detailing the steps in the above procedures.

b. PRIMARY TRAINING

The purpose of primary behavioral training is to build up a very strong button press habit highly resistant to extinction, to acquaint the animals with strong schedule requirements that will later be used with the primate environmental control tasks, and as a means of manipulating the animal's rate of response to maximize the probability of the observing response necessary for successful performance.

Primary training will prevail initially in the subject's home cage and will be controlled by a variety of schedules of reinforcement. These schedules, as they shape the animal's response behavior, permit the experimenter to make fine-grain analyses and evaluations of each individual subject and his behavior strength and motivation, early in the training program. The reinforcement schedules utilized in primary training are briefly described below:

Continuous Reinforcement (CRF)

This schedule promotes the swiftest acquisition of the button press response as it rewards the subject with a food pellet for every successful response.

Fixed Ratio (FR)

This schedule rewards the response only after "n" responses to the button have been completed. It promotes a very high response rate to the button and permits characteristic pauses following rewards on high fixed ratios.

Variable Ratio (VR)

This schedule also generates fast response rates and rewards the response only after an average of "n" responses have been completed. It tends to eliminate pause characteristic of the fixed ratio. Both schedules are fairly resistant to operant extinction.

Fixed Interval (FI)

This schedule rewards the first response after a specified time lapse of x sec. It generates slower response rates in the initial component of the interval and higher rates in the later component. Commonly, this curve appears as a series of "scallops" reflecting an implicit time discrimination.

Variable Interval (VI)

This schedule reinforces a response after an average time lapse of x sec and is frequently used to generate a baseline of a stable, linear response rate. In its stablest form, it generates a non-fluctuating response curve and each subject develops his own characteristic, stable rate. It is a valuable schedule against which to compare the effects of other environmental, clinical or alternate program changes.

Differential Reinforcement for a Low Response Rate (DRL)

This schedule rewards a response after a specified time lapse only when no other responses have preceded it. This can be a behaviorally aversive schedule, but characteristically generates a waiting response frequently substituted by alternate forms of behavior which avoid the operant response button. It also induces a sharper temporal discrimination, strengthens observing and lengthens inter-response times.

Further compounding and mixing of the above schedules will afford the experimenter additional control of behavior and will generate more elaborate response curves from which to evaluate motivation, alertness and responsiveness of each candidate individually.

The primary behavioral display panel is shown in Fig 9. Each panel shall have a speaker to generate tone signals to the subject as discriminative and reinforcement cues. There shall be up to three such panels per cage to require a more extensive orienting responsiveness from each subject.

The primary training protocol is submitted in Appendix A, part I of this document.

c. TRAINING BOOTH ADAPTATION

1. After sufficient success with the primary training procedures, the trainer will lead the primate to the training booth. The house light and background noise shall be constant throughout all booth training. The primate then should spend only brief periods (15-20 min) initially in the booth. The trainer will be present at these times to assess any behavioral anomolies and to provide voice reassurances when necessary.
2. The primate's daily rations should be offered while he is in the booth, as the adjustment to the new surrounding will take

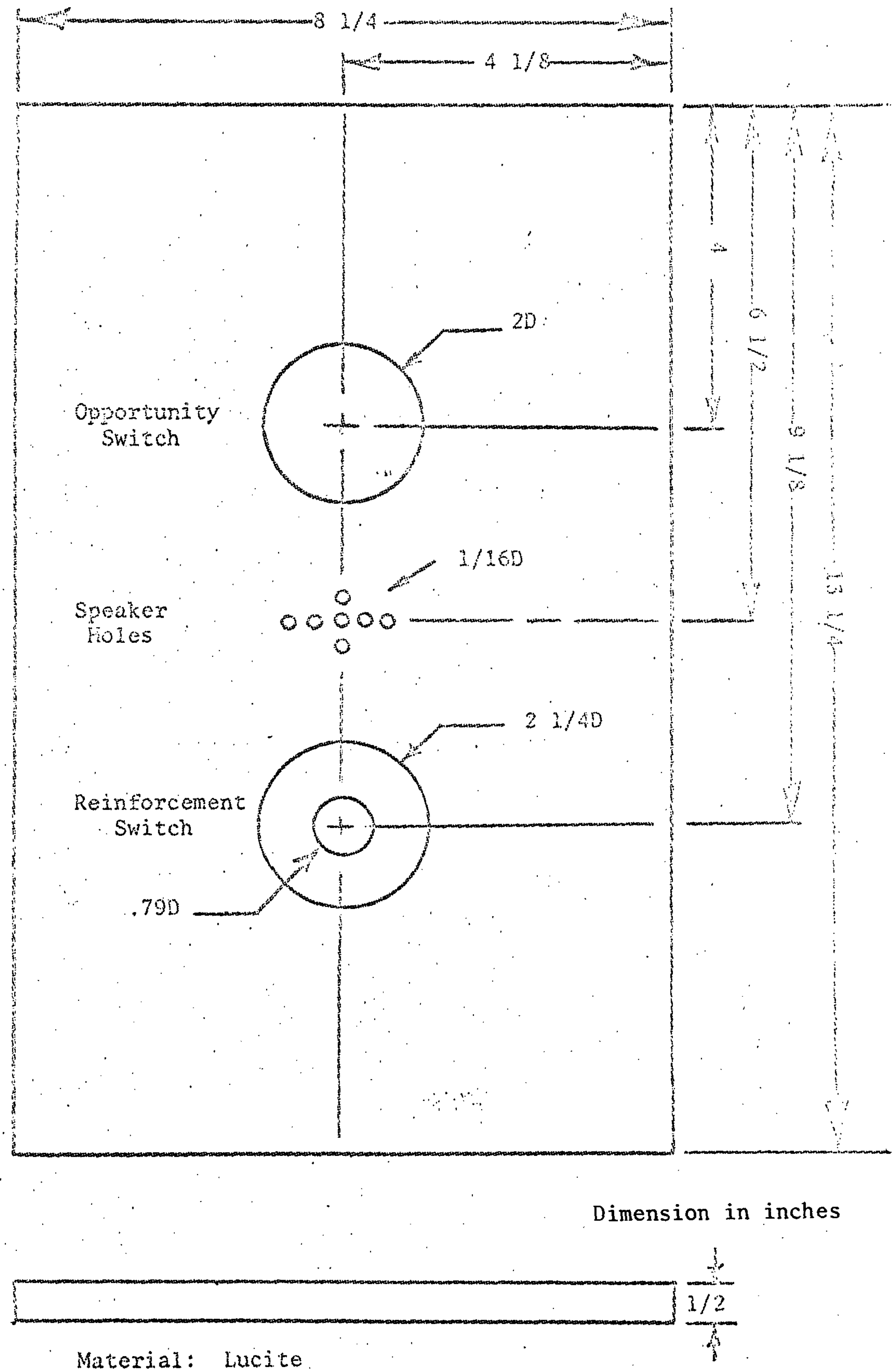


FIGURE 9

PRIMARY BEHAVIORAL
DISPLAY PANEL

place more efficiently. Gradually longer periods should be spent and each stay should be terminated with full food reward.

d. MATCHING TO SUCCESSIVE SAMPLE TRAINING

The training of the candidates to the MSS task shall be carried on in sound-retarded light-controlled booths to provide minimum interference. The techniques utilized shall be a combined use of operant schedules and multiple attenuation schemes which emphasize stimulus control to the learning subject and minimize the probability of error.

After a sufficient and satisfactory library of response-curve records from the button pressing schedules have been obtained, the primates shall be adapted to the training booths for MSS training.

The MSS display panels shall be of flight configuration and shall be capable of displaying up to a five symbol matching to successive sample task, (see Fig 10 and 11).

The first phase after button pressing training will be to condition a rhythm of response to a single sample-single matching task. That is, one sample appears on one of the five switches. A press response to it extinguishes the sample and initiates a 0.5 sec delay. The identical symbol then appears randomly on any other (or possibly the same) switch. A press response to this one extinguishes the symbol and lights the reinforcement button. A press response to this extinguishes the reinforcement light and pulses a pellet dispenser which delivers the reinforcement. Although

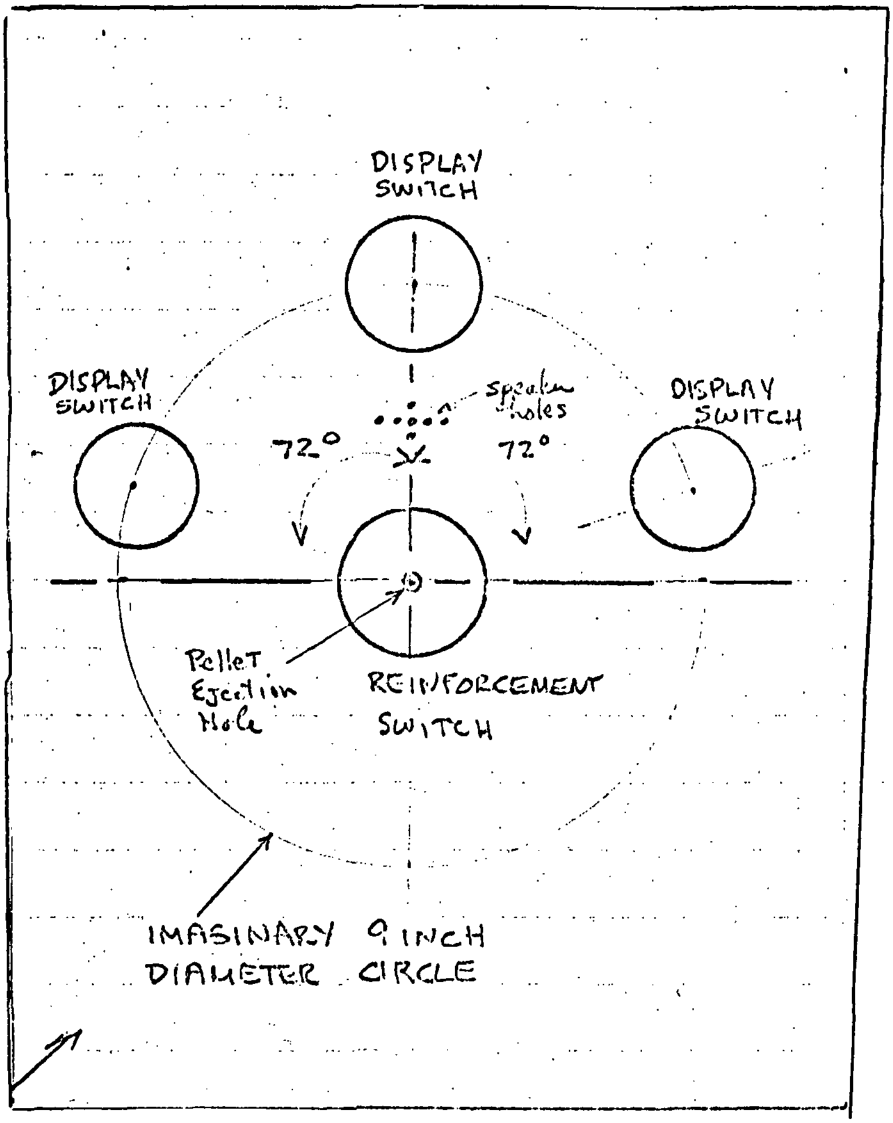
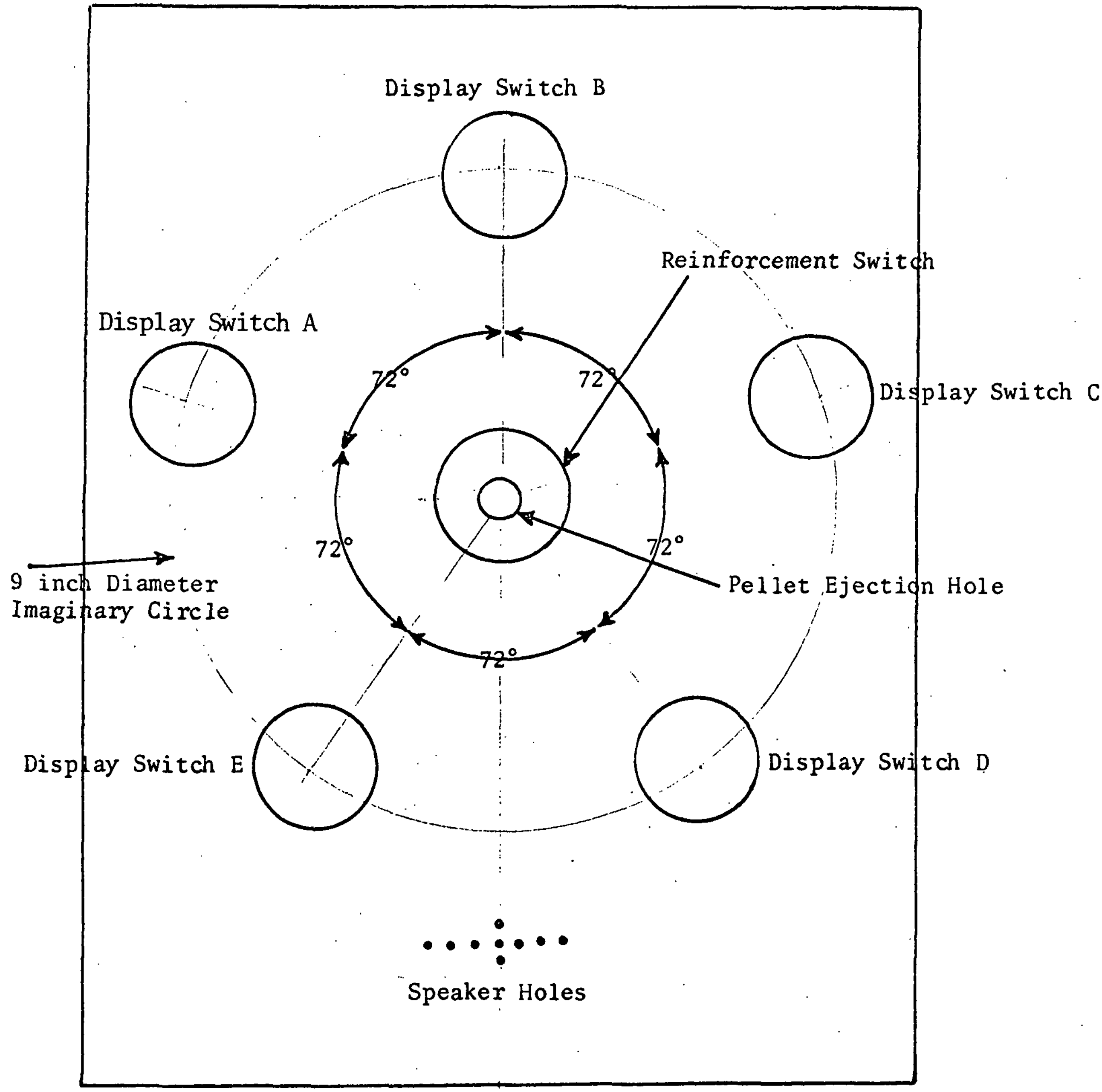


FIGURE 10

MSS TRAINING BEHAVIORAL PANEL



Surface Color : Black

On back side of behavioral panel mount 1-45 pin male connector part no. FK-46-32S

FIGURE 11

FLIGHT CONFIGURATION BEHAVIORAL PANEL

the above sequence is a discrete trial paradigm, a free operant schedule may be selectively superimposed to maximize the observing response to the sample. Upon achieving a 0.9 success ratio for no less than 200 trials, the subject shall be advanced to two symbol MSS training. Training the subject to the two symbol MSS through the five symbol MSS task shall employ the same basic combination of techniques.

The first sample of a pair (O,X) appears on any one of the five switches accompanied by a 400 cycle tone. An FR schedule on the first sample is required to extinguish the symbol. Upon extinction, there is a 0.5 sec inter-sample interval terminated by the appearance of the second sample on the same or any other switch. A single discrete response to this extinguishes the sample and produces the random display of both symbols on any two of the five switches accompanied by an 800 cycle tone. There is a center window which will at this time redisplay the first sample, though a response to this window is ineffective and is for reference only. The incorrect symbol shall be, at first, maximally attentuated along three dimensions: Brightness, Focus, and Size. That is, during this event which requires a single response to one of two particular symbols, the incorrect symbol is (1) very small, (2) very dim and (3) very much out of focus. A press response to this symbol would terminate the trial. A correct response to the bright, sharp matching symbol extinguishes that symbol and its mate in the center redisplay window and produces a bright, clear image of the attenuated symbol. A press response now to this symbol arms the reinforcement light and button, and a press response to this button delivers the sweetened reward pellet and initiates an inter-trial interval. The correct response for this trial shall reduce the attenuation of the next second (or incorrect) symbol along all three dimensions by about one-sixtieth of their respective scales. This attenuation change is automatic between trials but each dimension can be manually set at any point on its scale at any time between or during trials. The order of sample presentations through all trials shall be random as shall be the presentations during the choice event. When the score of any candidate is 20/25 after reaching minimum attenuation along all three dimensions, the attenuators are all inhibited. If the subject scores 120 correct/150 trials without any attenuation, he shall be advanced to the next symbol pair and must satisfy the same criteria before moving on to the next pair.

Once criterion is achieved on all symbol pairs, the subject is advanced to three, four and finally five symbol MSS. Once the subject has achieved a score of 120/150 on five MSS with the samples redisplayed in the reference window, he reverts back to (O,X) two symbol MSS and again commences training. Now the re-displayed symbol becomes dimmer for every successful trial. Every incorrect increases the brightness of the subsequent re-display for the next trial. As the reinforcement rate becomes high enough to extinguish the redisplayed symbol, the first bank of 20/25 or better warrants inhibition of the redisplay option. A score of 40/50 on (O,X) two MSS without redisplay shall advance the subject to the next symbol pair. As criterion performance is displayed for all symbol pairs, the subject advances to three, four and five MSS with dimming and subsequent inhibition of all sample redisplays. Criteria for advancement from two through five symbol MSS without sample redisplay are as follows:

two to three MSS	40/50
three to four MSS	37/50
four to five MSS	35/50.

Any candidate who can sustain three daily sessions of five MSS at 65% or better shall begin the delay phase of training. This entails gradually increasing the time delay between extinction of the fifth sample and the onset of the five symbol choice display. These delay increments shall be instituted in 250 msec steps so as not to strain high performance levels.

At any time the experimenter feels that certain additional reinforcement schedules should help the candidate differentiate the order of his responses to the samples, these schedules can be swiftly programmed into the training sessions.

The matching to successive sample training protocol is submitted in Appendix A, part II.

e. ENVIRONMENTAL CONTROL TRAINING

For training the chimpanzees for the environmental control tasks, color coded, circular two inch diameter proximity switches have been mounted on one wall of a behavioral booth (see Fig 12). The training procedure, included in Appendix A, part III, is designed to teach the subject to control both house lighting and temperature.

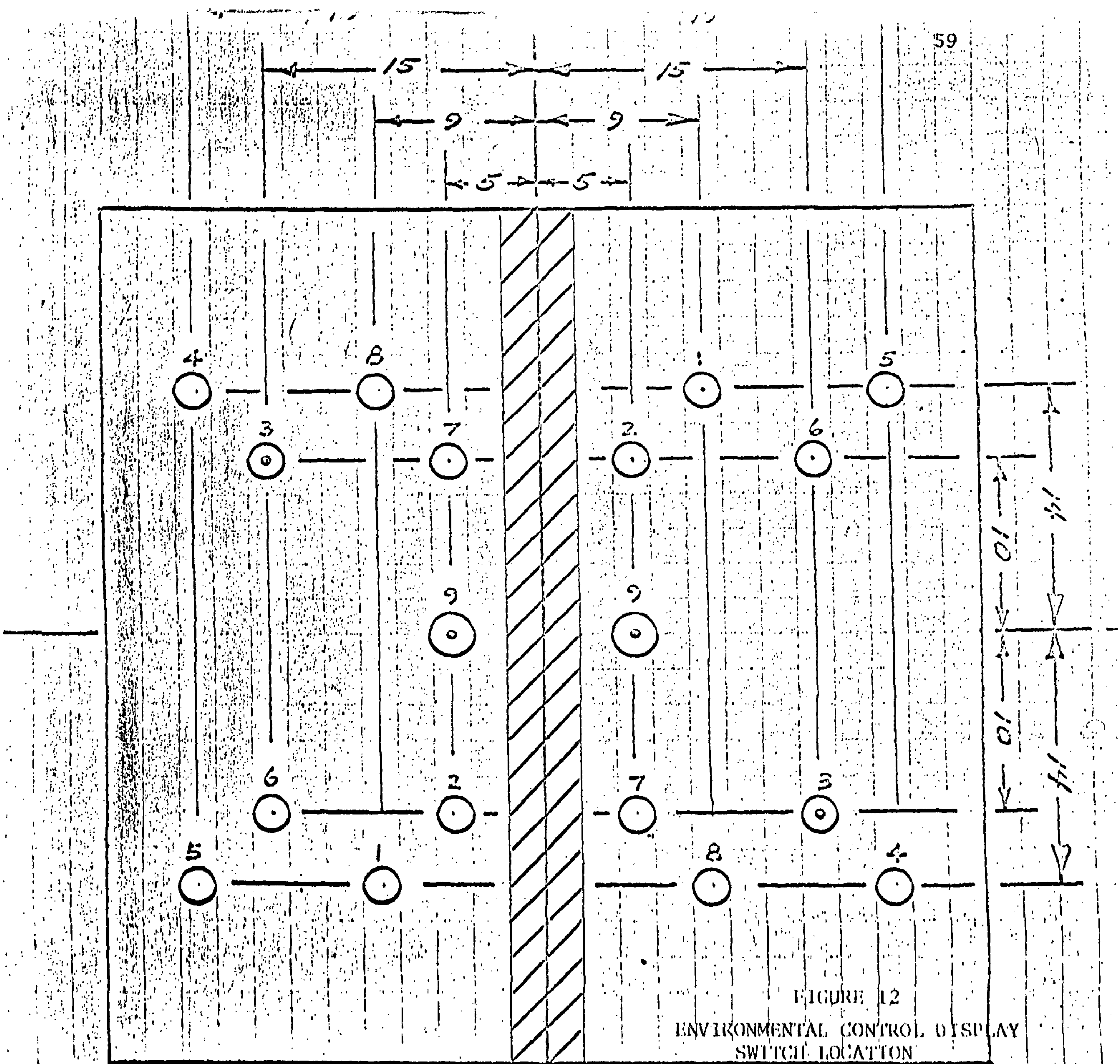


FIGURE 12
ENVIRONMENTAL CONTROL DISPLAY
SWITCH LOCATION

Dimensions in inches

Switch Designation	Function	Color	Diameter	Shinkolite A Color Number
1	Decrease lighting intensity	Dark Blue	2.00 inches	302*
2	Increase lighting intensity	Yellow	2.00 inches	993*
3	Water dispenser	White	2.25 inches	432
4	Auditory enrichment	Purple	2.00 inches	375
5	Decrease temperature	Light Blue	2.00 inches	300*
6	Increase temperature	Orange	2.00 inches	264
7	Behavioral session initiate	Green	2.00 inches	343*
8	Not connected	Black	2.00 inches	502
9	Food reinforcement**	Red	2.25 inches	136

* Colors are transparent and require the addition of a white translucent background

** To be non-operative during system test

II. PRIMATE INTERFACE

F. IMPLANTED TELEMETRY

Totally implantable telemetry systems will gather data from the central and peripheral nervous system and cardiovascular system. Implanted telemetry eliminates the potential infection inherent in a conventional telemetry system at the lead entrance to the body and results in an animal continuously available for data acquisition while being completely unrestrained.

The telemetry system will be divided into separate independent telemetry subsystems as discussed in Section III F of this report. The acquisition of cardiovascular data will be obtained from a telemetry subsystem implanted in the pleural cavity of the primate. This area of implantation was selected primarily for its low rejection characteristics. The ease of surgical implantation combined with the dynamic damping characteristics of the cavity's fluid were additional advantages of selecting this area. The telemetry subsystem implanted in the pleural cavity must weigh no more than 100 g and be of specific gravity 1.0 to 1.1. The optimum shape for this telemetry unit is shown in Fig 13.

The neurological data acquisition unit will transmit data obtained from implantation of surface and deep brain electrodes in accordance with the stereotaxic techniques established in this laboratory. The telemetry subsystem will be implanted in the area as shown in Fig 14 and 15. Typical brain electrode locations are shown in Fig 16.

F.1 DATA ACQUISITION REQUIREMENTS

The physiological data to be transmitted by "local" telemetry to the capsule data acquisition system is presented in Table 3. Psychological and physiological data requirements relating to the primate and processed directly to the capsule data acquisition system is shown in Table 4.

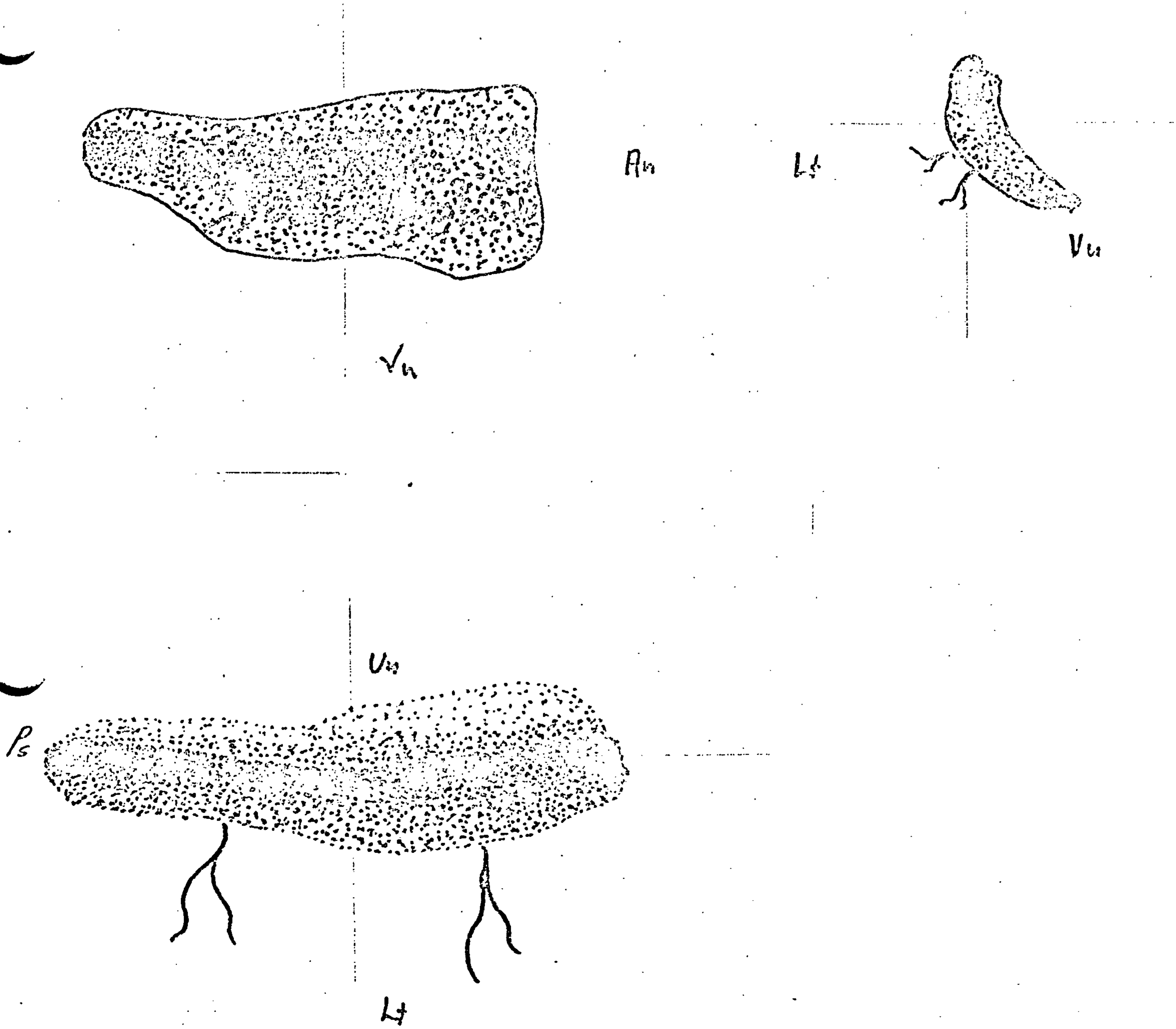


FIGURE 13

PLEURAL CAVITY TELEMETRY UNIT

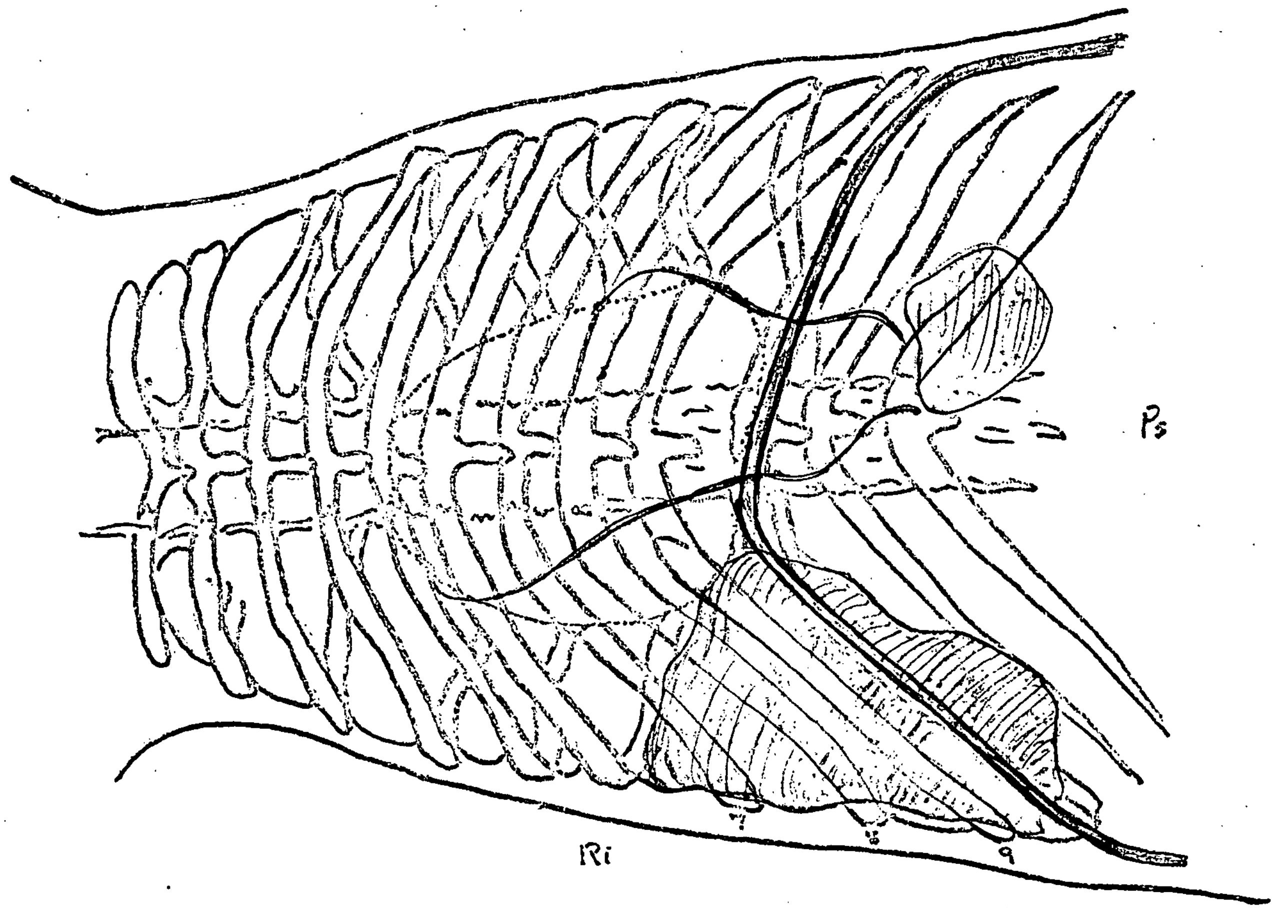


FIGURE 14

TELEMETRY UNITS AREA OF IMPLANTATION

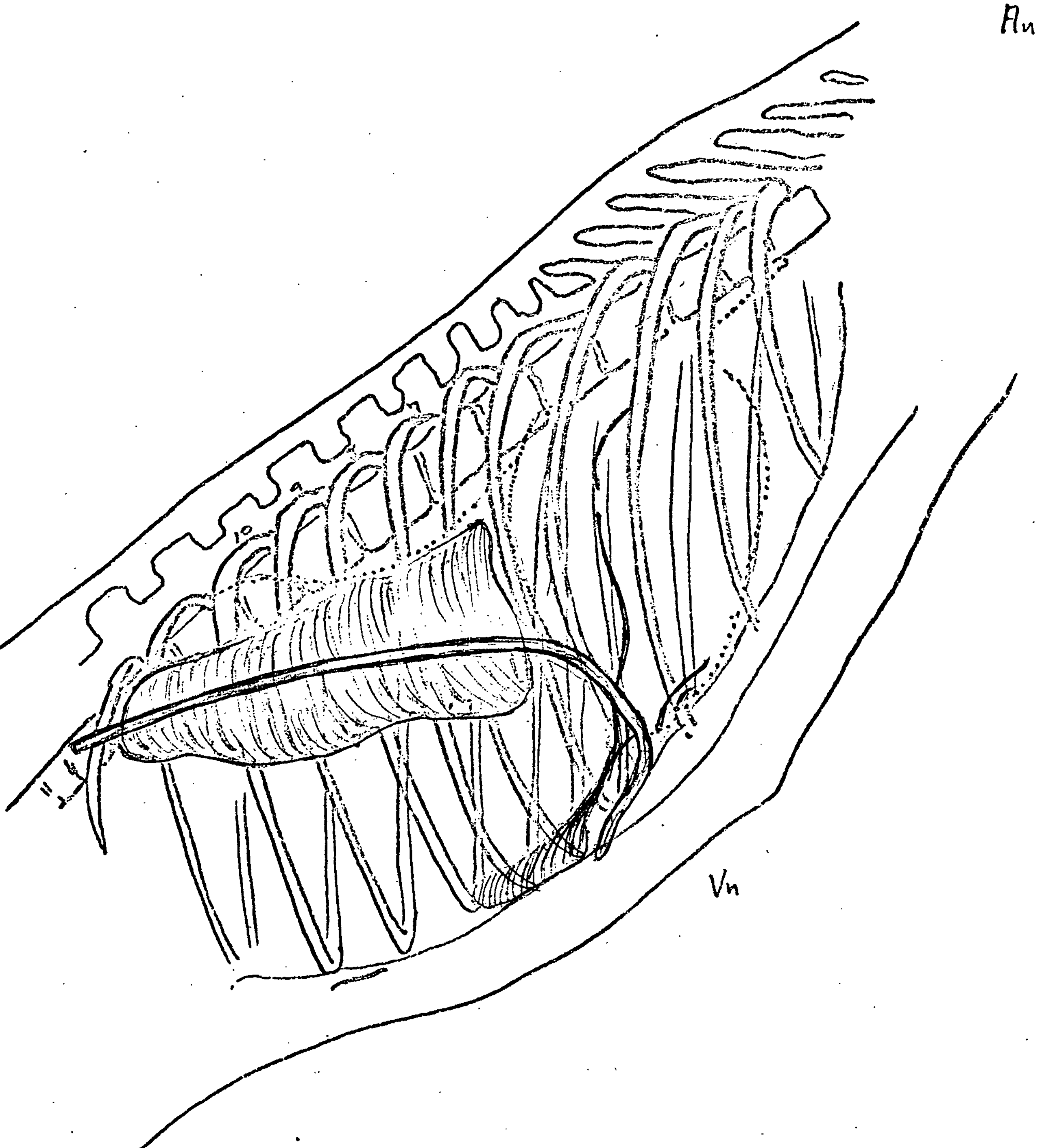


FIGURE 15

TELEMETRY UNITS AREA OF IMPLANTATION

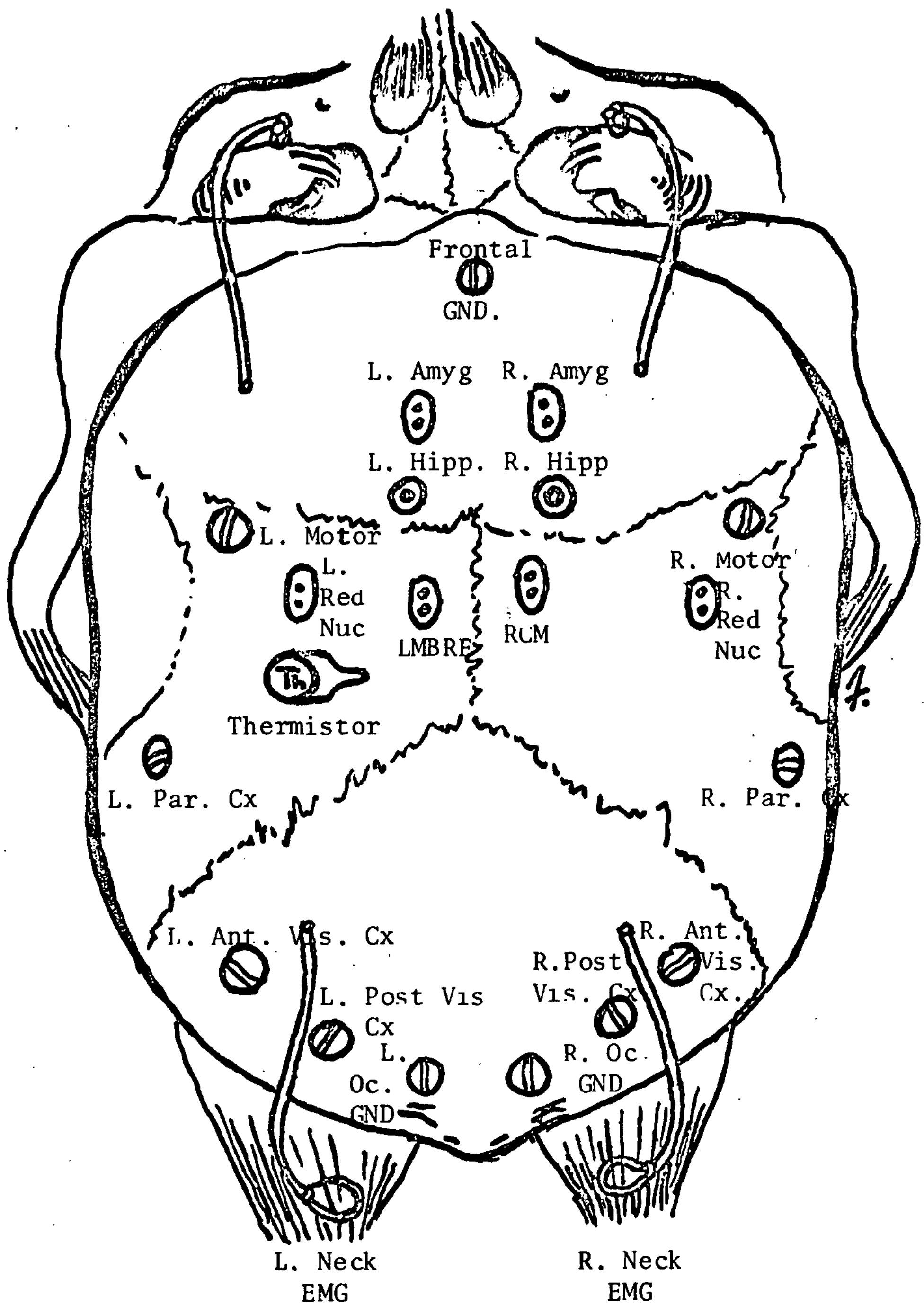


FIGURE 16

TYPICAL ELECTRODE LOCATIONS

TABLE 3

PHYSIOLOGICAL DATA REQUIREMENTS
TRANSMITTED BY DIGITAL TELEMETRY SYSTEM

PRIMATE IMPLANTS

Description	No. Of Channels	(Hz) Freq. Range	(μv) Physiological Input Range	Resolution Bits Min/Max	(Sec^{-1}) Sampling Rate Min/Max	(Bits/Sec) Data Rate Per Channel Min/Max	(Bits/Sec) Data Rate Per Parameter Min/Max
1. EEG	16	0.5-100	2-500	6/8	250/512	1500/4096	24,000/65,538
2. EOG	2	0.5-20	100-5000	6/8	100/140	600/1120	1,200/ 2,240
3. EMG	2	10-50	100-5000	6/8	250/350	1500/2800	3,000/ 5,600
4. EKG	1	0.5-100	100/5000	6/8	250/512	1500/4096	1,500/ 4,096
5. Blood Flow	2	0-50	N/A	6/8	250/350	1500/2800	3,000/ 5,600
6. Blood Pressure	2	0-50	N/A	6/8	250/350	1500/2800	3,000/ 5,600
7. Galvanic Skin Response	1	0-10	N/A	6/8	50/70	300/560	300/560
8. Brain Temperature	1	0-1	N/A	8/10	5/7	40/70	40/70
9. Core Temperature	1	0-1	N/A	8/10	5/7	40/70	40/70
10. Brain Impedance	1	0-1	N/A	8/10	5/7	40/70	40/70
11. Intercranial Pressure	1	0-1	N/A	6/8	5/7	30/56	30/56
Total	30	---	---	---	---	---	36,270/89,724

TABLE 4

PHYSIOLOGICAL DATA REQUIREMENTS
TRANSMITTED BY DIGITAL TELEMETRY SYSTEM

CAPSULE GENERATED

Description	No. Of Channels	Freq. Range (Hz)	Resolution Min/Max (Bits)	Sampling Rate Min/Max (Sec^{-1})	Data Rate Per Channel (Bits/Sec)	Data Rate Per Parameter (Bits/Sec)
1. Orientation	2	0-10	8/10	50/70	400/700	800/1400
2. pCO_2 in Capsule	1	0-1	6/8	5/7	30/56	30/56
3. Behavioral Test	2	0-50	6/8	250/350	1500/2800	300/5600
4. Behavioral Test	4	0-1	6/8	5/7	30/56	120/224
5. Water Consumption	1	0-1	6/8	5/7	30/56	30/56
6. Food Consumption	1	0-1	6/8	5/7	30/56	30/56
7. Ergometric	4	0-1	6/8	5/7	30/56	120/224
Total	15	---	---	---	---	4130/7616

Selected channels of the data will be acquired on magnetic tape flight recorders as well as telemetry. Since only limited channel capacity would be available on flight recorders, a wider range of data would be telemetered in real time during encounters with ground stations. There would be a minimum requirement of one such encounter per orbit, with a data capture duration per orbit being approximately ten min.

II. PRIMATE INTERFACE

F.2 AUTOMATIC ELECTROENCEPHALOGRAM ANALYSIS

One aspect of the Central Nervous System (CNS) studies performed extensively by this laboratory is the analysis of the times of occurrence and the spectral content of the five basic stages of sleep. The ordinary sleep progression through the night is as follows: Wake, drowsy, Stage II (light), Stage III (medium), Stage IV (deep) and REM (Rapid Eye Movement) in a time interval of approximately 70-90 min. In man, as well as other primates, the percentage of time spent in each of these states is critical to the psychological and physiological well-being of the subject, and, therefore, in the study of primates in weightlessness, the ability to determine the time percentage of each phase is vital. Very little is known about the ability of primates to maintain a healthy sleep/wake cycle while in a zero gravity environment. An example of the way in which this cycle can change was experienced during the Biosatellite III flight when the primate rapidly shifted between stages of sleep in a manner never experienced in a 1 g environment.

A description of various states of sleep with accompanying exemplory data epochs (Fig 17) follows:

<u>Awake Alert</u>

The subject has eyes open and is alert. Cortical EEG is low amplitude, high frequency (usually above alpha frequency) accompanied by much EOG activity.

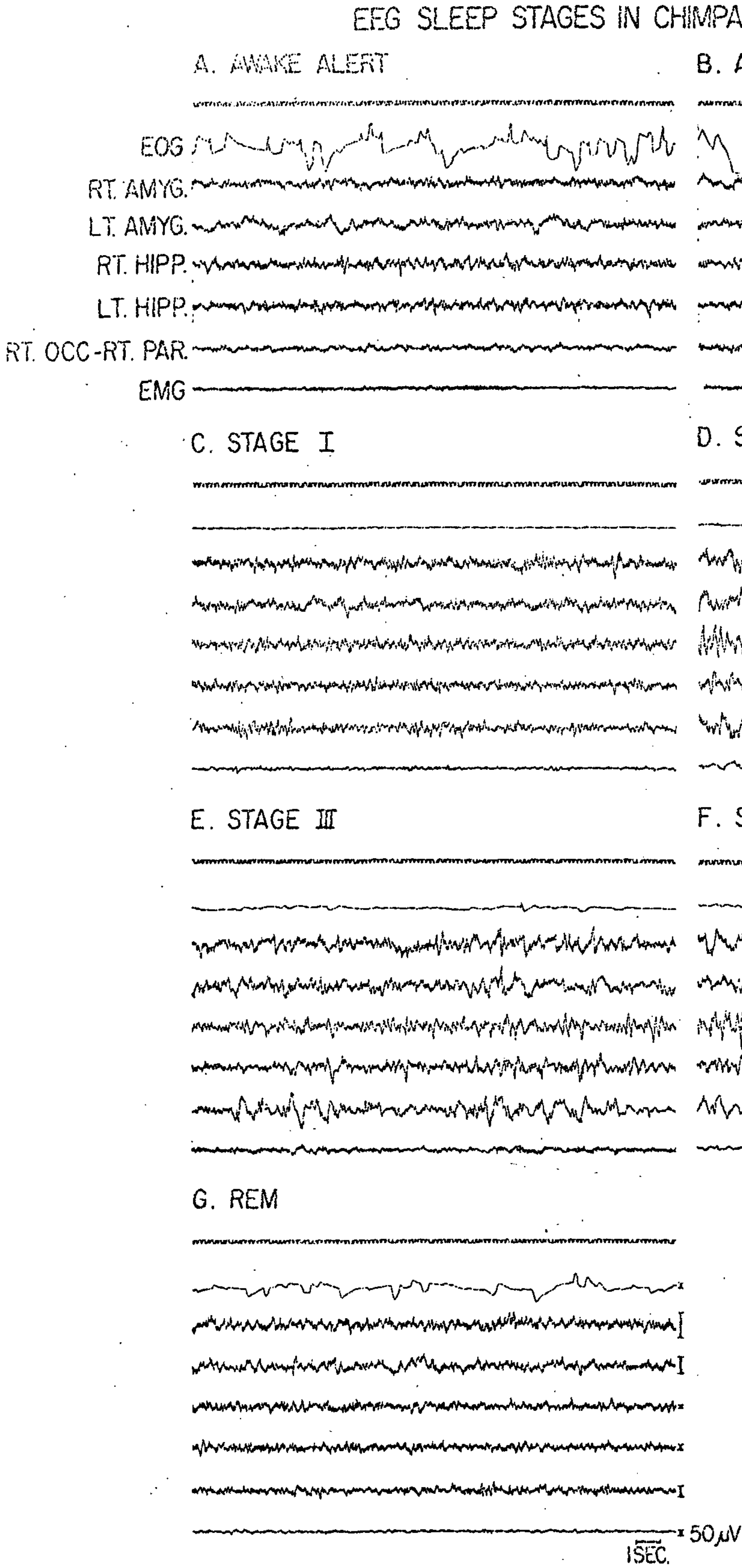

EEG SLEEP STAGES IN CHIMPANZEE
A. AWAKE ALERT
B. AWAKE DROWSY
EOG
RT. AMYG.
LT. AMYG.
RT. HIPP.
LT. HIPP.
RT. OCC-RT. PAR.
EMG
C. STAGE I
D. STAGE II
E. STAGE III
F. STAGE IV
G. REM
50µV
1SEC.

FIGURE 17

Awake Drowsy

The subject is in a sleeping posture with eyes closed or blinking. The EEG is low voltage, mixed frequency (LVMF). Rhythmic alpha activity is present posteriorly for at least 50% of epoch.

Stage I

The subject's eyes are closed; movements are few. The EOG is silent except for slow eye movements. The EEG amplitude is somewhat higher than the LVMF EEG of Alert or Drowsy and contains occasional theta activity. Beta activity and K-complexes are not present.

Stage II

EEG contains delta slowing of less than 20% of the record. Beta activity in spindle bursts lasting longer than 0.5 sec or a definite K-complex consisting of an initial high amplitude negative wave followed by a positive wave accompanied by beta activity. No EOG activity.

Stage III

EEG contains 20-50% delta of higher amplitude than Stage II. No EOG activity.

Stage IV

EEG contains over 50% delta activity from 1/2-3 Hz with moderate to large amplitude. No EOG activity.

REM

The hallmark of REM is rapid EOG activity associated with periodic rolling eye movements. The EEG is characterized by

LVMF activity often of higher amplitude than Stage I. No K-complex is present and very little beta spindle activity is present. Sawtooth waves are frequent.

Several computer analyses (power spectral density, cross power spectral density, coherence as well as others) are performed on selected epochs of tape recorded EEG data and form the basis of CNS studies in the Space Biology Laboratory. At the present time, selection of these epochs is done manually by highly trained personnel who scan the data for important physiological activities. However, considerable emphasis has been placed in developing computer programs capable of recognizing various EEG patterns, such as those described here.

In space flight, where power consumption of implanted telemetry systems, real time data acquisition, and on-board tape recording provisions are limited, continuous physiological data monitoring may be impractical. On the Biosatellite III flight real time data acquisition was limited to one pass per orbit (approximately 5 min of every 90 min) and on-board tape recording limited to approximately 2 hr per day.

For the above reasons a flight system that pre-processes the data by recognizing the various sleep stages is proposed. The design would require only certain pre-selected EEG telemetry channels to remain on continuously, thus conserving power. When a siginificant state occurs, the analyzer would initiate a signal to turn on all physiological telemetry channels and the on-board recording equipment for a fixed duration. If a syncronous orbit were used for the experiment, the signal could also be used to turn on ground based recorders. A separate channel from the analyzer, coded with a unique signal for each stage, could also be developed and used to determine the percentage of time occupied by each phase of activity. This channel would have a three-fold purpose: (1) It could be condensed by playing back at a faster rate and telemetered to earth at the end of a pre-selected period (e.g. 24 hr); (2) It could be used as a check of the instrument itself by allowing ground based physiologists to compare their analysis of the raw data to that of the analyzer and; (3) It could be monitored by a relatively untrained (in EEG analysis) astronaut who could report the time sequence of the various deep stages.

A block diagram of the proposed system is shown in Fig 18. The feasibility of the system is dependent upon a unique definition in engineering terms of the various states of the data. Difficulties encountered due to differences in frequency and amplitude ranges between primates may be overcome by incorporating in the design an initial condition "calibration" adjustable for each primate.

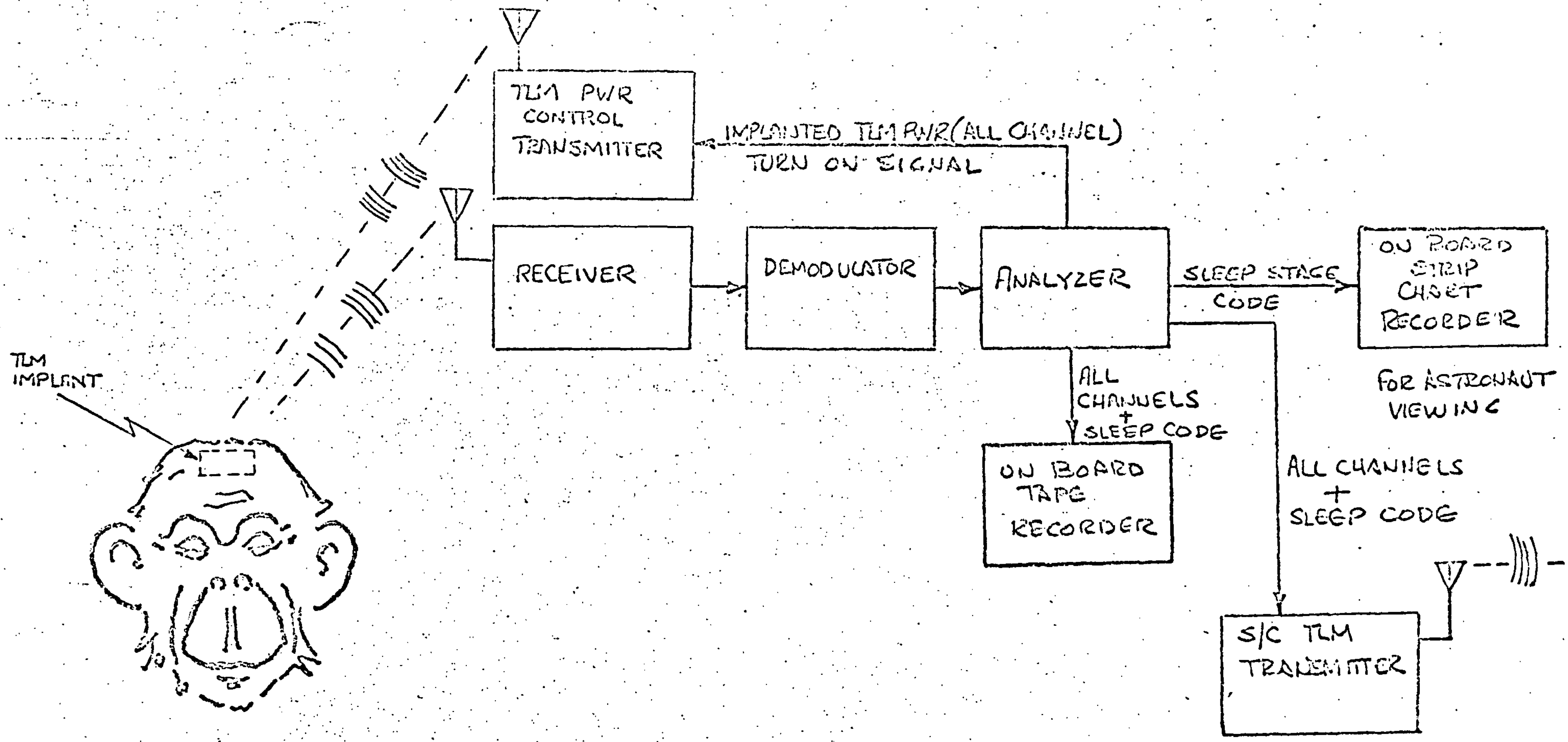


FIGURE 18

AUTOMATIC EEG ANALYZER

BLOCK DIAGRAM

II. PRIMATE INTERFACE

G. WASTE PRODUCTION

G.1 FLUIDS

a. PRIMATE URINE DEFINITION

The capsule's waste management system is required to transport all solid and fluid waste from the capsule enclosure to the spacecraft's waste storage compartment. Provided in this section is a definition of the hydraulic properties of primate urine and feces.

PRIMATE URINE DEFINITION

	Parameter	Nominal	Min.	Max.	Units
1.	Specific Gravity	1.012	1.002	1.040	---
2.	Viscosity at 68°F	1.0	0.9	1.1	Centistokes
3.	Surface Tension	65	50	80	Dynes/cm
4.	pH Factor	7.25	6.0	8.85	---

b. WASTE FLUID PRODUCTION

1. Maximum Urine Output: 1200 cc/day
2. Average Urine Output: 850 cc/day
3. Maximum Metabolic Water Including Feces Water: 400 cc/day
4. Average Metabolic Water Including Feces Water: 370 cc/day

G.2 SOLIDS

a. FECES

1. Maximum Feces Output: 310 gm/day
2. Average Feces Output: 120 gm/day
3. Specific Gravity of Feces: 1.65 Nominal

4.	Viscosity of Feces:	To be determined
5.	Surface Tension of Feces:	To be determined
6.	Maximum Dimensions of Single Fecal Bolus:	To be determined
7.	Maximum Surface Area Encompassed by Single Fecal Bolus:	12 cm^2

b. PARTICULATE MATTER PRODUCTION

The primate will produce particulate matter of the material and volume as shown below. The life support subsystem shall be capable of operating within specificiation requirements when exposed to that particulate matter.

		Particule Size	Quantity
1.	Food pellets or pieces thereof, regurgitated matter of specific gravity = 1.2	10 cc	30 cc/day
2.	Skin (maximum)	0.1 cc	1.0 cc/day
3.	Hair (maximum)	0.1 cc	75 cc/day (unmatted volume)
4.	Fingernails (maximum)	0.5 cc	1.0 cc/day

II. PRIMATE INTERFACE

H. ORIENTATION CONSIDERATIONS

The animal's orientation in relation to capsule interior will be monitored, so that limb positions and direction of gaze will be continuously known. This information will be stored in the on board tape recorder and dumped at specified ground station passes. To complement the orientation monitoring system, photographs will be taken at a rate of 4 frames/sec during selected periods of the mission. The field of camera view will approach 180° in order to record head, trunk, and limb movements, and will have sufficient resolution to indicate direction of gaze. The system used to accomplish head to trunk relationship and trunk to capsule orientation is discussed in Section III H.

II. PRIMATE INTERFACE

I. ACOUSTIC CONSIDERATIONS

The total continuous sound pressure level during orbital phase at any point within the capsule shall not be greater than 75 db. Excursions not lasting more than 1 second may reach a sound pressure level of 100 db during the day cycle only.

The components which are the major contributors to the sound pressure level intensity shall be so placed around the spherical chamber, that no orientation cue is offered to the primate as a result of such noise.

The programmed orientation cues (audio tones) during behavioral task sessions are not to be considered as part of the above specifications.

II. PRIMATE INTERFACE

J. LIGHTING

J.1 HOUSE LIGHTING

The interior of the spherical chamber shall be maintained at specified lighting intensities throughout the day and night periods. This shall be accomplished by illuminating various triangular segments of the chamber wall in such a manner that no orientation cue is offered to the subject.

The triangular segments shall be uniformly illuminated over their entire surface. The lighting intensity within the capsule is to be uniform throughout the entire volume with a maximum of 5% tolerance allowable to the following specifications:

Day Time:*	To be determined
Night Time:*	To be determined.

Opportunities to select light/dark cycles and light intensity shall be offered to the primate at selected periods during the flight.

Task lighting will be accomplished by illuminating symbols at programmed times. Symbol definition and specifications are presented in Section III F. A symbol "on" intensity of greater than 4 millilamberts is sufficient for primate distinguishing characteristics. In the "off" condition, the symbols must not be visible to the primate. The lighting intensity of all symbols is to be uniform over their entire surface area ±1%.

---

* Measured at the center of the sphere.

II. PRIMATE INTERFACE

K. PRIMATE CONFIGURATION

This section contains a compilation of the available and relevant data on chimpanzee body measurements. The basis of design for mechanical subsystems subjected to direct primate participation, should be compatible with the body measurements contained in Tables 5 and 6. The measurements include 54 straight dimensions, 21 circumferential dimensions, and total body weight.

Table 5

CHIMPANZEE FLIGHT CONFIGURATION
STRAIGHT MEASUREMENTS
(Figures 19 Thru 21)

No.	Description Of Measurement	Minimum*	Maximum*	Mean*
0	Weight	16.0	19.0	17.5
1	Sitting Height	41.4	57.7	49.5
2	Top Head to Top Shoulder	9.6	14.7	12.2
3	Acromial Height	22.8	43.2	33.0
4	Popliteal Height	15.7	19.8	17.8
5	Shoulder-Elbow Length	15.7	24.9	20.3
6	Head	16.5	19.1	17.8
7	Buttock-Knee Length	15.0	25.4	20.3
8	Buttock-Posterior Calf Length	17.5	20.6	19.1
9	Foot Length	14.2	18.8	16.5
10	Knee Height	21.8	26.4	24.1
11	Bideltoid	22.8	20.5	26.7
12	Body Width	12.7	22.9	17.8
13	Body Width	14.5	20.1	17.3

*Weight in Kilograms, other measures in centimeters; refer to Fig. 19 thru 21 for measurement number designation

No.	Description Of Measurement	Minimum*	Maximum*	Mean*
14	Body Width	12.4	22.1	17.3
15	Waist	13.7	16.8	15.2
16	Hip Breadth	15.0	18.0	16.5
17	Elbow-Elbow	23.1	35.3	29.2
18	Total Arm Reach	52.1	67.3	59.7
19	Forearm-Hand Length	29.2	39.4	34.3
20	Hand Length	11.9	18.5	15.2
21	Distance	21.6	33.3	27.4
22	Distance	14.2	16.3	15.2
23	Distance	6.6	13.7	10.2
24	Distance	5.1	10.2	7.6
25	Distance	22.8	30.5	26.7
26	Distance	4.3	10.9	7.6
27	Distance	2.0	5.6	3.8
28	Distance	9.6	13.2	11.4
29	Distance	3.8	7.9	5.8
30	Body Thickness	8.6	10.7	9.7
31	Body Thickness	12.7	14.2	13.5
32	Body Thickness	13.5	16.0	14.7
33	Body Thickness	14.5	16.0	15.2
34	Body Thickness	6.3	11.4	8.9
35	Arm Thickness at Axillary Space	2.0	7.1	4.6
36	Arm Thickness at Biceps	2.3	6.9	4.6
37	Arm Thickness Above Elbow Break	2.5	6.6	4.6
38	Arm Thickness Below Elbow Break	3.5	6.6	5.1
39	Arm Thickness at Mid-Forearm	3.3	5.8	4.6
40	Wrist Thickness	3.0	4.6	3.8

No.	Description Of Measurement	Minimum*	Maximum*	Mean*
41	Hand Thickness	1.3	6.4	3.3
42	Leg Thickness at Crotch	4.6	9.7	7.1
43	Leg Thickness at Thigh	4.6	9.7	7.1
44	Knee Thickness (flexed)	3.0	7.1	5.1
45	Leg Thickness Below Knee	2.8	7.4	5.1
46	Calf Thickness	2.3	6.9	4.6
47	Ankle Thickness	3.3	5.8	4.6
48	Wrist Width	3.0	4.6	3.8
49	Hand Width	1.3	5.3	2.5
50	Leg Width at Crotch	7.1	9.7	8.4
51	Leg Width at Thigh	2.5	10.2	5.8
52	Leg Width at Knee	3.6	6.6	5.1
53	Body Height (Standing)	74.6	98.1	86.4
54	Prone Length	118.6	155.3	136.9

Table 6

CHIMPANZEE FLIGHT CONFIGURATION
CIRCUMFERENTIAL MEASUREMENTS
(Fig 22)

No.	Description Of Measurement	Minimum*	Maximum*	Mean*
1	Head	46.5	50.0	48.3
2	Neck	23.9	34.5	29.2
3	Shoulder	56.4	75.7	66.0
4	Body Circumference	51.3	65.5	58.4
5	Body Circumference	54.4	62.5	58.4
6	Body Circumference	55.1	61.7	58.4
7	Body Circumference	41.6	49.8	45.7
8	Scye	18.3	32.5	25.4

No.	Description Of Measurement	Minimum*	Maximum*	Mean*
9	Axillary Arm	17.0	22.6	19.8
10	Biceps	15.5	24.1	19.8
11	Arm Above Elbow Break	7.5	20.3	14.0
12	Arm Below Elbow Break	18.8	21.8	20.3
13	Arm at Mid-Forearm	14.7	19.8	17.3
14	Wrist	9.7	17.3	13.5
15	Hand	11.9	18.5	15.2
16	Leg at Crotch	22.3	31.0	26.7
17	Leg at Thigh	13.7	29.5	21.6
18	Leg at Knee	5.1	21.8	12.7
19	Leg Below Knee	15.5	19.1	17.3
20	Calf	15.2	21.8	18.5
21	Ankle	11.9	18.5	15.2

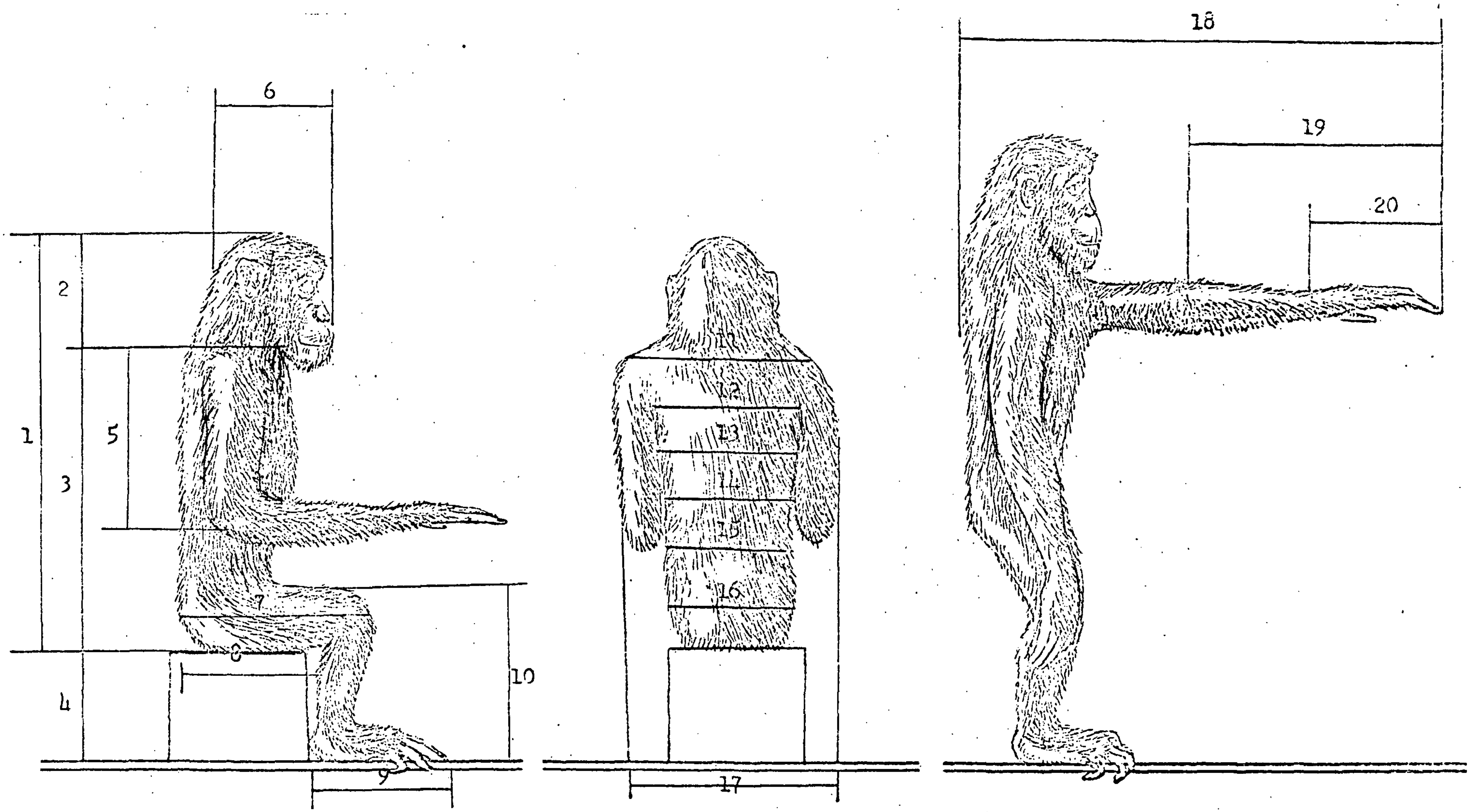


FIGURE 19

STRAIGHT MEASUREMENTS

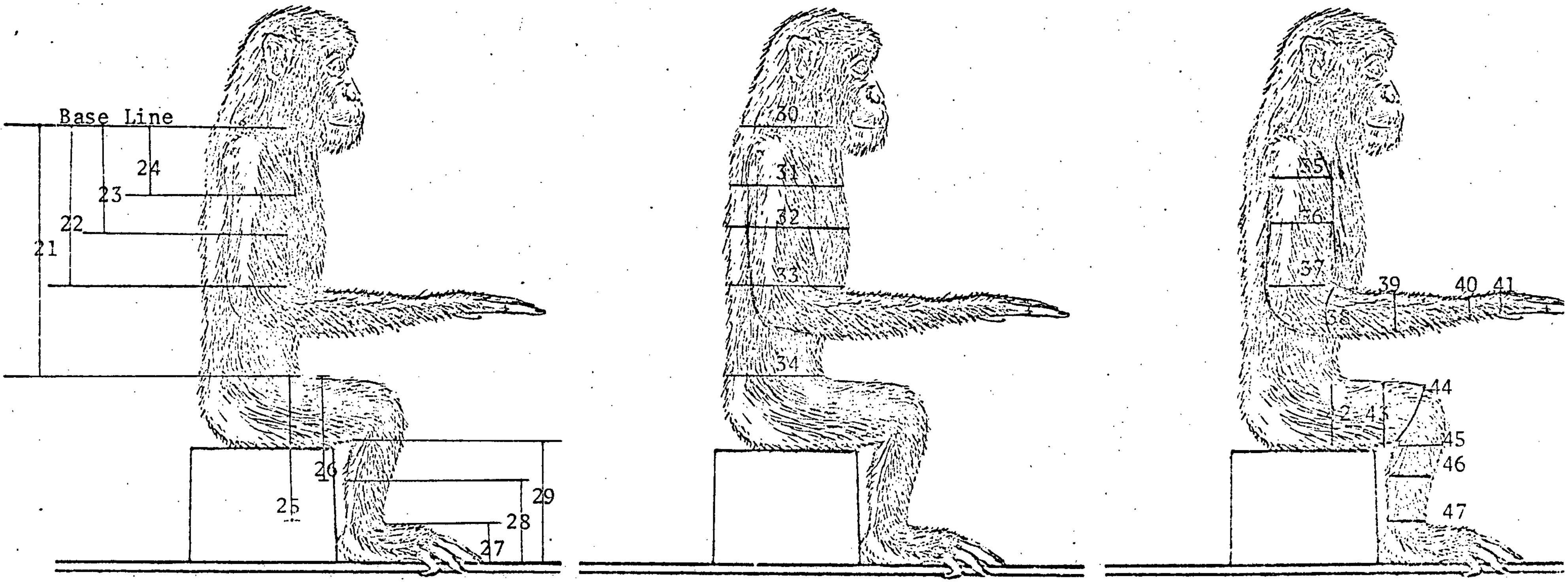


FIGURE 20

STRAIGHT MEASUREMENTS

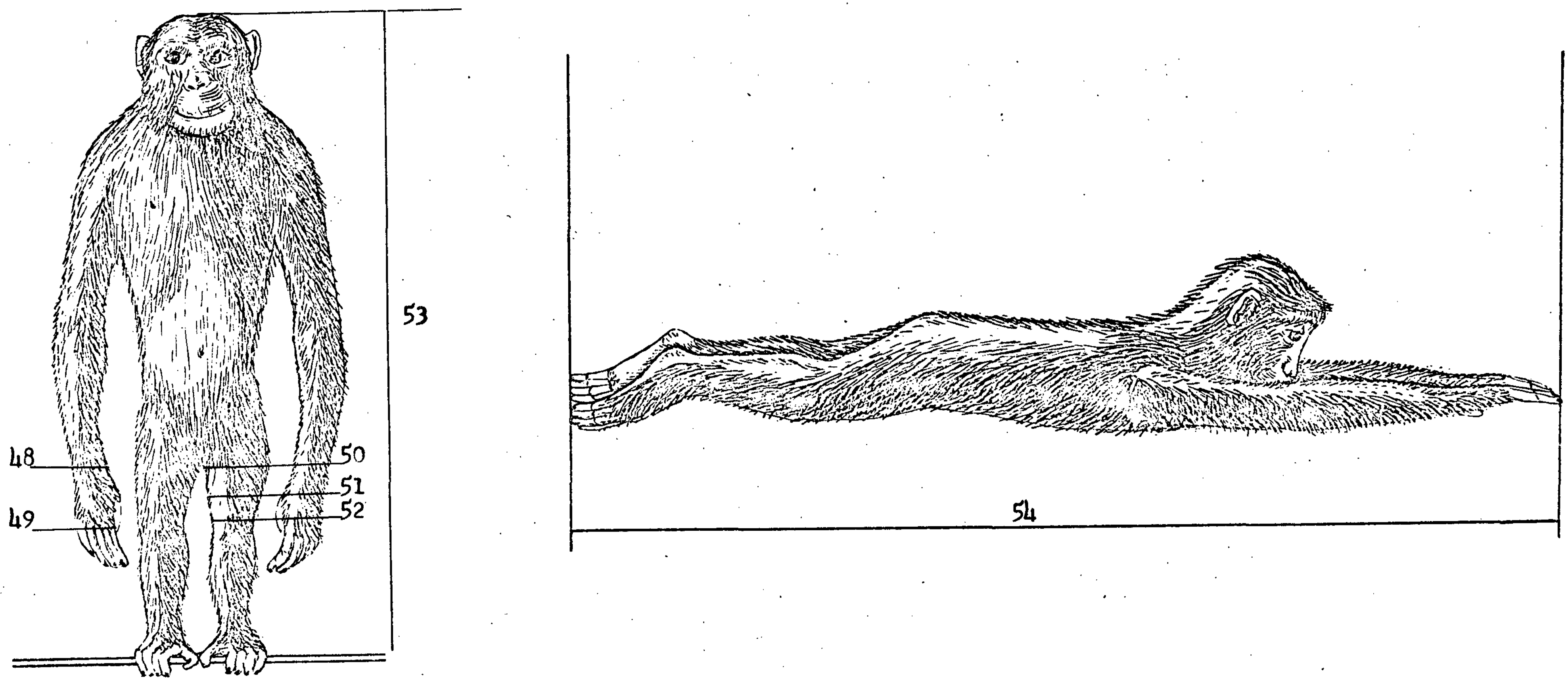


FIGURE 21

STRAIGHT MEASUREMENTS

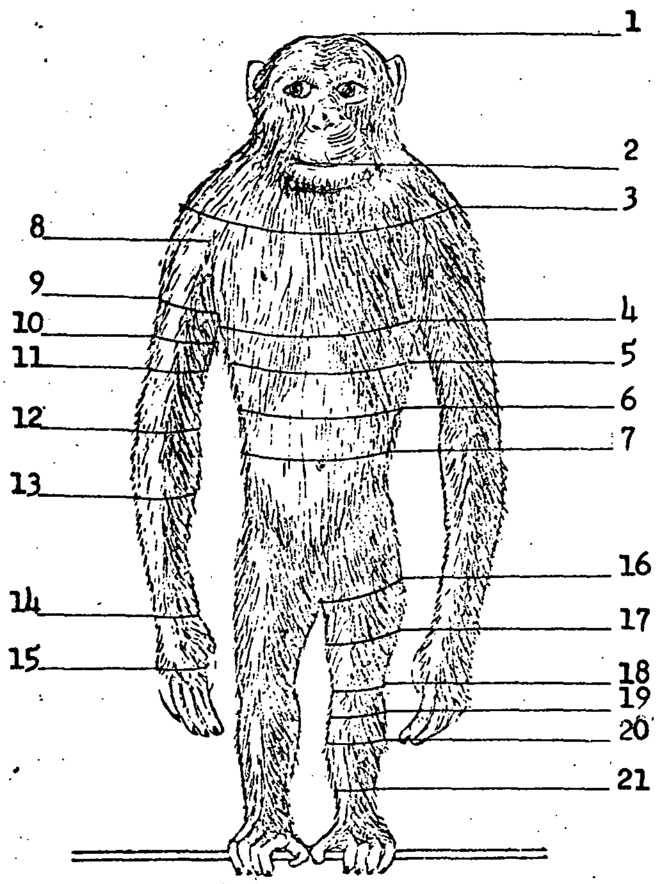


FIGURE 22

CIRCUMFERENTIAL MEASUREMENTS

II. PRIMATE INTERFACE

L. ACCEPTABLE LIMITS OF ENVIRONMENT

The POCO spacecraft will be subjected to a range of external environmental conditions during its launch and orbital phases which must be taken into account in the design and testing of the subsystems and component parts. Equipment to physically support the primate's body through the launch phase may be incorporated within the spherical chamber in order to eliminate possible degradation of the primate's health as a result of these environmental conditions as described in Section L.5.

The POCO experiment may be designed to operate within an orbiting space station, workshop, or a module associated with its own launch vehicle. At this time, the means of launch and recovery and the location of the experiment envelope have not been selected. Compatibility between available launch vehicles and payload location is to be established at a later date. One such possibility would be to launch the primate within the spherical chamber mounted inside the Saturn-1B spacecraft LM adapter. The available payload envelope is 4525 cubic feet as shown in Fig 23. The environmental conditions characteristic of a launch of this vehicle are described below:

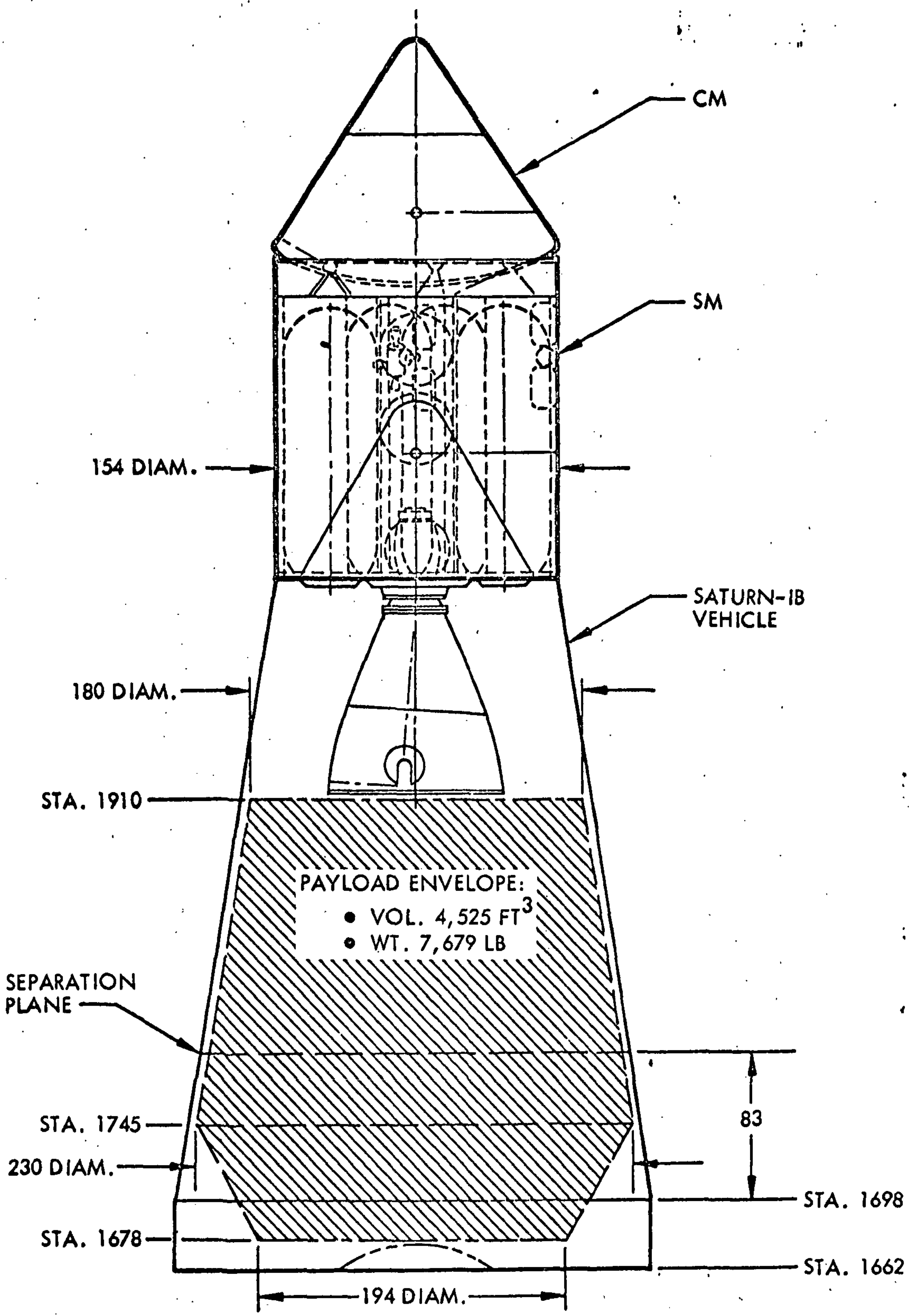
L.1 ACCELERATION

The approximate acceleration-time histories for a nominal trajectory of the S-1B are shown in Fig 24 .

L.2 VIBRATION

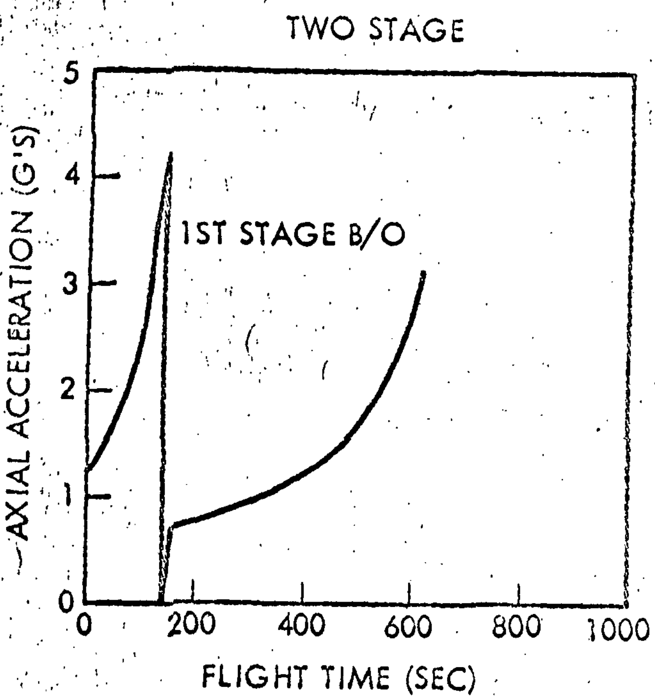
a. SINUSOIDAL

The sinusoidal vibration amplitude-frequency time history is shown in Fig 24 .

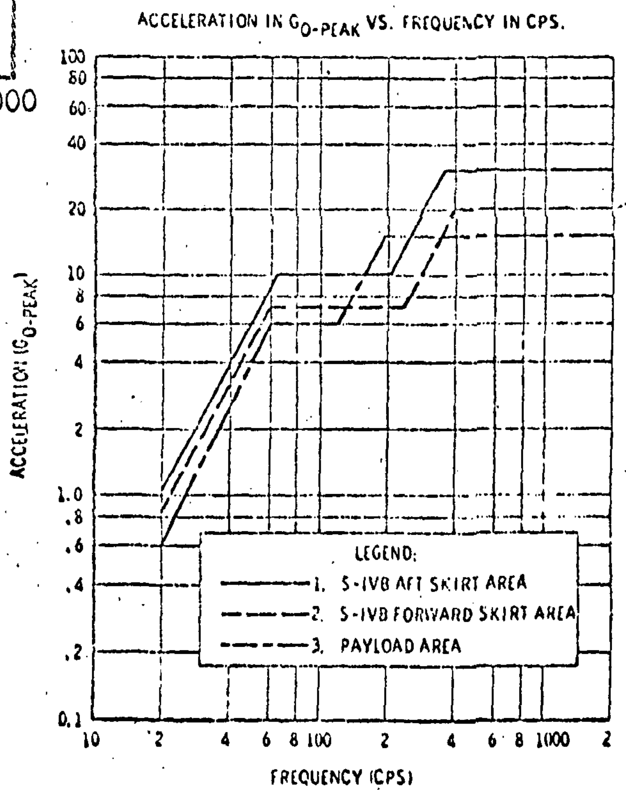


Available Space Inside LM Adapter

FIGURE 23



NOTES:
1. COPLANAR DIRECT ASCENT LAUNCH FROM ETR
2. AZIMUTH = 90°



NOTE:
1. THE VIBRATION INPUT IS ASSUMED TO BE APPLIED IN EACH OF THREE MUTUALLY PERPENDICULAR DIRECTIONS.
2. THE LOGARITHMIC SWEEP RATE IS ASSUMED TO BE ONE OCTAVE PER MINUTE OVER THE FREQUENCY RANGE FROM 20 TO 2000 AND BACK TO 20 CPS.

a) S-1B vehicle acceleration-time history

b) S-1B sinusoidal vibration amplitude- frequency- time history

FIGURE 24

b. RANDOM

The random vibration amplitude-frequency-time history is shown in Fig 25.

L.3 SHOCK

The shock, along any axis must not exceed 20 g for a duration not to exceed 2 msec.

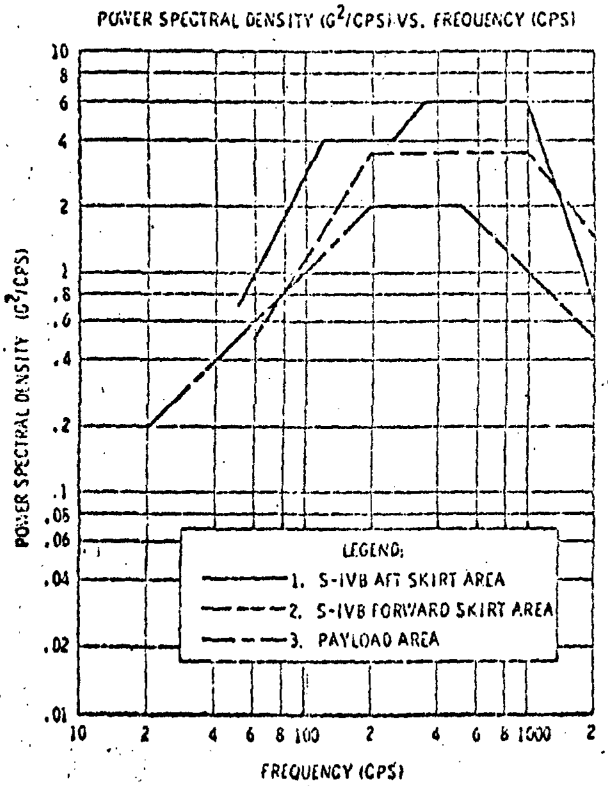
L.4 GUIDANCE AND CONTROL

The spacecraft must be stabilized to within 10^{-4} g steady-state and 10^{-2} g transient accelerations.

L.5 PRIMATE LAUNCH SUPPORT EQUIPMENT

The acceleration-time history and vibration spectrum of the S-1B vehicle are such that no primate launch support equipment may be required. As part of the development program, primate tests will be performed to determine the necessity of incorporating primate restraint equipment during launch.

In the event that test results indicate the need for such equipment, the method of launch restraint would be strongly dependent upon the waste collection concept selected for flight. For the various waste collection concepts considered in this report, a brief description of the associated primate launch support equipment is offered in Table 7.



NOTE:
1. AMPLITUDE DISTRIBUTION IS ASSUMED GAUSSIAN
2. DURATION IS ASSUMED TO BE TWELVE MINUTES FOR EACH OF THREE MUTUALLY PERPENDICULAR DIRECTIONS

Figure 25.

S-1B random vibration amplitude-frequency-time history

TABLE 7

PRIMATE LAUNCH SUPPORT EQUIPMENT

Waste Collection Concept	Associated Launch Support Equipment
1. Backpack	The animal will be placed and held into the position he will assume during the periodic backpack emptying process. Any necessary additional padding may be incorporated and withdrawn to the exterior of the sphere after orbit is attained and the animal is released.
2. Twin Sphere	The animal will be located within the connecting tunnel between the two spheres during launch. This tunnel may be fitted with padding and/or suspended to reduce the forces characteristic of launch.
3. Mechanical a) Wiper Blade b) Continuous Surface Exchange 4. Primate Training 5. Diet Application to Harden Fecal Matter 6. Ultrasonics	The animal may be secured to the sphere wall with padding and conventional restraint straps. The padding will be inflatable so that after use, it shall be deflated and then retracted with the restraint straps through a temporary opening in the sphere wall.

II. PRIMATE INTERFACE

M. DRUG ADMINISTRATION

A number of pharmaceuticals are to be housed on board to be dispensed to the primate for medicinal purposes upon ground command. The optimum drug configuration as well as dispensing techniques are presently being studied. Gaseous and aerosol forms as well as drug incorporation into solid food are being considered. If astronaut participation is available, the dispensing technique may merely consist of dropping a solid pellet through an access hole or opening a valve to enable a specified aerosol to enter the capsule. The drugs being considered for this application and their associated disorder are presented in Table 8.

TABLE 8

PHARMACEUTICAL ADMINISTRATION

	Drug	Disorder
1.	Pediatric Vitamin Preparation	Poor Appetite
2.	Danthron (D-calcium pantothenate)	Constipation
3.	Kaolin Pectin	Diarrhea
4.	Tetracycline	Infection
5.	Caffeine Benzoate	Depression
6.	Hard Sweet Candy	Poor Appetite
7.	Fresh Fruit	Vitamin Deficiency

A study will be conducted in our laboratory to determine the criteria for pharmaceutical administration based on the data to be available from the flight data acquisition system (see Table 3 for implanted TLM channels). The end result of the study will provide the procedure and specifications for pharmaceutical administration in flight and primate inserted system test.

Page 94 Left Blank Intentionally

III. EXPERIMENT INTERFACE

A. INTRODUCTION

Section III of this report presents the interface between experimenter supplied equipment and the spacecraft. A definition of each experimenter supplied subsystem necessary to support the mission requirements as set forth in Section II is included. The experiment is planned as part of the Apollo Applications Program; hence, the design goal of "Physiology of Chimpanzees in Orbit" is to achieve compatibility with the Saturn Apollo Application Program.

In areas where more than one concept is currently under consideration, each concept is presented independently in the order of our preference to date.

III. EXPERIMENT INTERFACE

B. PELLET FEEDER

B.1 DESCRIPTION

The primate's basic nutritional requirements are furnished from a storage and dispensing device, hereinafter referred to as the pellet feeder. The solid food requirement for the primate throughout the mission will be met by a supply of pellets to be dispensed on a behavioral task reward basis controlled by the behavioral electronics.

The food supply system is divided into six separate units; one associated with each behavioral panel. Each unit consists of a storage container, a loading device to transfer the pellets from storage to the dispenser, an actuator system, and a dispensing device. Upon feeder actuation, the dispenser shall protrude inside the chamber wall making a pellet available for primate consumption. The pellets are approximately spherical in shape with a diameter of 1.7 cm ± 0.17 cm. The arrangement of the storage container, loading device and delivery system is shown in Fig 26.

B.2 CONCEPT

The pellets are stored in a spherical shaped container made of stainless steel or anodized aluminum. The exit port of the container, point B, is located directly above a rotary disc. Compressed air is metered into the container at entrance A. The air flow directed at the storage exit port combined with a vacuum at point C directs the pellets through the exit of the container and into one of the ten circular receptacles equally spaced around the rotary

Chimp Pellet Dispenser for Zero G Usage

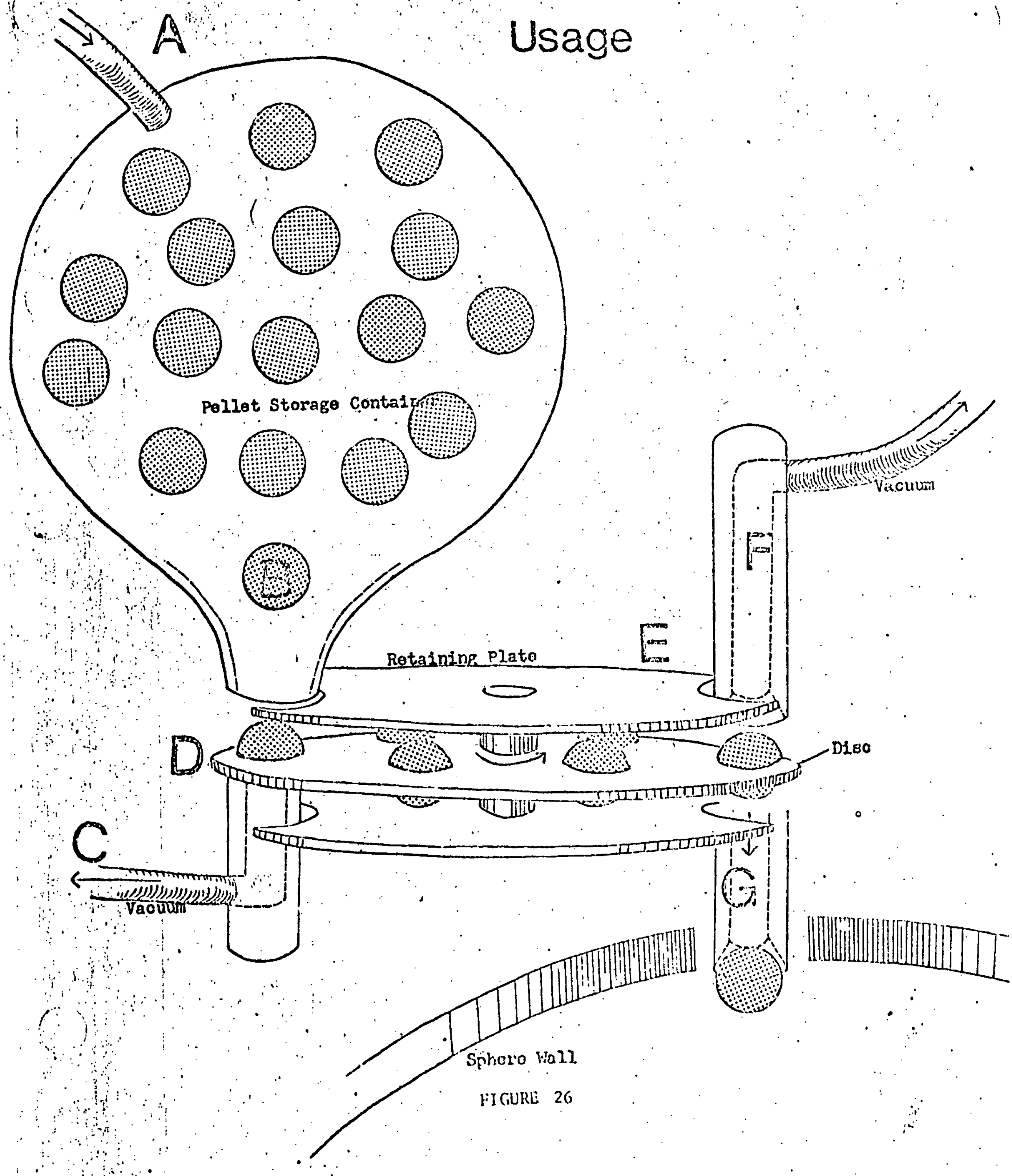


FIGURE 26

disc periphery. Each receptacle is designed to accept one pellet so that as the disc rotates 36°, pellets are collected from the container and transferred around to the dispensing unit. When a pellet drops into the opening, above point C, the change in air flow through C, detected by the pressure differential increase, will be used to terminate the compressed air flow and vacuum at point C. No change in air flow through C would indicate a pellet jam. To provide against the possibility of pellets becoming jammed together, the air flow will be reversed momentarily with compressed air coming through C and a vacuum at A reversing the motion of pellets sufficiently to dislodge any jammed pellets. The pellet, now centered in a receptacle of the rotary disc is advanced one station as the disc advances. A pellet already situated in a receptacle simultaneously is advanced to a position adjacent to vacuum cylinder F. This pellet is positioned against the opening in F and is held there by vacuum. Cylinder F now advances into position G, placing the pellet into the interior of the spherical housing, making it available for primate consumption. The change in pressure at G due to pellet extraction is sensed to indicate primate pellet consumption. After pellet extraction, the cylinder retracts back into its position at F. This cycle is repeated each time a particular pellet feeder receives an actuation signal from the behavioral electronics. In view of the large number of feeding cycles to take place throughout the mission, significant care must be taken to ensure maximum reliability of this system.

B.3 SPECIFICATIONS

a) Each pellet feeder shall be capable of storing 8,000 pellets.

b) The force necessary to remove a pellet from its dispenser shall be 60 to 200 grams.

c) The feeder shall be capable of dispensing spherical pellets of 1.7 cm ± 0.17 cm diameter within 200 msec after feeder actuation.

d) The pellet feeder shall be capable of operation under 1 g as well as 0 g environment.

e) Pellet removal verification is to be available within 50 msec after pellet extraction.

f) Dispenser location is defined in Fig 26.

g) Pellet ejection hole dimension: 2.0 cm ± .01 cm diameter.

h) The pellet shall protrude into the spherical chamber by not less than 1.1 cm.

III. EXPERIMENT INTERFACE

C. WATER DISPENSER

Water is to be delivered to the primate in a quasi-*ad lib* manner in measured amounts and at specified rates. The average water requirement of a 17.5 kg chimpanzee is 800 cc/day; however, to insure water availability on an *ad lib* basis, the following limits shall be placed on water consumption:

200 cc ± 5 cc per hr - day cycle

200 cc ± 5 cc per 3 hr - night cycle.

The maximum water automatically allotted shall be 2000 cc/24 hr. Provision shall be made to allow dispensing of 200 cc/hr during the night cycle by ground command. To accommodate the programmed water dispensation, a total supply quantity of 540 kg of drinking water must be stored on board (this amount includes 50% above the programmed quantity to accommodate water usage during the countdown and recovery phases of the mission and to accommodate any primate water loss due to increased perspiration).

Six water dispensers will be situated at the ends of three mutually perpendicular axes; each being contained within one of the 60 triangular segments of the chamber wall. A mouth device requiring primate suction for water dispensation shall protrude through the chamber wall at each of the six specified locations.

C.1 CONCEPT

The approach selected for the storage and dispensation of water is shown in block diagram in Fig 27. The water system consists of a primary water storage tank, a one-way valve, two bacterial filters, an accumulator, a flow meter, a solenoid valve, six demand regulators and six mouth devices (nipples).

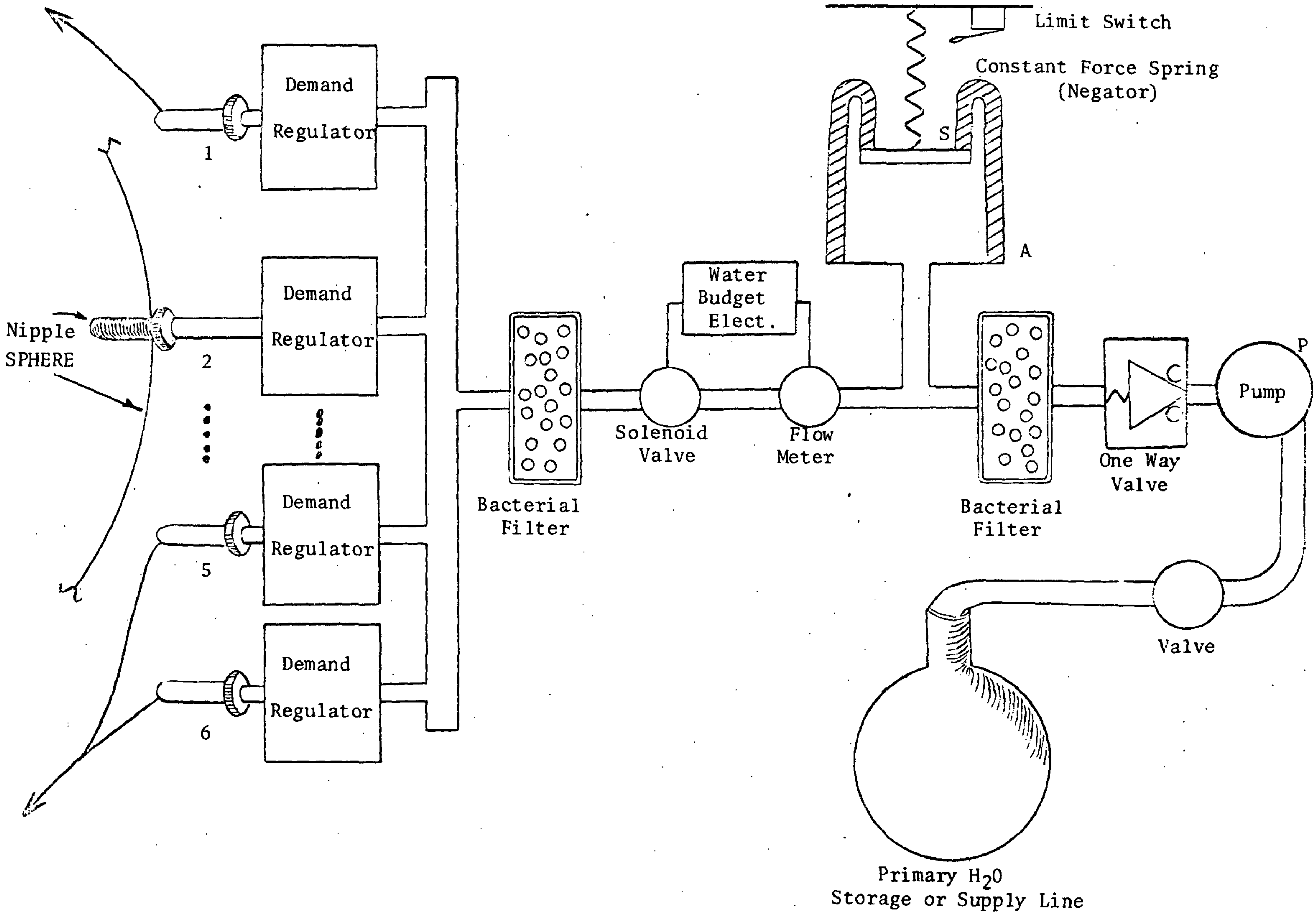


FIGURE 27

WATER DISPENSATION - BLOCK DIAGRAM

Water is pumped once a day from the primary water storage tank to Reservoir A by pump P, compressing the spring S; thus, both energy and one days supply of drinking water are simultaneously stored. The pump is turned off by a limit switch located in the reservoir. The reservoir is a cylindrical elastomeric container which collapses inward. The compressed spring maintains a pressure in the reservoir of 2 to 3 psi above ambient pressure. The demand regulator (see Fig 28) senses the suction applied by the primate on the mouth device and dispenses water to the primate at a flow rate depending on the primate's suction, but always within the flow rate specification established in the primate interface of Section II C. The amount of water consumed by the primate will be monitored by the flow meter and controlled to the specified limitations by the solenoid valve. A second bacterial filter is placed downstream to the solenoid valve to prevent back contamination by dissolved material, particulates, or microorganisms through the mouth device. The duration of the pump actuation each day will be used as a redundant measurement of water consumption.

The demand regulator (Fig 28) operation depends on suction at point A which causes a low pressure at B. Diaphragm C flexes upward, moving the differential bellows $D\text{-}D^1$. The differential bellows are linked to valve E lifting it off its seat, allowing water to enter the nipple.

C.2 SPECIFICATIONS

The water delivery system shall provide suitable water storage for a period of no less than six months and ten days and shall dispense programmed limited amounts of water to the primate on an *ad lib* basis.

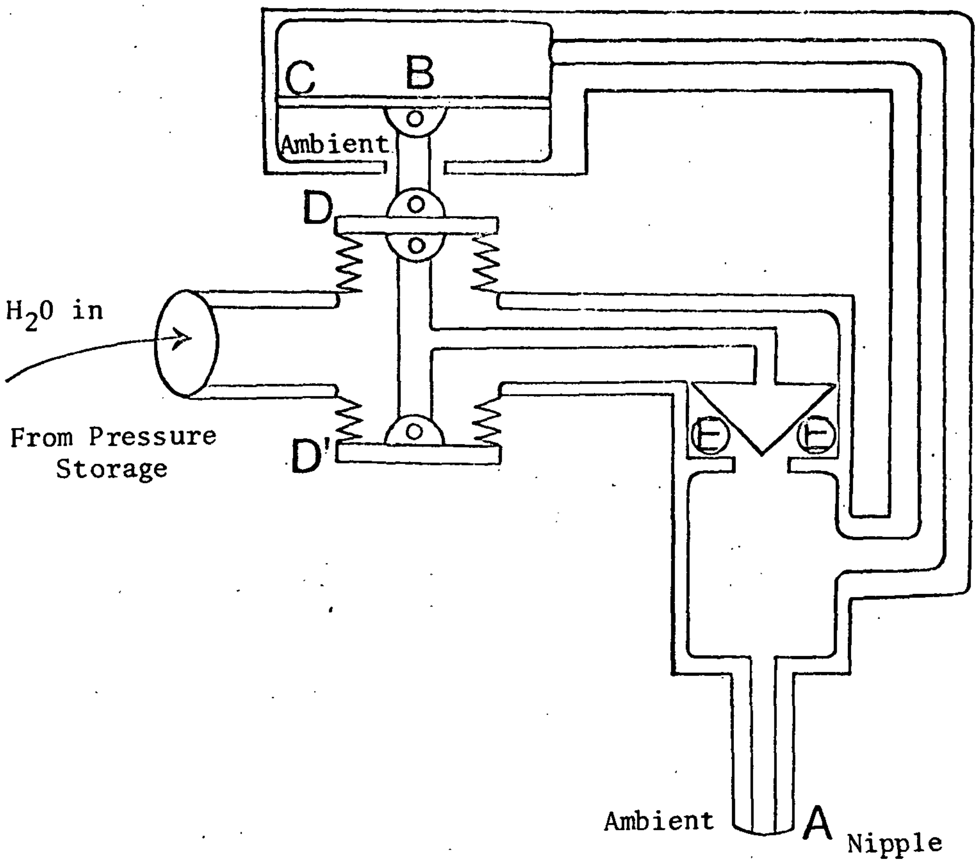


FIGURE 28

DEMAND REGULATOR

The requirements of the water system are as follows:

a) The water system shall be capable of storing 340 kg of water for a six month mission.

b) The water dispenser shall deliver a maximum of 200 cc ± 5 cc per hr or 200 cc ± 2 cc per three hr depending on direction of the behavioral electronics.

c) The water flow rate shall vary from 0.2 cc/sec to 0.7 cc/sec over a suction range from 22 torrs to 40 torrs.

d) The water system shall be capable of withstanding a suction of 150 torrs and abusive forces of up to 30 kg. at any point of the mouth devices and applied in any direction.

e) The water supply and dispensing system components shall be manufactured from stainless steel to prevent corrosion.

f) The entire drinking water system shall be asceptically handled throughout its manufacture, assembly, test, and delivery.

g) The water shall be delivered to the animal at a temperature of 55°F to 80°F.

h) The waterer shall operate in 0 and 1 g gravitational environments.

i) The water system shall provide a signal representing delivery of water within 10 msec of that event.

j) The water system shall indicate the amount of water consumed by the primate on an hourly basis to within ±2 cc.

k) The water dispenser shall be capable of filling the reservoir upon receipt of a ground command.

l) That portion of the mouth device which may come in contact with the primate's mouth shall be isolated from spacecraft ground by at least 80 MΩ.

m) The mouth device dimensions are as follows:

Inside diameter:	0.3 cm
Outside diamerer:	1 cm
Length protruding into capsule:	5 cm

n) The water system shall conform to the contaminant limitation requirements and particle specification as listed in Section II C.

III. EXPERIMENT INTERFACE

D. GAS MANAGEMENT SYSTEM

The gas management system must maintain the life cell's atmospheric environmental conditions within the specifications established in Section II D. The system's specific requirements may be summarized by the following controls:

(1) Atmosphere composition

(2) Capsule pressure

(3) Capsule temperature

(4) Trace gas contaminants

(5) Removal of CO_2

(6) Capsule relative humidity

(7) Particulate matter concentration

(8) Ventilation rate

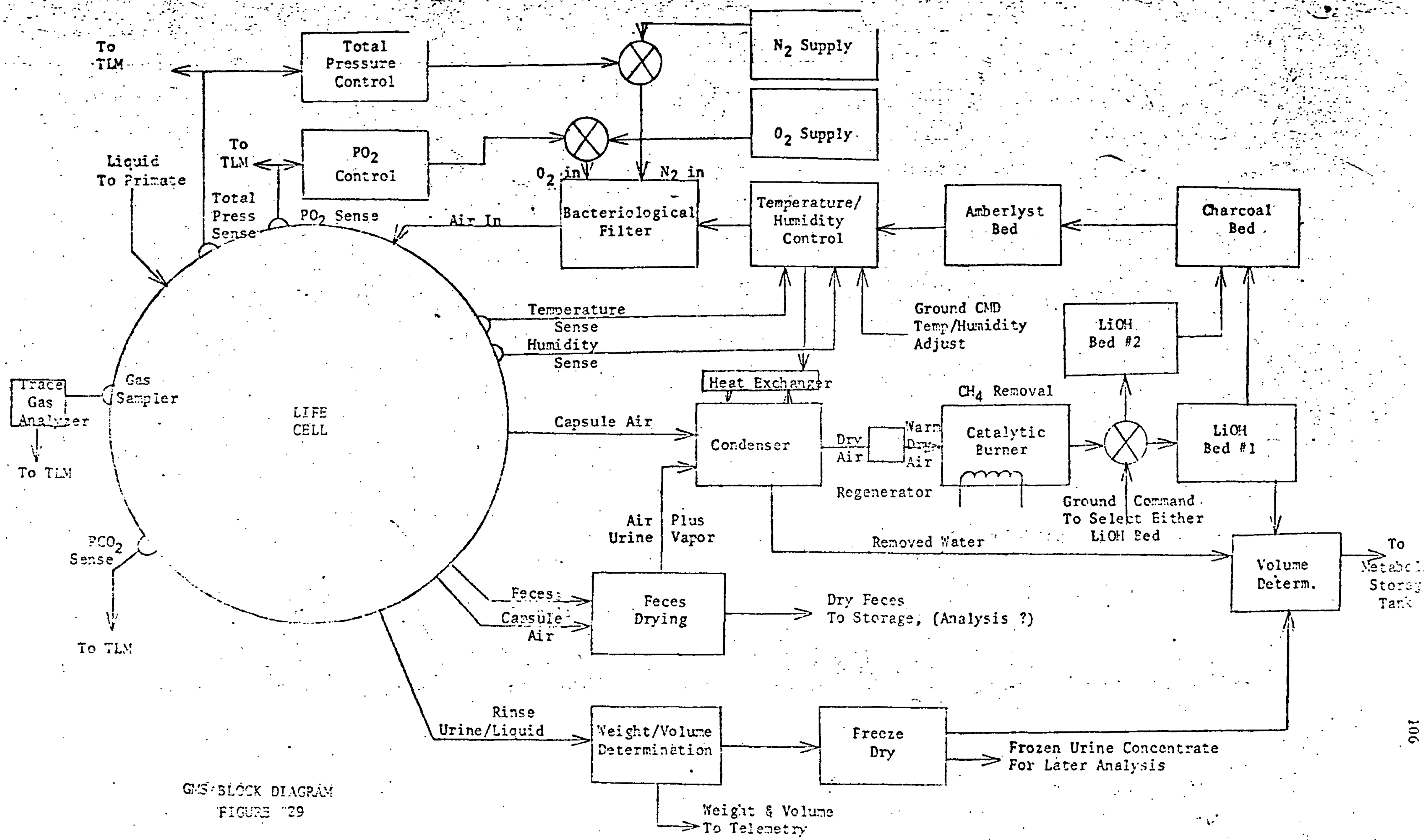
The system required to perform the specified environmental control functions is necessarily presented in its basic form (Fig 29). Additional refinement of the gas management system requires a firm definition of its supporting subsystems as a prerequisite. The basic system serves as a point of reference in the evolution of a total system.

D.1 CONCEPT

The purification aspects of the gas management system may be divided into two major categories: (1) carbon dioxide removal, conversion, and atmosphere regeneration and (2) trace contaminant detection and removal.

(1) Carbon Dioxide Removal and Atmosphere Regeneration

Of the various methods employed for carbon dioxide (CO_2) removal, solid absorption using alkali-metal alumino



GMS BLOCK DIAGRAM
FIGURE 29

silicates is the most highly developed to date and has been the system used in manned flights. Alternate methods for CO_2 removal include an electrodialysis system using the interaction between CO_2 and hydroxize ions to form carbonate ions. A subsequent reaction between carbonate and hydrogen ions is utilized to reform concentrated CO_2 that is routed to a storage tank. Solidification of CO_2, using cryogenics, was a third concept under consideration; however, the solid absorption method, using a bed of lithium hydroxide (LiOH) as an absorbent, has been selected because of increased reliability. The principal disadvantage of the LiOH absorbent technique is a significant weight penalty compared to other techniques for a six month mission. This may be overcome by incorporating a desorption of the bed by venting to a vacuum at elevated temperatures.

CO_2 absorption by alkali metal combinations such as LiOH is a dry air absorption process requiring water vapor removal prior to passage through the absorber. It is necessary to provide gas to the LiOH bed at a relatively high temperature as well as low humidity to prevent the formation of lithium hydrate ($LiOH\text{-}H_2O$) which in extensive quantities would terminate the removal of carbon dioxide.

Cold coolant, at a controlled temperature and flow rate enters the condenser from a heat exchanger to cool the gas stream below the dew point and thereby to remove water vapor and control the relative humidity in the life cell atmosphere. The condensed water is separated from the gas stream by a static wick-type water separator internal to the condenser. The condenser output (Fig 29) is a source of relatively dry gas. A regenerator (reheater) is placed between the condenser and absorption bed to provide the gas at an elevated temperature. An additional source of thermal energy is derived from the catalytic burner (used for trace gas removal, to be discussed later) located between the regenerator and the LiOH bed. Thus, both the temperature and humidity constraints placed upon the gas have been satisfied. To increase the reliability and useful duration of the CO_2 removal system, two LiOH beds are provided with switching capabilities provided by ground control.

(2) Trace Contaminant Detection and Removal

The absorbent bed, located downstream of the LiOH bed removes trace gases, and odors from the atmosphere. The absorbent bed is a composite structure containing activated charcoal, phosphoric acid, impregnated charcoal, and calcium carbonate. The activated charcoal removes most odorous compounds while the acid impregnated charcoal removes ammonia from the gas stream. The calcium carbonate removes most acidic trace gases; the LiOH bed is also useful in removing acidic trace gases. The absorbent beds are supplemented in controlling trace gases by a catalytic burner located in the flow stream to the LiOH bed. The catalytic burner is used to oxidize compounds such that the products are removed by other absorbent beds, primarily the LiOH bed. The products of oxidation from the catalytic burner are carried with the gas flow to the LiOH bed and retained. The multi-purpose lithium hydroxide bed, which is primarily for carbon dioxide removal, also serves as a post-absorbent bed for the catalytic burner, a main absorbent for acidic trace gases, and an effective disinfectant.

A summary of contaminant provisions is offered in Table 9.

TABLE 9

SUMMARY OF CONTAMINANT CONTROL

	Gas	Source	Removal Method
1.	Ammonia	Urine, Flatus, Perspiration	Amberlyst Bed
2.	Bromine	Perspiration	Sorbent Bed
3.	Iodine	Perspiration	Sorbent Bed
4.	Fluorine	Perspiration	Sorbent Bed
5.	Hippuric Acid	Urine	Calcium Carbonate, LiOH Beds
6.	Amines	Flatus	Catalytic Burner
7.	Hydrogen	Flatus	Catalytic Burner
8.	Hydrogen Sulfide	Flatus, Feces	Activated Charcoal
9.	Indole	Flatus, Feces	Activated Charcoal
10.	Mercaptan	Flatus	Activated Charcoal
11.	Methane	Flatus, Feces	Catalytic Burner and Pass Over Nickel
12.	Methyl Mercaptan	Feces	Activated Charcoal
13.	Paracresol	Feces	Activated Charcoal
14.	Nitrogen	Flatus, Perspiration	Not Necessary
15.	Skatole	Flatus, Feces	Sorbent Bed
16.	Carbon Monoxide	Spacecraft	Catalytic Burner
17.	Carbon Dioxide	Primate Exhaust	LiOH Bed

It is desirable to have a gas analyzer on board capable of detecting and qualitatively analyzing trace contaminants. The analyzer's output may be telemetered to ground stations for evaluation. In case an unsuitable atmosphere is present within the capsule, a purge valve, activated upon ground command, shall be utilized to flush the atmosphere of contamination. The subsequent development phase of the POCO program will necessarily involve testing with primates to determine the performance criteria required of a trace gas control system.

The environmental functions other than purification are summarized below:

a) Atmosphere Supply

The atmosphere supply subsystem stores the major constituents of the atmosphere, oxygen and nitrogen, and regulates this atmosphere within the life cell. Oxygen and nitrogen are added upon demand to maintain the atmospheric conditions specified in Section II D.

b) Oxygen Partial Pressure

Depending upon future development of instrumentation, either a mass spectrometer or ultraviolet-infrared gas analyzer will be used as a controlling element.

c) Pressure Control

Pressure control is accomplished, using a total pressure, aneroid-controlled, demand regulator. A relief valve shall be incorporated in the design to protect against overpressurization of the spacecraft in the event of malfunction of the demand regulator.

d) Humidity Control

Humidity control is accomplished by a condenser cooling the gas atmosphere to below the dew point and separating the gas and liquid phases. The output of the humidity control dictates the flow rate of heat exchanger coolant which, in turn, determines the extent of water removal from the gas stream.

e) Temperature Control

Temperature control will be accomplished by a main heat exchanger acting in conjunction with redundant sensing elements. Temperature control by the primate and ground command or astronauts within pre-established limitations is under consideration.

III. EXPERIMENT INTERFACE

E. BEHAVIORAL TASK DISPLAY

E.1 DESCRIPTION

The function of the behavioral task display is to present to the primate the behavioral tasks described in Section II E. The behavioral task display is comprised of six separately mounted behavioral display panels located on the sphere walls at both ends of three mutually perpendicular axes as shown in Fig 30. To present an orientation cueless environment to the subject, the behavioral electronics shall be programmed to present the tasks in a display panel to be chosen randomly for each behavioral task trial.

The mechanical configuration of one behavioral display panel is shown in Fig 1. Each panel is to consist of five circular switches equally spaced along the circumference of an imaginary 22.68 cm diameter circular segment of the chamber wall. The behavioral display panels are each contained within two of the 60 triangular segments comprising the surface of the sphere.

A pellet ejection hole is located at the center of the imaginary 22.68 cm diameter circle. At the successful completion of a behavioral task trial, a food pellet is dispensed through the ejection hole for primate consumption. The pellet ejection hole is surrounded by a reinforcement switch whose function is discussed in Section II E.

E.2 CONCEPT

The display panels are to be incorporated into the spherical chamber with non-displacement proximity switches smoothly integrated into the wall such that no protrusions or uneven surfaces exist.

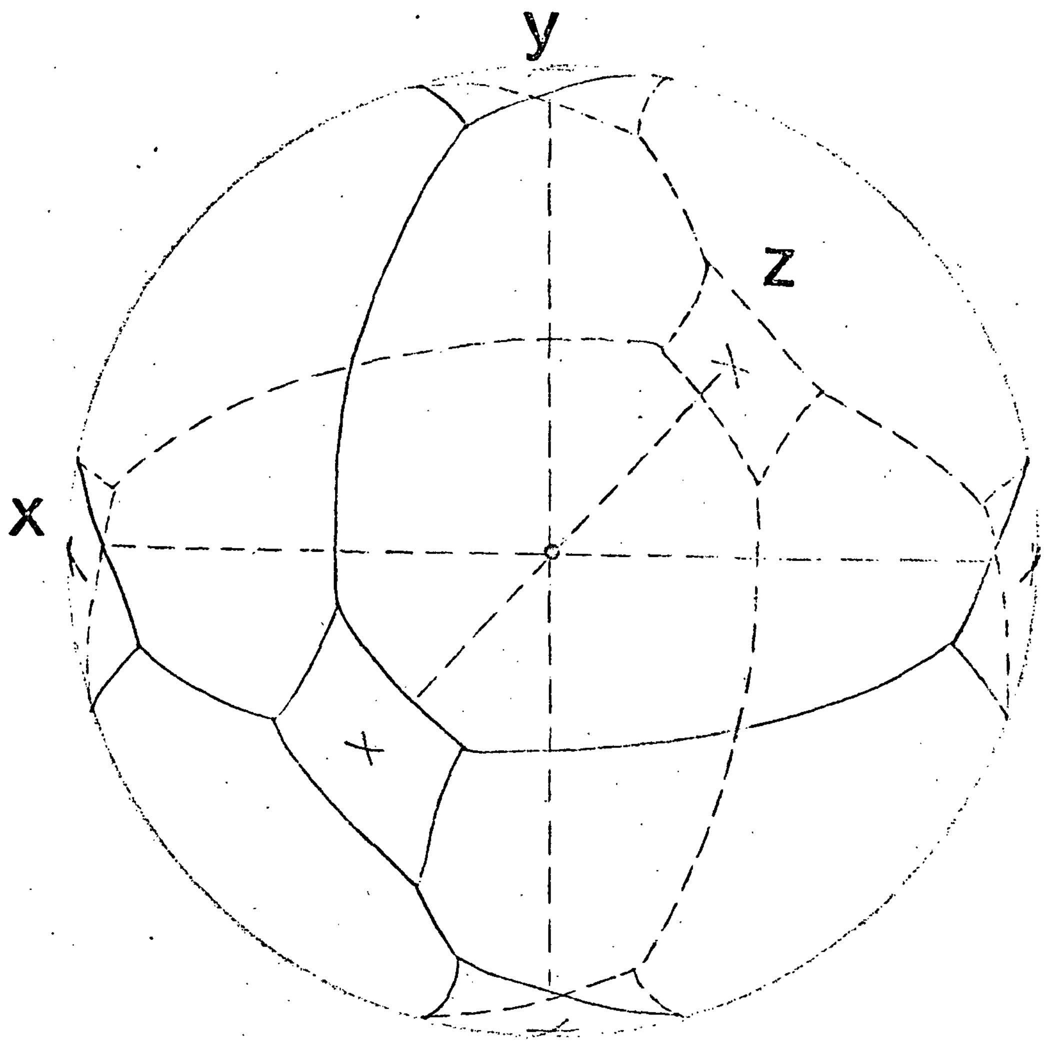


FIGURE 30

BEHAVIORAL DISPLAY PANEL

MOUNTING LOCATIONS

Each display switch is translucent, enabling the primate to see illuminated symbols located directly behind the switch.

Five distinguished symbols consisting of a circle, triangle, square, line and cross are to be displayed in a quasi-random orientation to further eliminate orientation cues. This will be accomplished by changing the orientation of the symbols with respect to each display switch. Each display switch will be capable of presenting each symbol in only one orientation; however, the symbol orientation shall be modified for each display switch to incorporate those orientations shown in Table 15.

The display symbols will be fabricated from electro-luminescent sheet. To prevent non-illuminated symbols from being visible to the primate, one of the following techniques will be employed:

a) Each symbol will be surrounded with non-energized electro-luminescent material. The symbols will be separated from the surrounding material by a non-conducting zone which may be screened into the pattern of the symbol.

b) The symbols will be covered by a polarizing material consisting of a circular polarizer and a linear polarizer similar to those used by Tektronix.

The symbols will be energized with a 400 Hz sine wave at the particualr voltage necessary to achieve the symbol intensity as specified in Section II E.

The display panels receive signals from the behavioral electronics defining task presentation to the primate. The display panels are to be of a modular construction with the display switches, pellet ejector, and reinforcement switch self-contained. The panels, as well as the switches and sources of luminosity are to be interchangeable. The display panels must be capable of withstanding abusive forces of up to 30 kg applied at any point and in any direction.

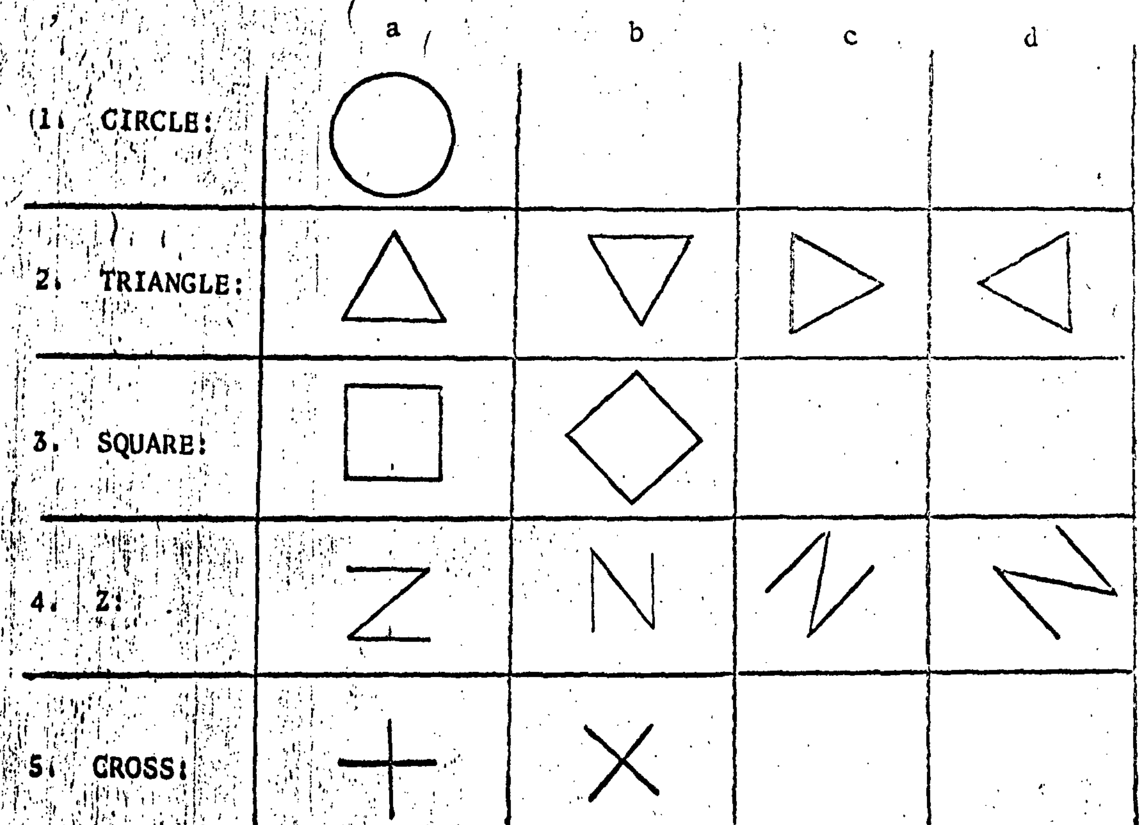


Table 10

SYMBOL PRESENTATION ARRAY

E.3 SPECIFICATIONS

3.1 SYMBOL DISPLAY

a) Symbol Size:

Symbol Size:	Square:	2.54 cm. on a side
	Triangle:	Isoceles; inscribed in square
	Circle:	2.54 cm. diameter
	Cross:	2.54 cm. per segment
	Z:	Two sides of square plus diagonal
Segment Width:		.16 cm.

b) Symbol Orientation Tolerance

The symbols for each display switch shall be presented in one of the orientations shown in Table 15 . Refer to Figure 27 for axis designations.

Square (a): Horizontal Side: Parallel to X axis ± 1°

Vertical Side: Parallel to Y axis ± 1°

Square (b): All four sides 45 ± 1° from X axis

Triangle (a & b): base parallel to X axis ± 1°. Imaginary line from apex to center of base parallel to Y axis ± 1°

Triangle (c & d): Base parallel to Y axis ± 1°. Imaginary line from apex to center of base parallel to X axis ± 1°.

Circle: N/A

Cross (a): Horizontal & vertical segments parallel to X axis and Y axis respectively

Cross (b): Segments 45 ± 1° from x axis.

Z (a): Parallel to X axis ± 1°

Z (b): Parallel to Y axis ± 1°

Z (c & d): 45° ± 1° from X axis

c) Symbol Location

Center of symbol to be located at center of switch ± 0.10 cm.

d) Symbol Intensity

ON: 5 millilamberts ± .05 millilamberts over the entire surface of the symbol

OFF: The symbols shall not be visible through the switches when viewed in an external environment of total darkness.

e) Focus:

Symbols are to be clearly defined in terms of definition and equality between segment intensities and symbol intensities

f) Symbol Depth:

There must be no apparent difference between the depth of any two symbols. The depth of the symbols beneath the transparent display switches is 0.317 cm ± .076 cm.

g) Illumination Delay:

At all occurrences during which adjacent symbols are to be presented simultaneously, the time increment between full illumination of any combination of symbols is to be no greater than 10 msecs.

3.2 SWITCHES (Non-Displacement Proximity)

a) Switch Size:

1. Display Switch: 5.08 cm ± .051 cm

2. Reinforcement Switch: 5.715 cm ± .051 cm diameter

b) Switch Actuation

1. Display Switch: Less than .25 cm^2 skin surface area required

2. Reinforcement Switch: Less than .25 cm^2 skin surface area required

c) Switch Actuation Time Constant:

The propagation time between switch closure and corresponding task occurrence shall be less than 1 msec.

III. EXPERIMENT INTERFACE

F. LOCAL TELEMETRY

F.1 DESCRIPTION

The local telemetry system, a completely implantable system, shall be capable of continuously transmitting the physiological data requirements, as specified in Table 9 of Section II F, to the capsule data acquisition system for the duration of the mission. The telemetry system is divided into two separate independent biotelemeters for which the area of implantation and data transmission requirements are shown in Fig 31.

Each biotelemeter consists of differential amplifiers, multiplexer, and a transmitter, as shown for an eight channel unit in block diagram form in Fig 32.

AMPLIFIERS

Each subsystem is comprised of three Fairchild μA 735 integrated circuit operational amplifiers per data channel, two of which are connected as direct input voltage follower stages (unity gain). The output of each pair of amplifiers represents the differential physiological signal and is capacitively coupled to the third operational amplifier which is configured as a differential gain stage. The AC coupling between stages sets the lower 3 dB cutoff frequency to 0.5 Hz and is required to block the often large DC offset potential on the monitoring electrodes and to minimize the 1/f noise contribution between DC and 0.5 Hz. This design provides three important performance characteristics. First, the voltage follower stage has

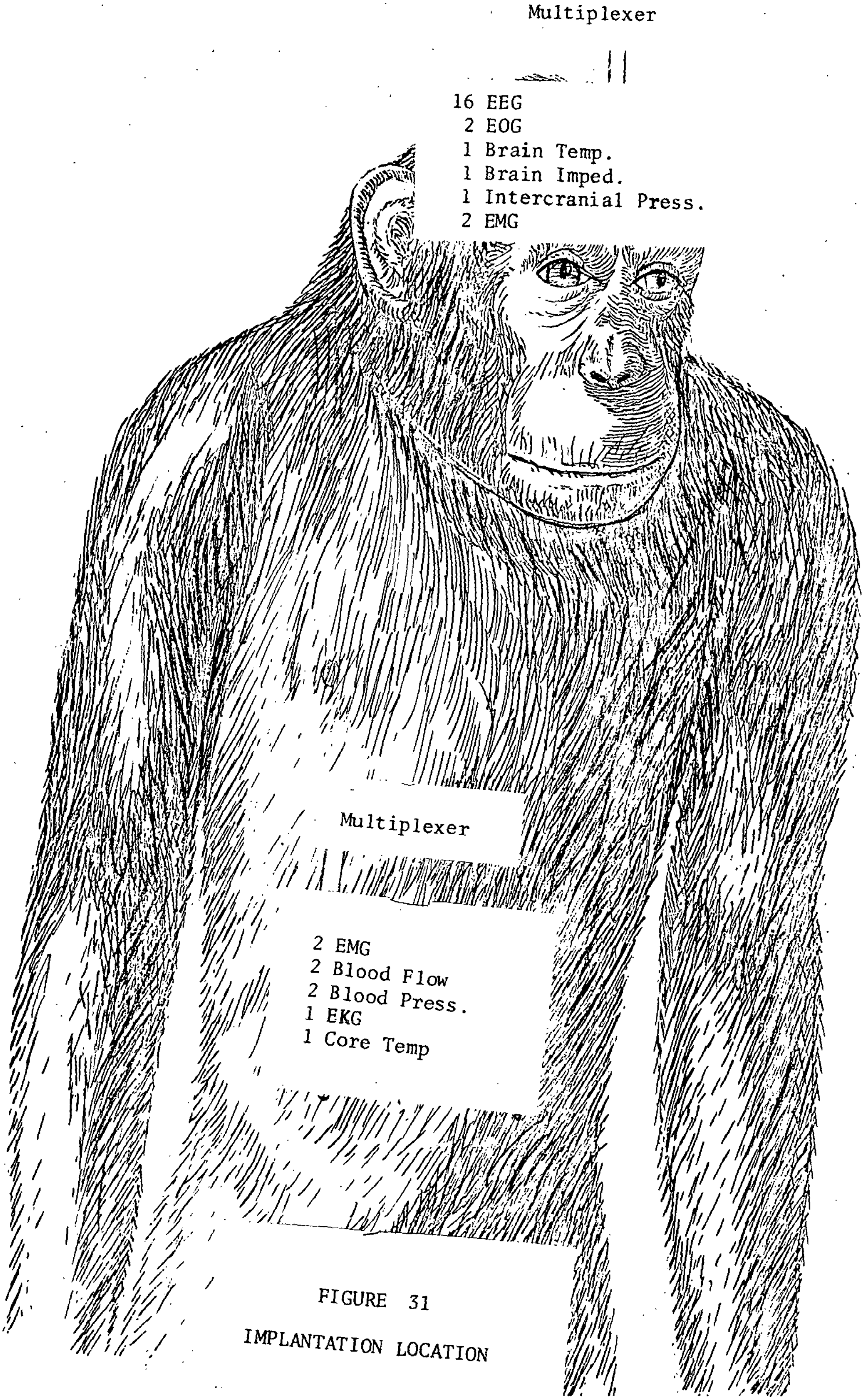


FIGURE 31

IMPLANTATION LOCATION

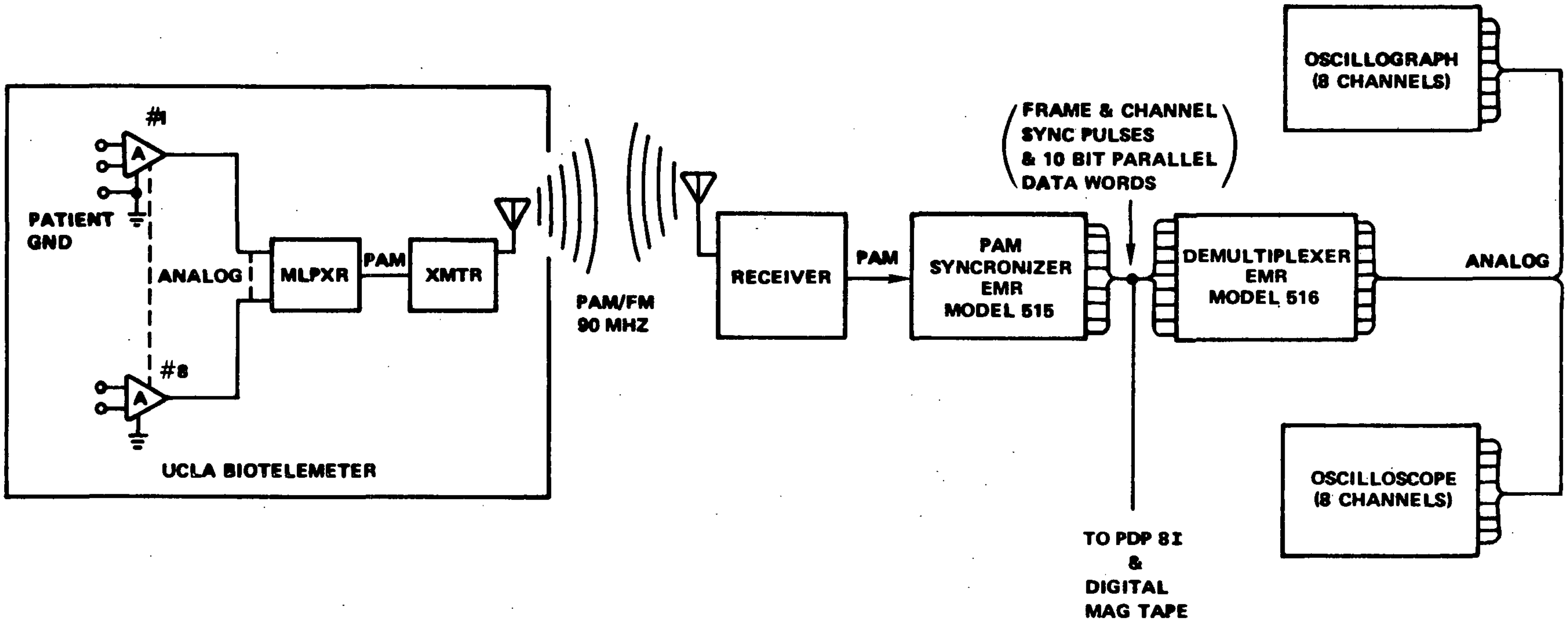


Figure 32. System Block Diagram

extremely high input impedance (>50 MΩ). Second, the low, reasonably matched source impedances of the voltage follower results in increased rejection of signals common to both inputs. Third, through the use of integrated circuits, the number of components is minimized, and optimal efficiency may be realized utilizing hybrid packaging techniques. The amplifier circuit design is shown in Fig 33.

MULTIPLEXER

Time-division multiplexing was selected in preference to frequency-division multiplexing after analysis of the size and power requirements of each. Moreover, after considering the trade-off between signal-to-noise ratio and circuit complexity, PAM was selected over PCM and other time-division methods. The resultant multiplexer design, shown in Fig 34 for an eight channel system is noteworthy for its simplicity and for its extremely low power consumption (<7 μA @ ±2.7 VDC). The eight channel multiplexer is comprised of two RCA CD4016 four channel analog switch integrated circuits, one RCA CD4001D, an integrated circuit device containing four dual input digital gates, two of which are interconnected as a free running multivibrator to provide the timing signal, and one RCA CD4017 decade counter integrated circuit. The multivibrator timing is set to provide a 2.56 kHz square wave to the decade counter which in response generates an output level sequentially from each of the ten gates. Two of the decade counter outputs are connected to resistive voltage dividers which generate appropriate voltage levels to form two synchronization pulses. The remaining decade counter outputs are used to control the eight analog gates. The

PERFORMANCE CHARACTERISTICS:

GAIN : 1000 ± 25
FREQ RESP : $0.5 H_z - 100 H_z$

INPUT IMPEDANCE : $>$50 MΩ
CMMR : $>$90 dB
NOISE : $<2\mu V$(P–P)
REFERRED TO INPUT
($Z_S = 50K$)
PWR : $<60\mu A$ @ ± 2.7V

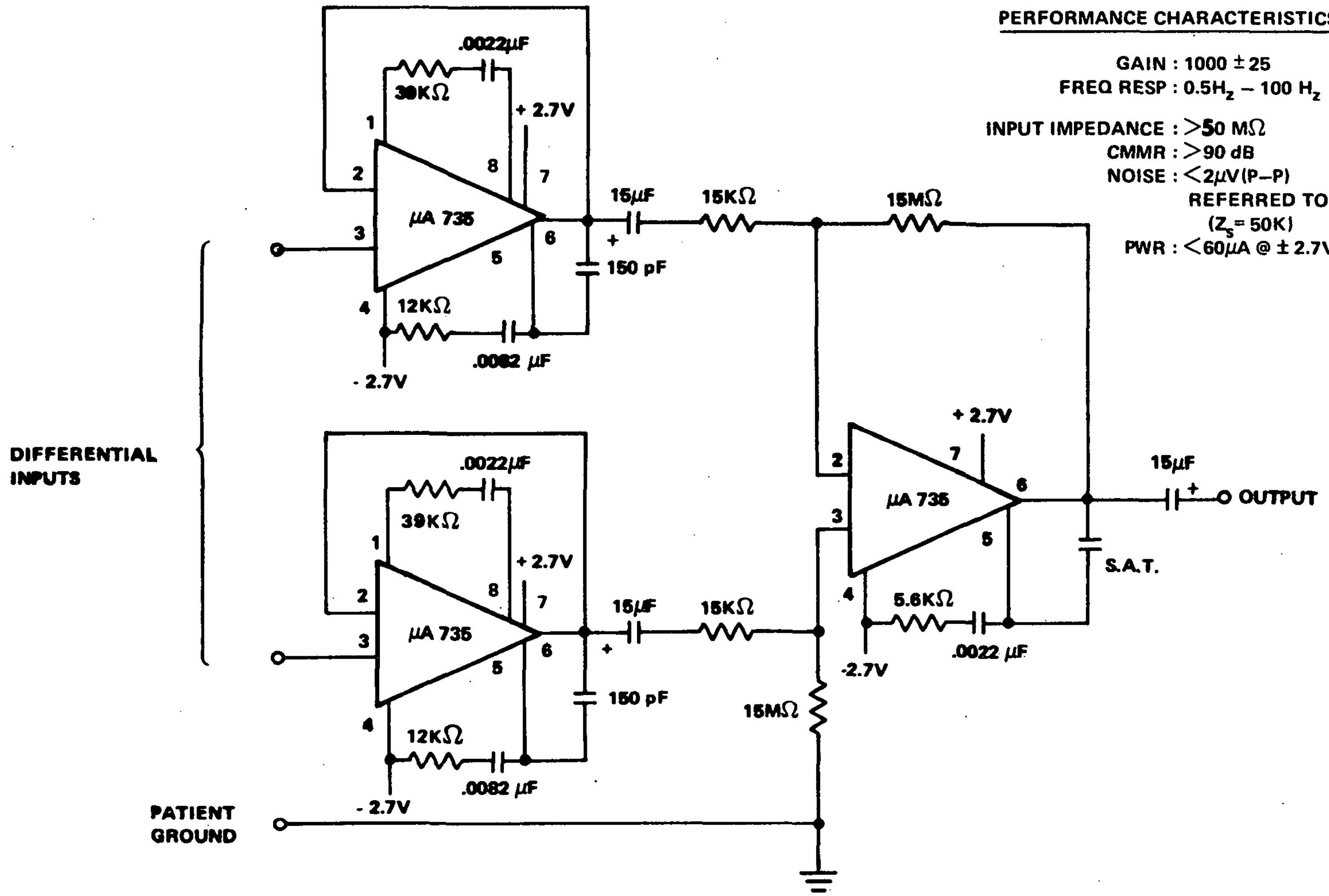


Figure 33. EEG Amplifier

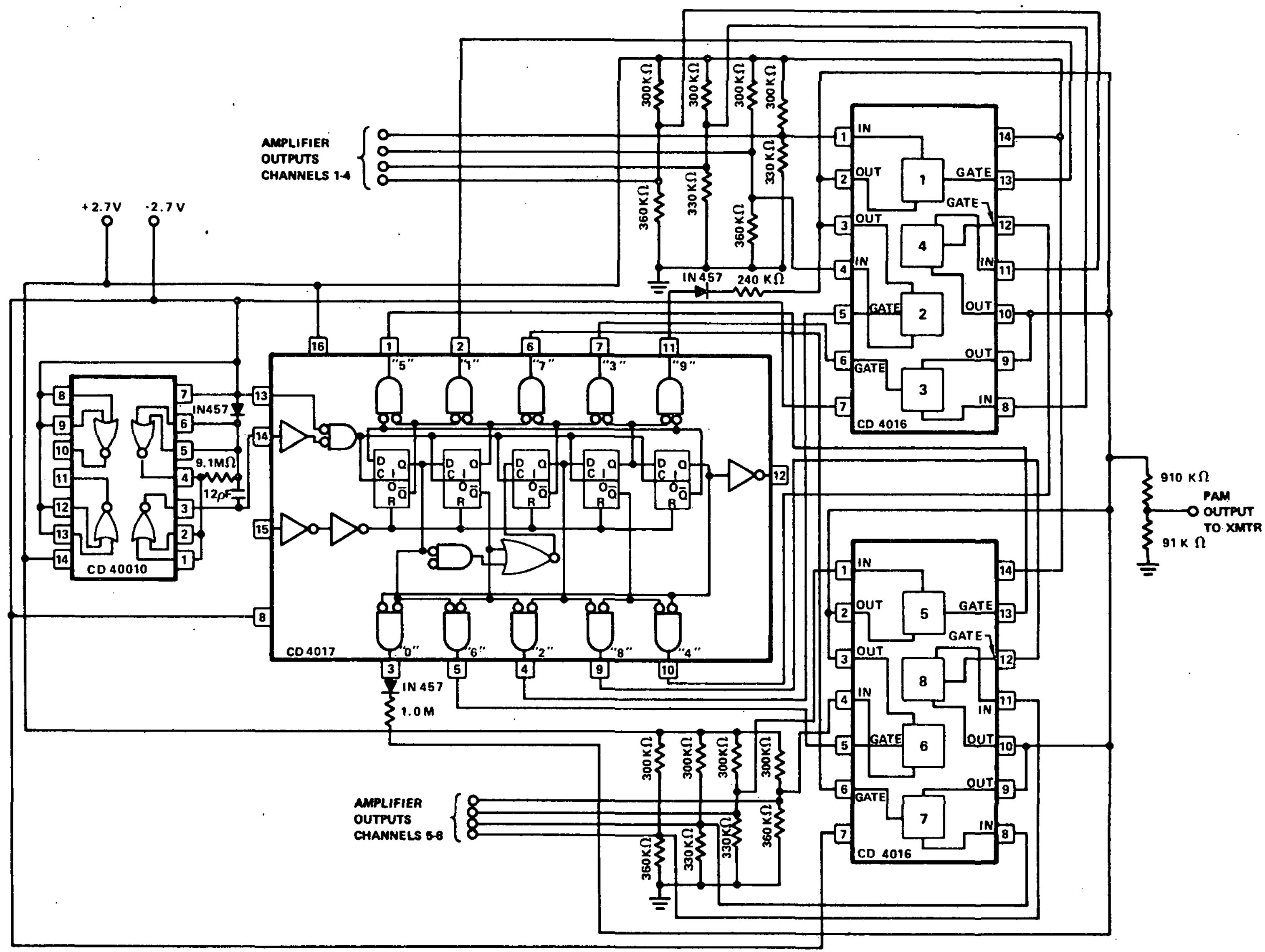


Figure 34. PAM Multiplexer Schematic

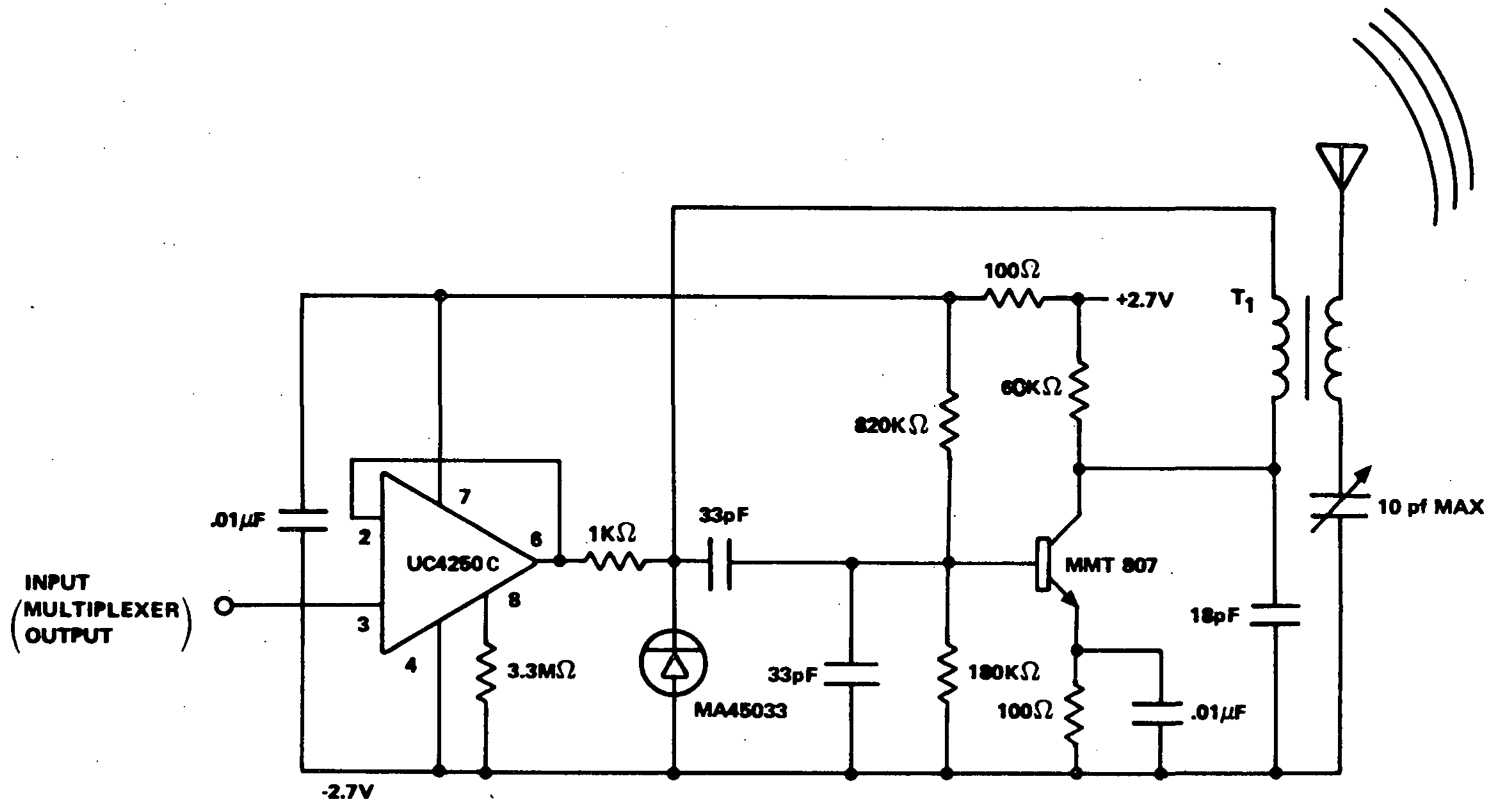
sync pulses and sampled analog levels are connected in common (summed) to form a single PAM pulse train. Each gate is sampled 256 times per sec. The voltage divider networks at the input of the analog switches are designed to deliberately offset the amplifier output signals such that they always remain positive. This is done to avoid the dead zone characteristics of the bipolar analog switches. In addition, the DC offset between adjacent channels are deliberately set to differ by 50 mV to reduce the possibility of losing channel synchronization.

TRANSMITTER

A 90 MHz variation of the Vackar oscillator is shown in Fig 35. The resultant design has excellent stability for a single transistor oscillator over a wide range of both temperature and supply voltage. The oscillator frequency is modulated by replacing one of the oscillator's tank circuit capacitors with a varactor diode fed by a voltage follower integrated circuit amplifier. The transmitter is operated at 330 μA @ ±2.7 VDC and, for the near field application, generates adequate RF power.

PACKAGING DESIGN

An eight channel implantable biotelemeter has been fabricated using thick film hybrid techniques. The assembly consists of eight hybrid thick film amplifiers fabricated on individual ceramic substrates. The substrate is processed using various conductive and resistive inks to form a passive network of resistors and conductors to which active devices are attached with conductor epoxy. The



NOTE: T_1 = 7 TURNS PRIMARY, 3 TURNS SECONDARY WOUND ON AMIDON T 30-12 CORE

Figure 35 Transmitter Schematic

units are mounted on a circular ceramic mother board containing the multiplexer circuitry. Internal interconnections are made using conventional fired thick film conductor patterns and thermocompression wirebonding techniques. Future assemblies will use beam lead techniques to maximize yield and minimize cost. After functional testing, the units will be sealed with glass. The amplifiers and multiplexer were combined on a circular alumina substrate, 7.35 cm in diameter by 0.97 cm thick (Fig 36).

F.2 SPECIFICATIONS

BIOTELEMETRY AMPLIFIER (Fig 33)

1.	Gain:	1000±25 (Selectable)
2.	Frequency Response:	0.5 Hz to 100 Hz (3 dB pt.)
3.	Noise:	<2 μV P-P referred to input (Z_S = 50 K)
4.	Common Mode Rejection Ratio:	>90 dB
5.	Input Impedance:	>50 MΩ
6.	Power Consumption:	<60 μAC±2.7 VDC
7.	Maximum Voltage Swing:	±2.5 VDC
8.	Supply Voltage:	±2.7 VDC

FM TRANSMITTER (Fig 35)

1.	Frequency of Oscillation:	90 MHz
2.	Power Consumption:	330 μAC @ ±2.7 VDC
3.	Noise:	<1 μV rms (Z_S = 100 K)
4.	Size (printed circuit board):	5.08 cm x 2.16 cm x .635 cm

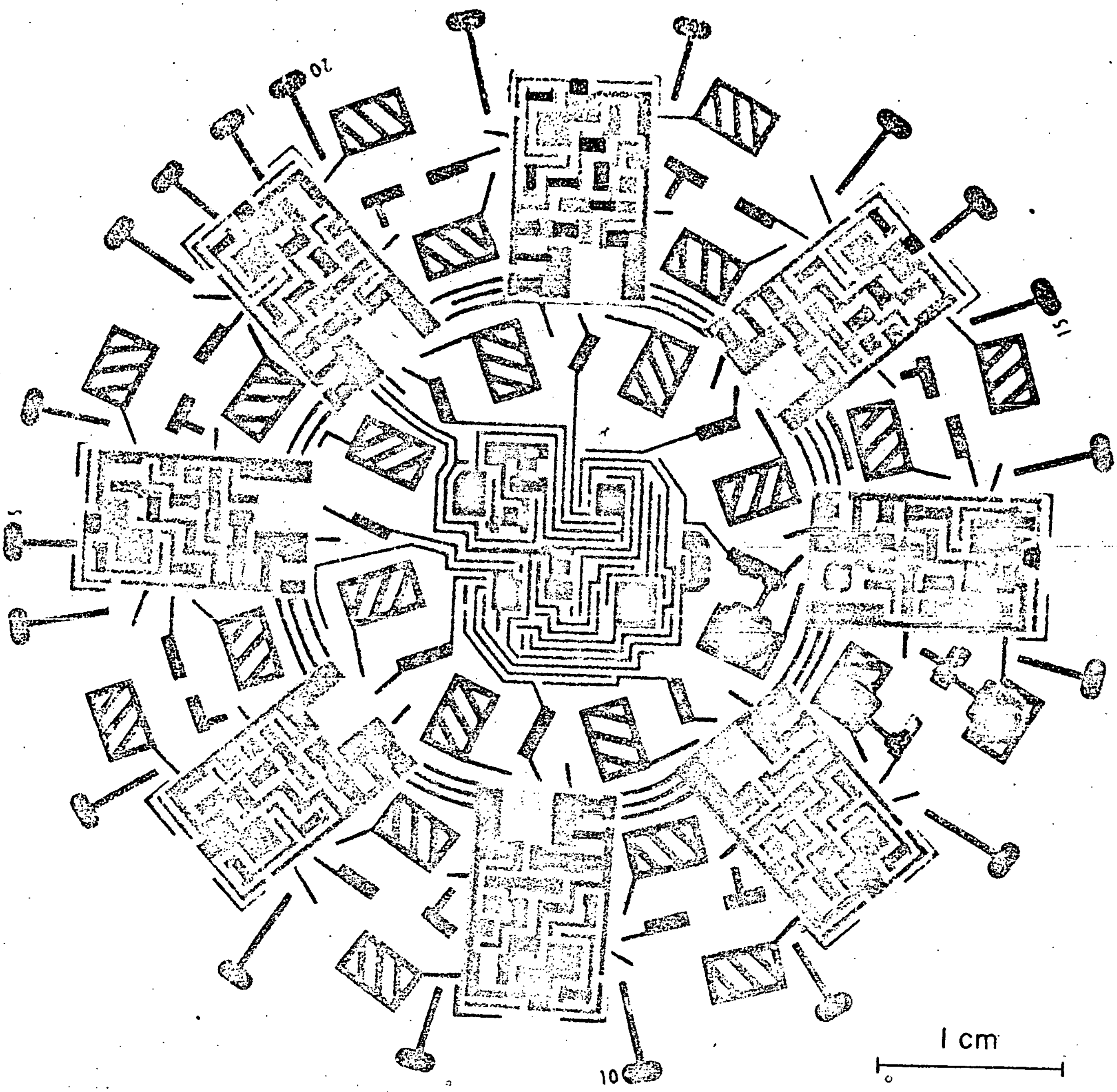


FIGURE 36

THICK FILM HYBRID PACKAGE
EIGHT AMPLIFIERS PLUS MULTIPLEXER

5.	Weight:	5 grams
6.	Deviation Sensitivity:	1 kHz/mV P-P
7.	Frequency Response:	DC to 10 kHz

LOCAL TELEMETRY RECEIVER SPECIFICATIONS

The specifications of the local telemetry on board receiver are presented below:

1.	Frequency Range	To be determined
2.	Frequency Change within Band	To be determined
3.	Antenna Impedance	50 Ω nominal
4.	VSWR	1.5:1 maximum
5.	Tuning Accuracy	±0.005%
6.	Local Oscillator Stability	±0.005%
7.	Noise Figure	To be determined
8.	RF Bandwidth	To be determined
9.	Image Rejection	Per MIL-I-26600
10.	Spurious Response Rejection	Per MIL-I-26600
11.	Maximum RF Input	2 V RMS
12.	Audio Frequency Response	To be determined
13.	Audio Output Sensitivity	0.01 V peak per kHz
14.	Sensitivity	20 dB quieting at 5 μV input with 200 kHz bandwidth
15.	Signal Level Indication	0 to 4 VDC into 10 KΩ load

F.3 POWER CONSIDERATIONS

	(VDC) voltage	(μ amps) current	(μ watts) power
Amplifier	±2.7	54	292
Multiplexer	±2.7	7	38
Transmitter	±2.7	330	1782

For an eight channel biotelemeter, the current drain would be

$$8\ (I_{amp}) + I_{mult} + I_{xmtr} = 8(54) + 7 + 330 = 769\ \mu amp$$

The 180 day mission contains 4320 hr, therefore, the power required during the mission is

$$(4320\ hr)\ (769\ \mu A) = 3.32\ amp\ hr$$

III. EXPERIMENT INTERFACE

G. WASTE REMOVAL SYSTEM

The task of waste removal presents a major problem in providing a life support system for the primate under the constraints of the experiment. The task becomes increasingly difficult when an orientation cueless environment is imposed. The waste removal system must be capable of operating in both a 0-g and 1-g environment, must not offer an orientation cue to the primate, must be effective to a degree compatible with the atmospheric environmental conditions as specified in Section II D, and must not compromise the experimental objectives. A number of alternate concepts are being studied to determine their feasibility. Presented in this section is a description of those concepts under consideration. It should be pointed out that a combination of two or more concepts may be utilized to obtain maximum reliability and effectiveness.

G.1 CONCEPTS

CONCEPT NO. 1 (Backpack)

A method to transfer feces and urine directly from the primate to a waste storage container is proposed. This method would be nearly 100% effective in addition to greatly reducing the complexity of the waste collection system by eliminating the necessity to extract the waste matter from the interior and walls of the spherical housing chamber, while leaving the primate in an unrestrained environment.

The concept consists of a receptacle shaped to conform with the anatomy of the urogenital region positioned over the anus and penis (See Fig 37). Upon primate excretion, a sensing device automatically activates a vacuum unit which directs the waste from the urogenital

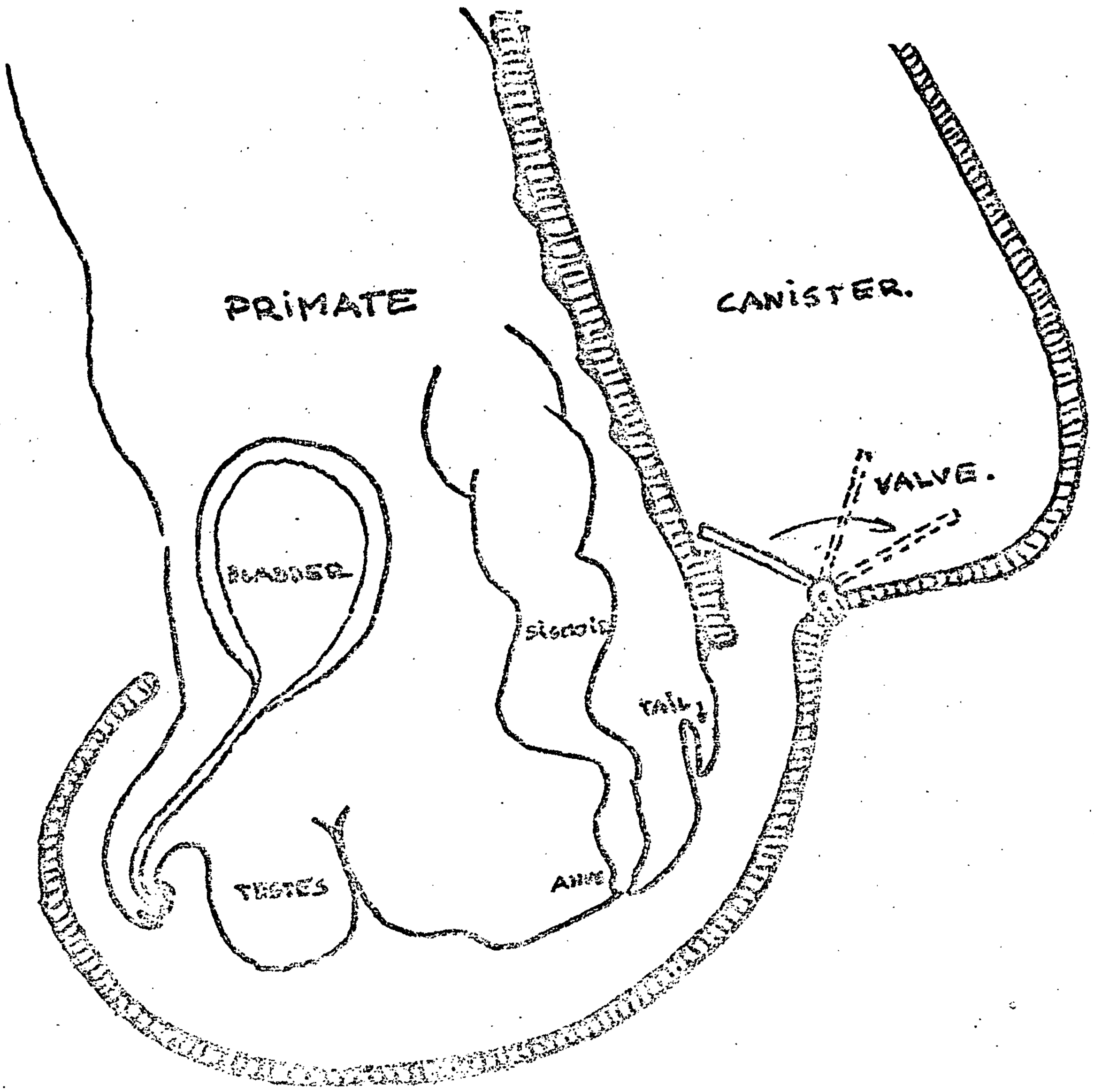


FIGURE 37

WASTE RECEPTACLE

region to a waste storage canister positioned on the primate's back.

EXCRETION SENSING DEVICE

a) Electrodes may be attached to the particular muscles that control urination and defecation (See Fig 38). The muscle activity will be amplified by a conventionally designed EMG amplifier whose output is applied to a "go/no go" level sensing circuit. Only muscle activity greater than a specified preset amplitude will be sufficient to transfer the level sensing circuit to its "go" state whereby it turns on a transmitter. Signals are transmitted to a receiver located within the storage canister (See Fig 39) to turn on a vacuum cleaning type device causing transfer of the effluent into the storage canister.

b) External sensing devices placed within the conduit but externally to the primate such as a thermistor or force transducer may be used in place of implantable EMG electrodes to detect defecation and activate the vacuum unit.

The storage canister will contain a number of porous bags, allowing only gaseous states to permeate. The system is limited to that amount of waste sufficient to cover the entire surface area of all of the porous receptacles.

The vacuum unit will be programmed to remain on for a specified duration after the last defecation has been sensed. Redundant sensing devices shall be used to ensure reliable operation of the system.

The storage container and associated battery pack will be replaced periodically (perhaps every ten days) whereupon the urine will be separated from the feces and analyzed.

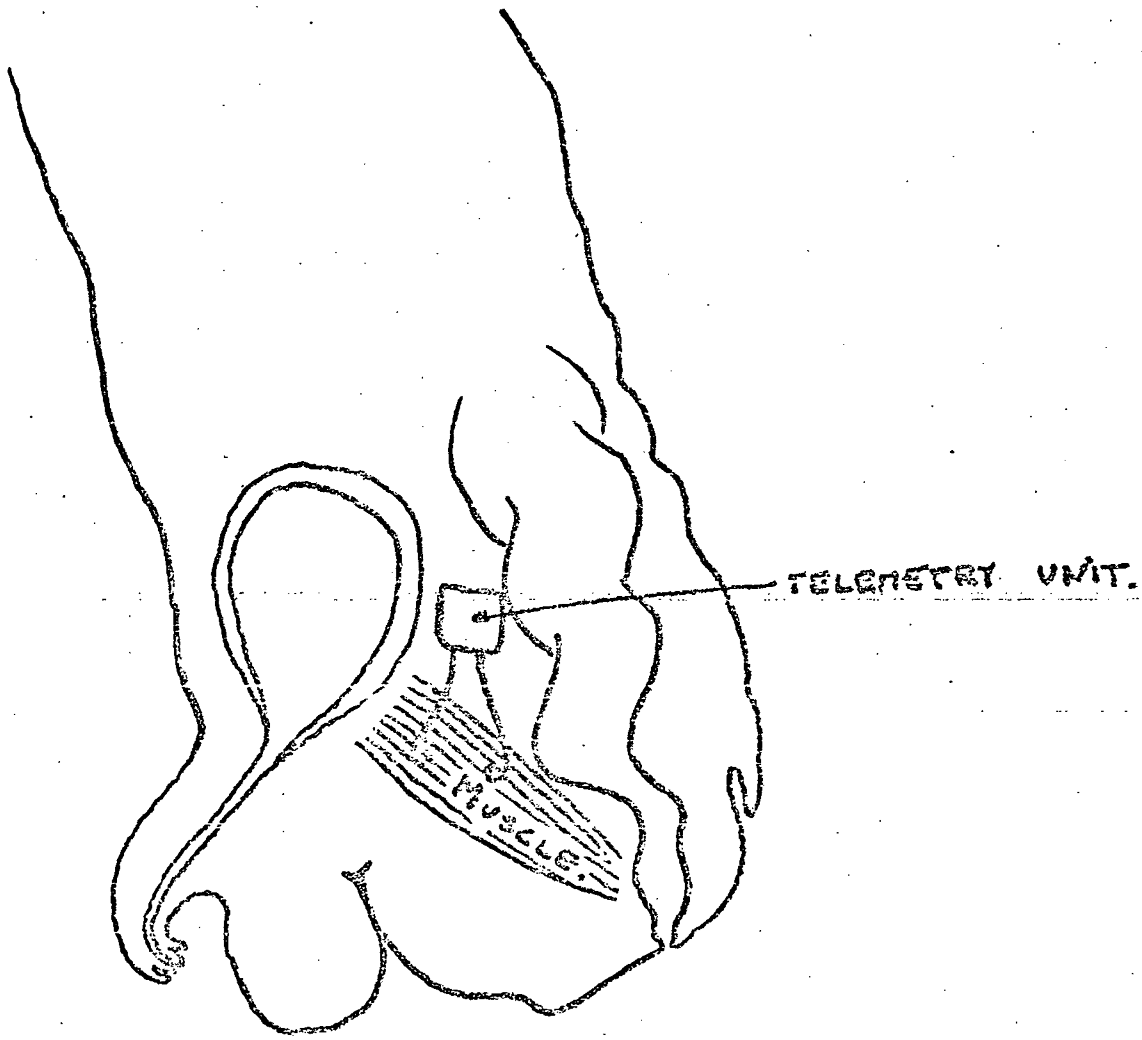


FIGURE 38

EXCRETION SENSING ELECTRODES

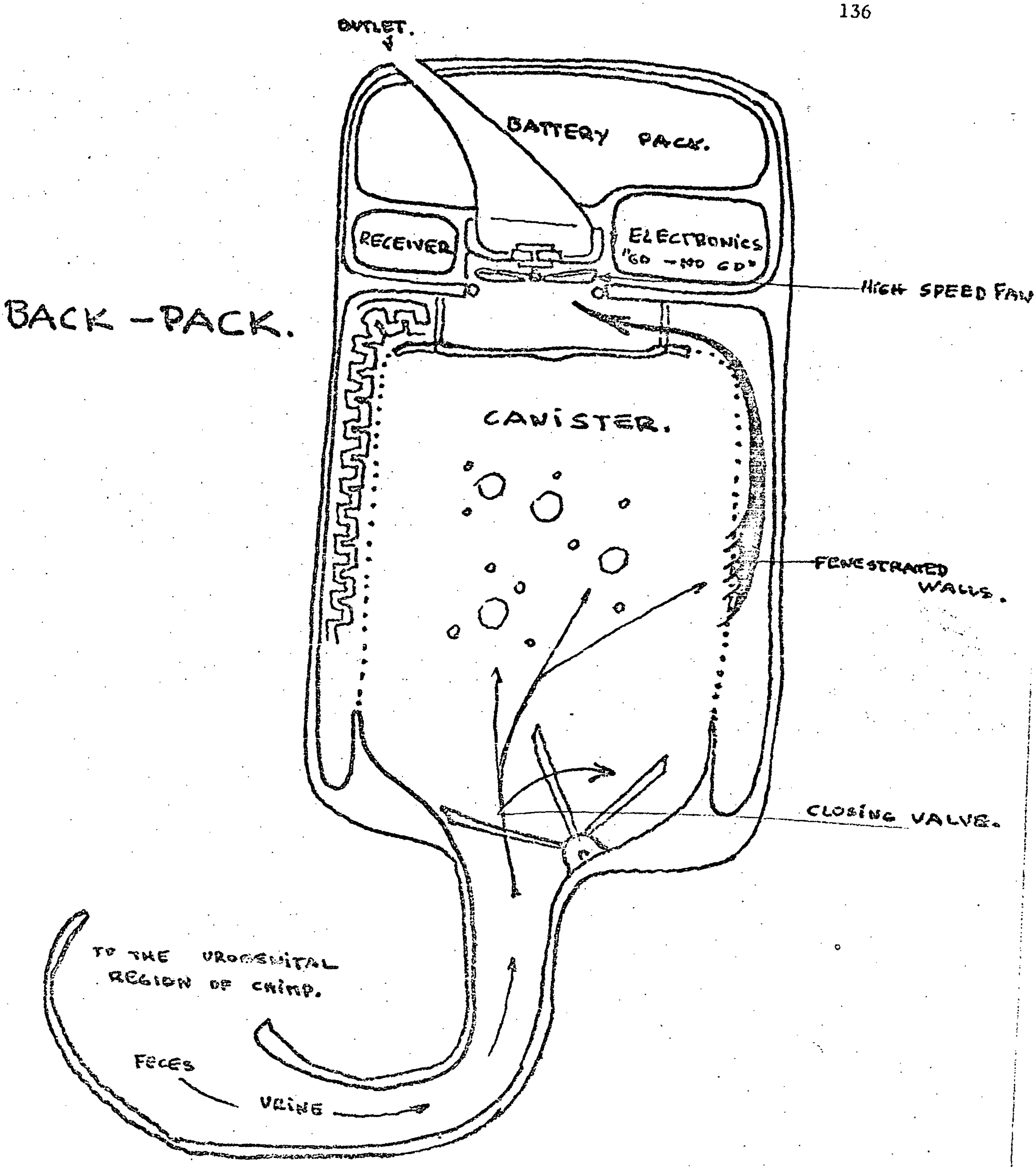


FIGURE 39

BACKPACK

In order to prevent the primate from damaging or otherwise tampering with the waste collection unit, a harness has been designed to isolate the system from primate activity. Fig 40 and 41 show a front and back view of the waste collection system harness.

CONCEPT NO. 2 (Twin Sphere)

If the concept in which waste is removed and collected directly from the primate, prior to entrance in the life cell, does not prove satisfactory, a method to remove the waste from the interior and walls of the spherical life cell must be incorporated.

A waste collection system having the effectiveness needed to maintain a habitable environment for the primate may require cleaning methods that compromise the animal's health. It is, therefore, deemed necessary to spatially separate the animal from the cleaning environment. For this purpose, it is proposed to have two identical life cells situated immediately adjacent to each other. When one sphere is scheduled to be cleaned, part of the sphere wall temporarily moves, providing the animal access to the other sphere. The primate would be trained to enter the other sphere in response to an orientation cue. When primate transfer is verified, the wall section is automatically transferred to its original position, and the cleaning process is initiated.

The particular method of removing waste from the walls of the uninhabited life cell has not been selected. A brief description of the methods now under consideration is presented below:

FRONT.

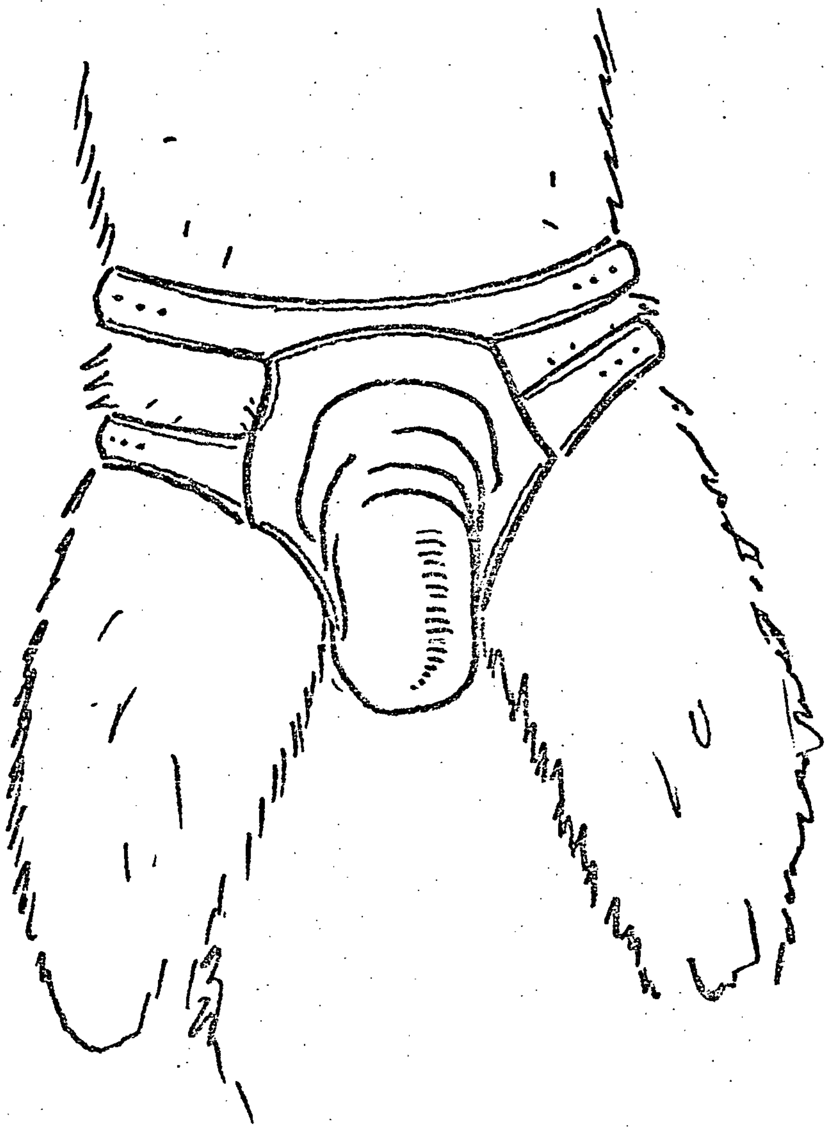


FIGURE 40

HARNESS

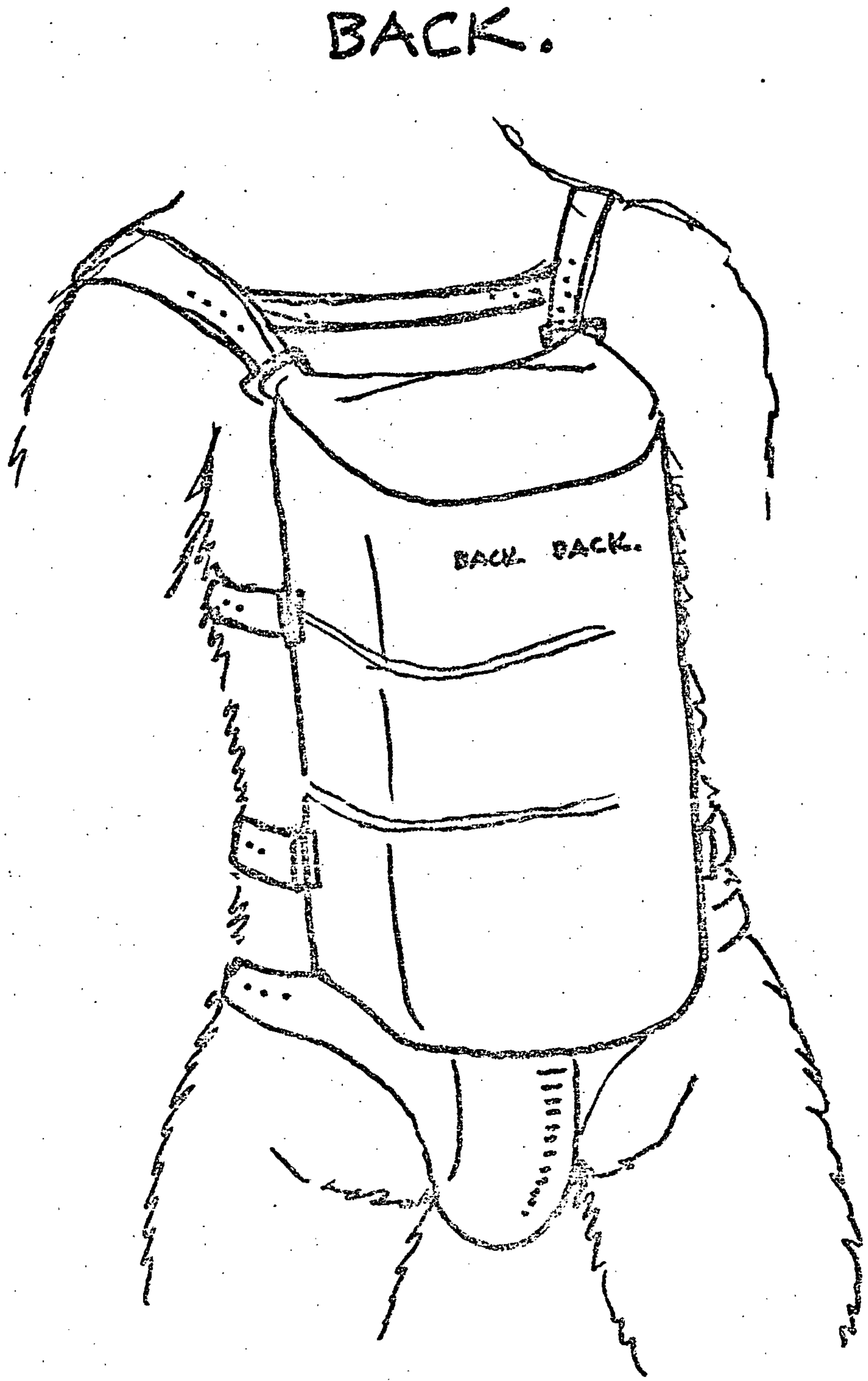


FIGURE 41

HARNESS

a) Water Jet: When the cleaning process is initiated, swivel type water jets are positioned internally to the spherical cell as shown in Fig 42. After the water jets are in place, a solution of water and an ingestible detergent, such as Dioctyl, are sprayed out of the swivel nozzels tangentially along the inner surface of the sphere wall to remove any waste material adhering to the wall. A continuous flow of filtered air will serve to scavenge the atmosphere by forced convection. This procedure would be repeated as required. Mechanical drawings of a prototype developed and tested in our laboratory are shown in Fig 43 through 46.

The spherical enclosure or life cell shall be composed of sixty identical curved triangular segments based upon the pattern of triangles comprising a non-regular polygon, the solid pentakis dodecahedron (detailed description of segments given on page 167 of this document). It consists of 32 vertices of which 24 will be used for air flow into and out of the capsule. There will be six subsystems comprised of four vertices, each separately manifolded with independent air movers. At any one time, five of these subsystems will serve as exhaust ports while one will act as the gas entrance port, having only one air mover energized at a time. In this manner, as the airborne waste matter moves toward the exhaust ports and partially blocks the flow of air, the total air flow will not be impeded since there are five exhaust ports available for air exit. Behind each

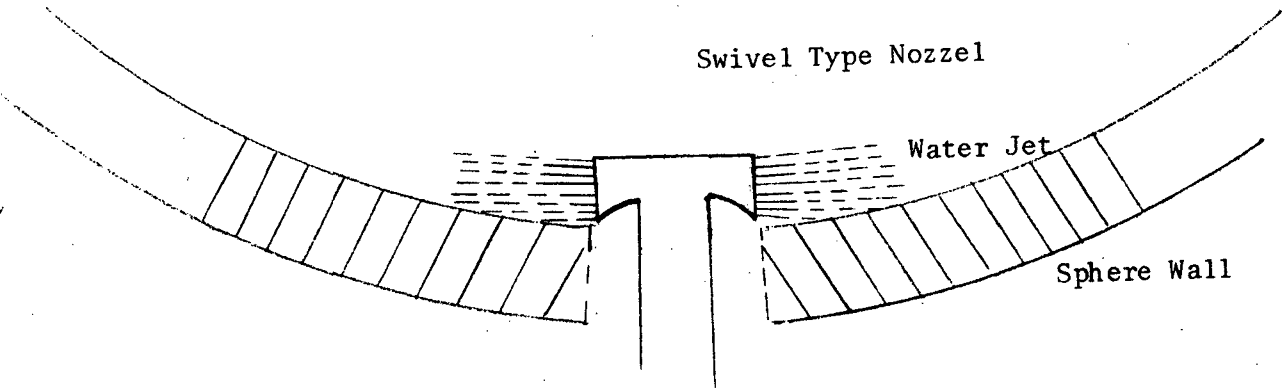
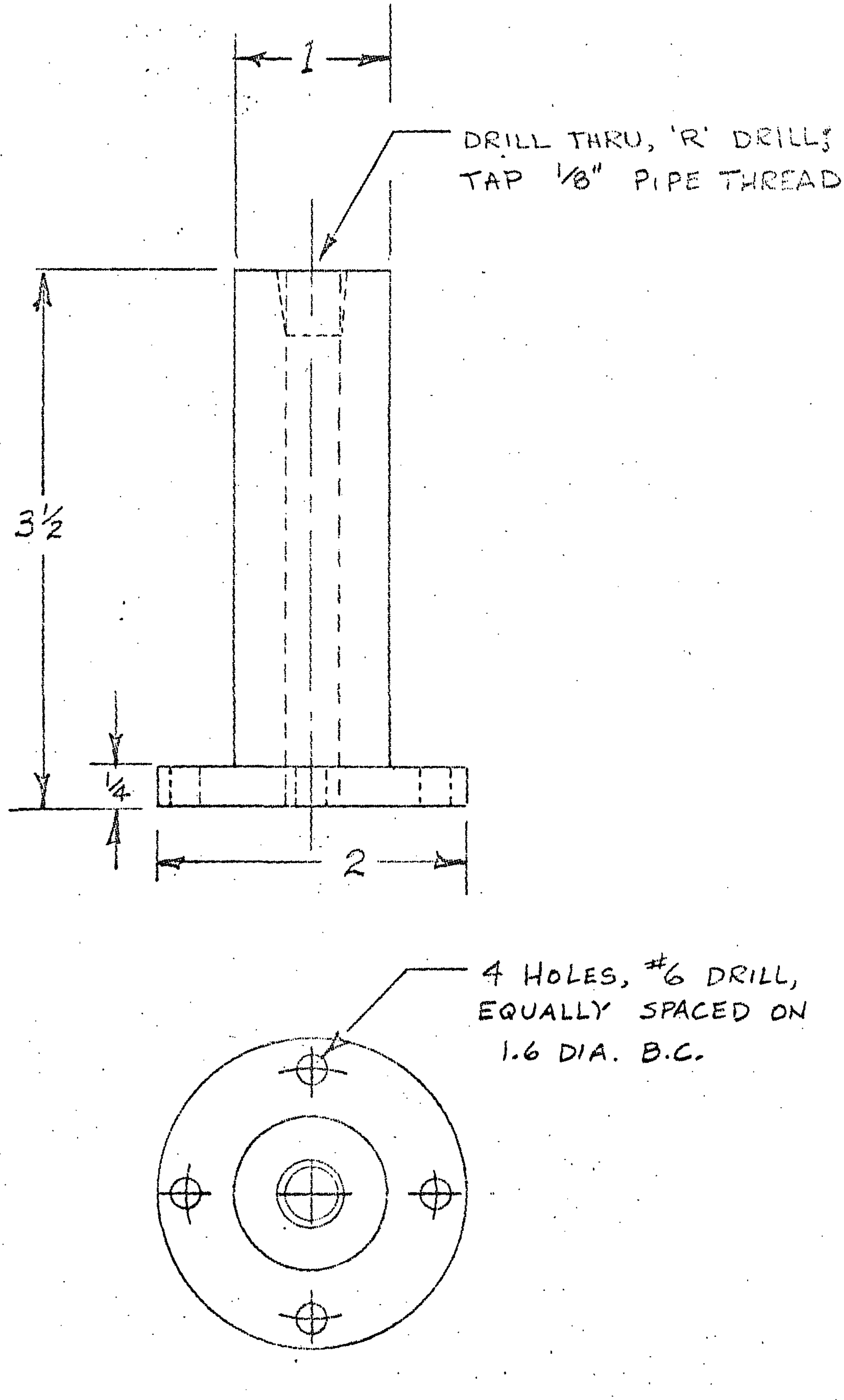


FIGURE 42

WATER JET CONCEPT



POCO WATER JET CLEANER
SUPPORT SHAFT

FIGURE 43

1 REQ'D

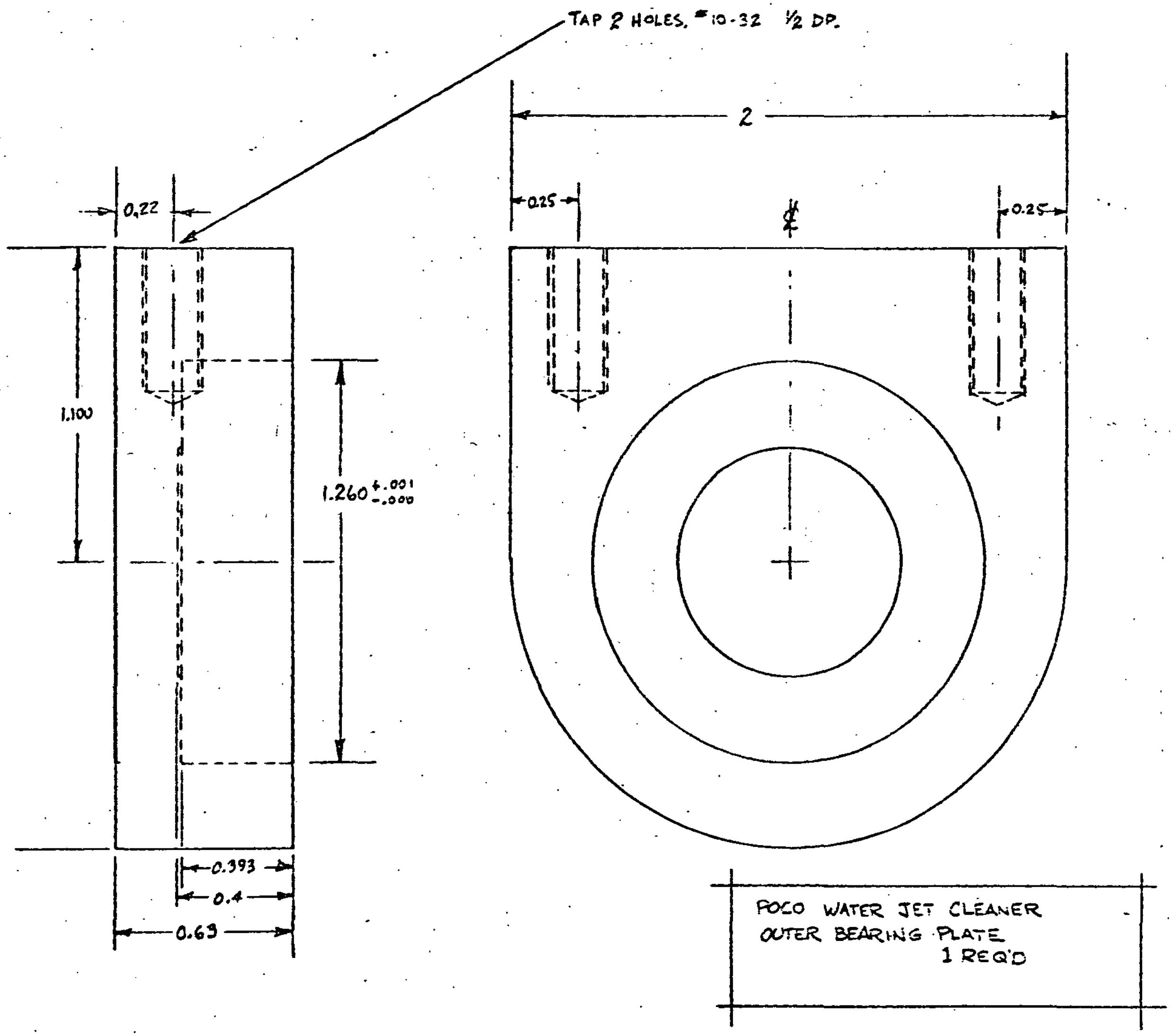


FIGURE 44
WATER JET PROTOTYPE

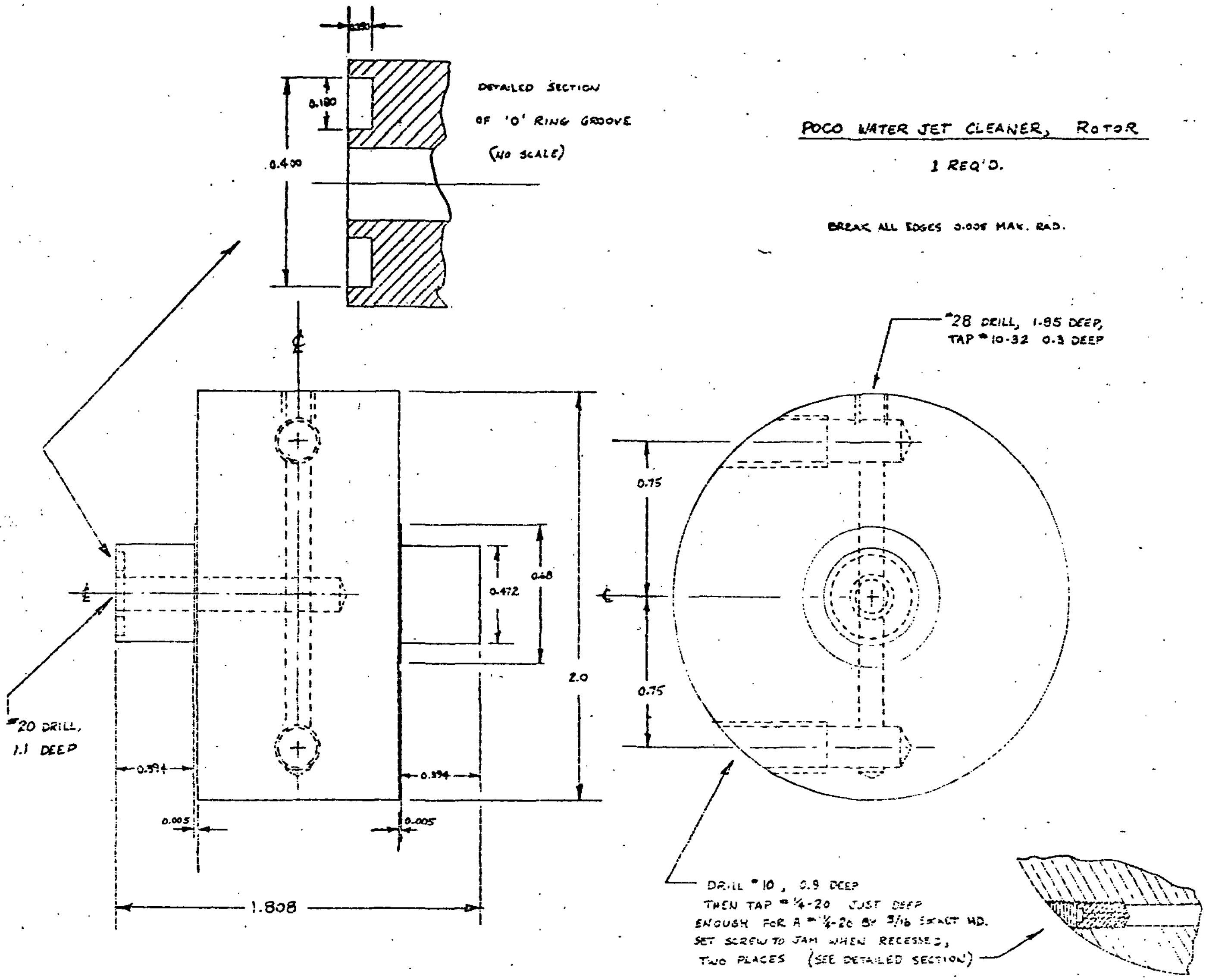


FIGURE 45
WATER JET PROTOTYPE

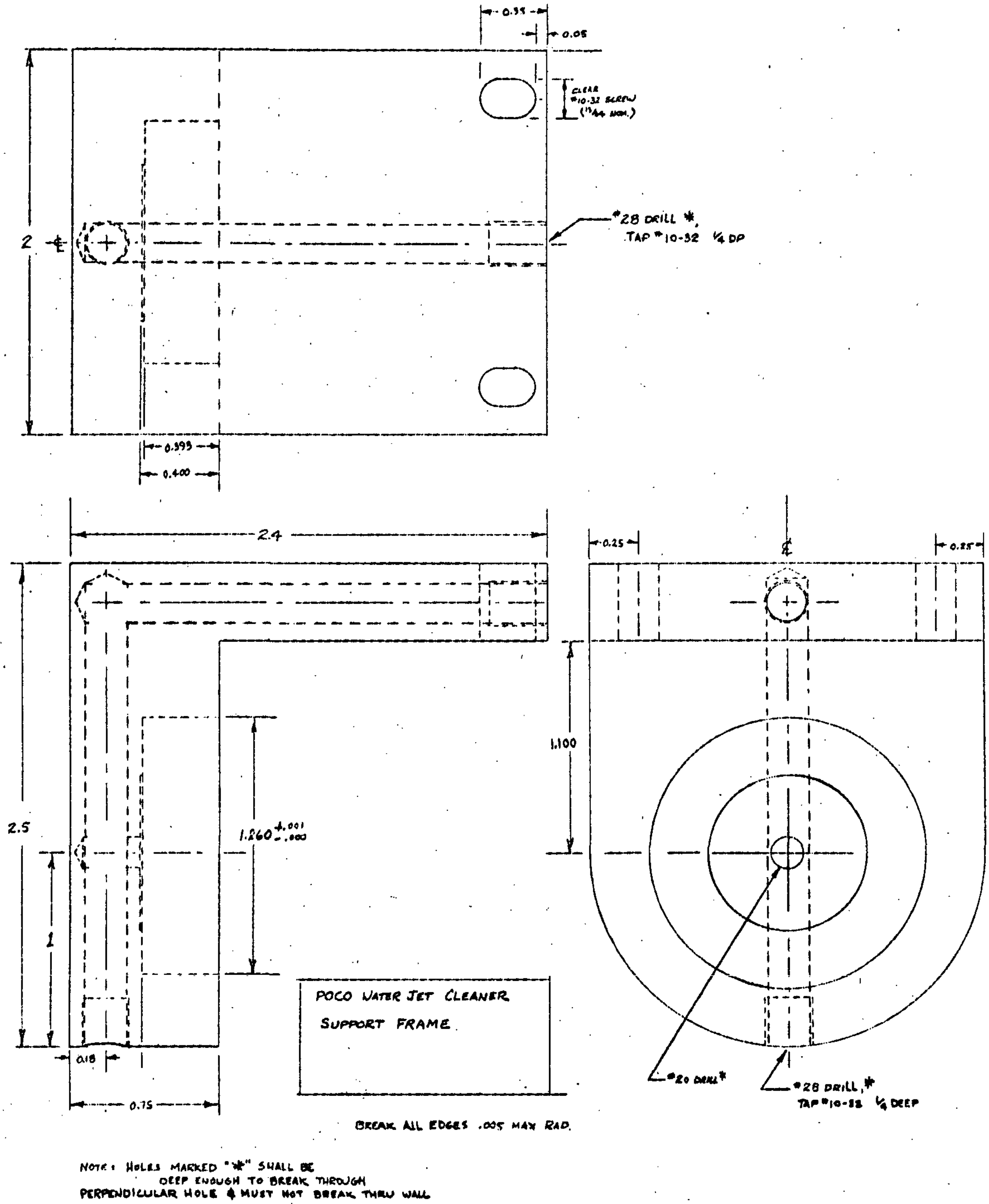


FIGURE 46

WATER JET PROTOTYPE

exit port will be a vacuum bag permeable only to gases. The bags are moved into position only when its associated port serves as an exhaust. The bags are mechanically replaced when their associated port serves as an inlet with the contained waste transferred to a liquid/solid separater and then on to storage.

b) Ultrasonics: Another method for removing waste matter from the walls of the life cell consists of filling the cell with water and energizing an ultrasonic generator. Sonic cleaning is accomplished by applying high frequency sound to a liquid in which the item to be cleaned is submerged. For maximum effectiveness, the liqud used should be a solvent for the materials to be removed. By far, the most important cleaning action is produced by cavitation near the surface. The collapse of bubbles during the decreasing portion of a pressure cycle produce shock waves which have an effect similar to that of mechanical scrubbing. Along with cavitation, there is a cleansing effect produced by agitation of the liquid. Ultrasonic cleaning without the use of a liquid medium is being investigated; however, preliminary studies in the area of "dry" ultrasonic methods do not appear favorable.

CONCEPT NO. 3 (Diet Compensation)

It is proposed to modify the solid food diet formulation by the addition of rice or Kaolin Pectin in order to harden the fecal matter of the primate. This would significantly decrease the amount of matter adhering to the life cell's wall. Fecal matter contacting the wall surface would have a tendency to "bounce" off the wall and eventually by utilizing forced air flow as previously defined, be transferred to one of the exit ports. The development program studies will include an investigation of diet modification effects to determine the feasibility of this technique.

CONCEPT NO. 4 (Primate Training)

The method of primate training is proposed in conjunction with one of the other methods contained in this section. Relying solely on the primate to defecate in a prescribed location and manner is not proposed. This method is intended to decrease the quantity of waste matter to be disposed of by a secondary waste collection system.

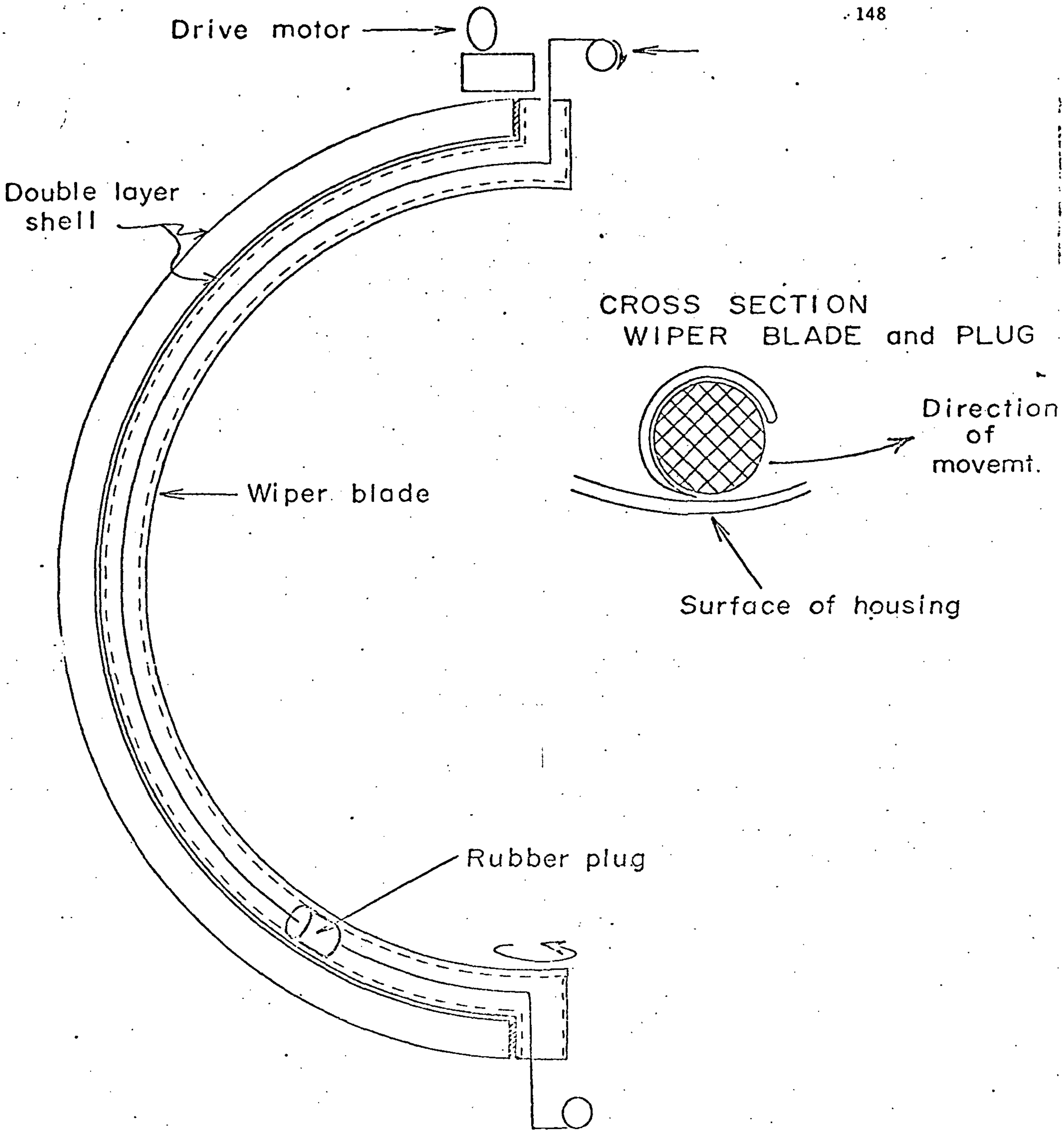
The concept is dependent upon the ability of chimpanzees to be successfully trained to defecate at specified times and locations.

An orientation cue would be presented to the primate with the required response being the primate positioning himself on the collection receptacle. A vacuum would serve to hold the primate in place while transferring the waste matter to a storage container.

CONCEPT NO. 5 (Mechanical)

A number of mechanical methods are potential candidates for removal of waste from the wall surface. The two most promising methods are described below:

a) A large semi-circular wiper blade (Fig 47) actuated by a motor-driven axle placed on the axis of the sphere is proposed. The blade will be channel shaped to scoop up any waste matter



WIPER BLADE CONFIGURATION

FIGURE 47

adhering to the capsule wall and will be mounted such that the entire inner surface may be swept. In order to maintain an orientation cueless environment, the wiper blade will come to rest in a new position each time it completes a cleaning cycle, thus randomizing its location within the sphere. After coming to rest, a silicon rubber plug at one end of the hollow blade is transferred along the blade's length, pushing the accumulated waste through a hollow axle of the blade and then returning to its original position.

b) A second mechanical means under consideration requires a thin pliable sheet of plastic, covering the interior surface of each of the sixty triangular shaped wall segments, to be mounted on rollers. At scheduled periods, a motor is energized to rotate the rollers and replace the inner surface of the sphere with clean plastic. Thus, periodically the inner surface of the sphere is free of waste matter. The waste will then be scraped off the "used" plastic sheet, processed and stored.

III. EXPERIMENT INTERFACE

H. ORIENTATION SENSING SYSTEM

Instrumentation is required to continuously monitor the relationship between the chimpanzee and a fixed reference within the life cell. It is desired to measure the primate's head and the primate's trunk relationship with respect to the life cell. An independent sensing system is proposed for each measurement. To obtain the trunk to capsule relationship, an electro-optical tracking system is proposed; the head to capsule relationship is gained by means of a magnetic sensing system.

H.1 CONCEPTS

ELECTRO-OPTICAL SYSTEM

a) Servo System

Electro-optical systems for monitoring displacement use a special photomultiplier tube to electronically servo on an optical discontinuity. The servo locks on any black and white target. A typical servo system (Fig 48) is shown "locked-on" and tracking a black and white target, an image of which is focused on the photocathode by a lens or telescope. A "dark and light" electron image is emitted from the inner surface of the photocathode and accelerated toward the aperture. The loop servo holds the edge or boundary of the black and white image at the aperture hole.

When the target in space moves up, the multiplier sees less electrons through the hole of the aperture. When the target moves down, the multiplier sees more electrons. The output from the multiplier is fed to the deflection yoke. As the object in space moves, this feedback holds the electron image at the aperture. The feedback

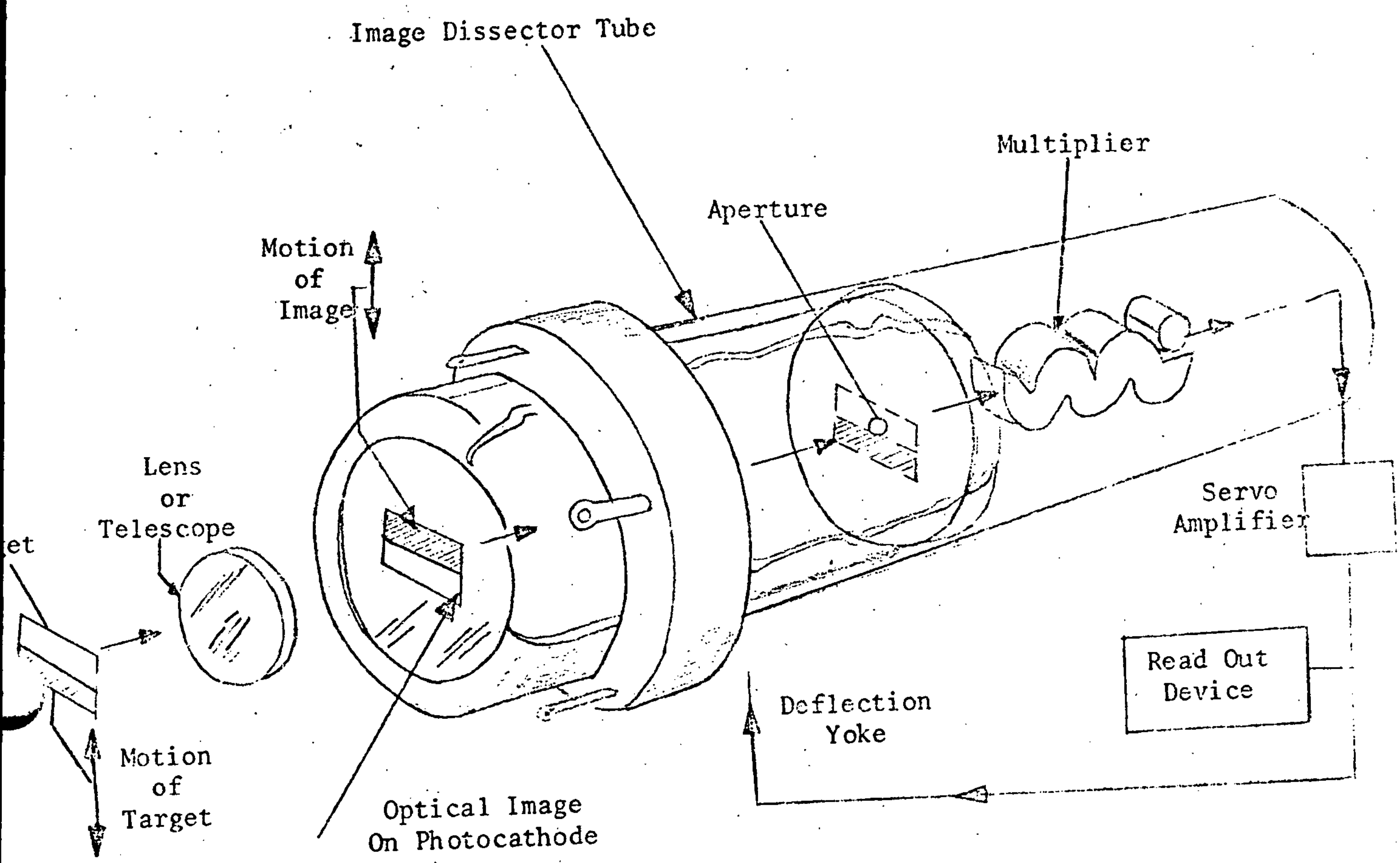


FIGURE 48*

TYPICAL SERVO ELECTRO-OPTICAL

TRACKING SYSTEM

*From February, 1967, issue of Instruments & Control Systems signal is a measure of the object's displacement. Hence, the output voltage from the servo tracker is a direct measure of the motion of the target and may be applied to any recording instrument or telemetry system as a measure of displacement.

Response time for an electro-optical servo system is typically 50 to 100 μsec---equivalent to 5 or 10 kHz frequency response. To maintain high resolution it is necessary to use a relatively small aperture in the electron image plane. However, with low light levels, a larger aperture is needed and this results in lower resolution. A small aperture (or high resolution) servo system also requires a sharp image in order to function. The discontinuity must completely transition from black to white in a small fraction of the aperture diamerter. For images that are slightly fuzzy or discontinuities that are not perfect, the image analyzer tube must have a larger aperture so that it will cover the entire transition from black to white. Image degrading factors such as viewing ports, heat waves, or semiclear media present in the optical path tend to limit the resolution of a servo type instrument and are inherent in the functional concept of a servo type electro-optical tracking system,

b) Sampling System

The Physitech Model 39 sampling type electro-optical tracking system monitors the position of any optical discontinuity perpendicular and relative to the longitudinal axis of the tracker. It is illustrated (Fig 49) tracking a black-white interface, although the target could just as easily be any other two-color interface capable of

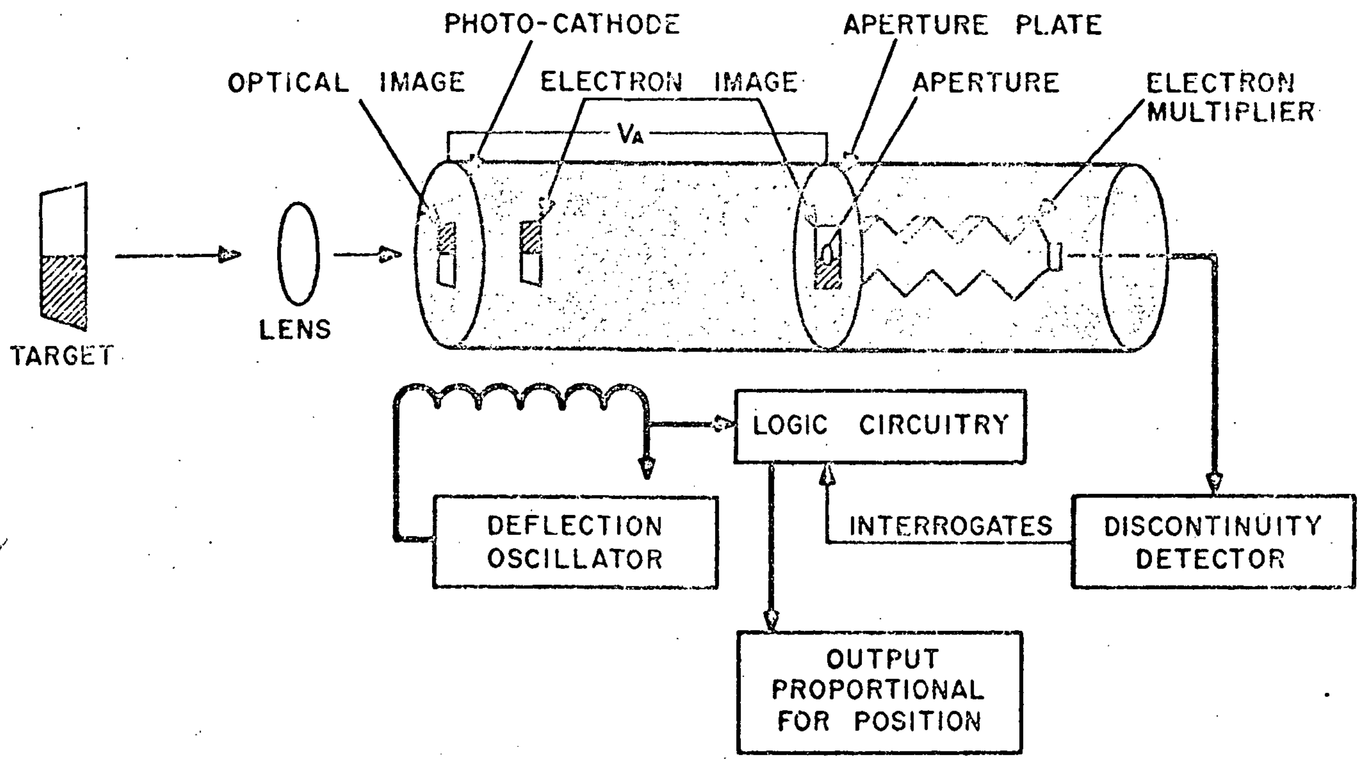


FIGURE 49

MODEL 39

SAMPLING TYPE TRACKING SYSTEM

providing the required 3:1 contrast ratio. The optical image of the area to be monitored is formed on the photocathode by an appropriate lens system. Wherever light falls on the photocathode, electrons are emitted from the inner surface, thus forming an electron image within the image analyzer tube. An applied electric field accelerates the electron image down the tube and focuses this image on the aperture plate which intercepts almost all of the image and only passes the part that falls on the aperture. The electron multiplier behind the aperture sees only that part of the image that passes through the aperture, and the multiplier's current output is a linear function of the intensity of a small portion of the optical image.

The deflection oscillator provides a scanning magnetic field which moves the electron image back and forth across the aperture. The discontinuity detector monitors the output of the electron multiplier and notifies the logic circuitry when the aperture transitions from a light to a dark area (the crossing of an optical discontinuity). The logic circuitry then interrogates the deflection system as to where the electron image was when the discontinuity was detected; this interrogated signal is a direct measure of the optical discontinuity's position relative to the tracker's optical axis.

The output signal may then be applied to any conventional recording instrument to indicate position, displacement, velocity or acceleration. With a sampling type system the output from the electron multiplier, as the discontinuity passes the aperture, appears as a transition from a current equivalent to dark, to a current equivalent to light. The fall (or rise) time of the transition is due to the width of the aperture as it crosses the discontinuity. A sampling system which has for any one of various reasons been presented with an unclear image will function successfully, just as well as if the image were clear, by the employment of a "gray level" adjust circuit.

A number of tracking systems will be situated symmetrically about the surface of the life cell to enable continuous tracking throughout the entire life cell volume. The view of a particular tracking unit will overlap the view of its adjacent unit such that two tracking units will be simultaneously locked on the target in these "transitory" regions. The logic of all units is transferred to a controlling element to accomplish the required "lock" within the transitory regions.

If something interrupts the optical path, obscuring the target from view of any of the tracking units, the system will lose its lock until the target reappears, whereupon target search and lock is re-established and data are again provided.

MAGNETIC SYSTEM

To satisfy the second degree of required orientation measurements, it is proposed to monitor the magnetic field of a permanent magnet discreetly placed on the primate's surface. Three magnetometers mounted externally to the life cell at mutually perpendicular axes will serve as the required magnetic sensors. The vector addition of the magnetic field sensed by each magnetometer will be accomplished on board, allowing pre-processed data to be telemetered to ground station or acquired by on-board recording equipment. All such data will be automatically designated by its corresponding spacecraft time.

III. EXPERIMENT INTERFACE

I. CAMERA SUBSYSTEM

The camera subsystem shall provide photographs of the primate with sufficient resolution to provide direction of gaze. The field of camera view will approach 180 degrees in order to monitor head, trunk and limb movements. There will be a "data box" in the field of view of the camera so that frame number, date and time are recorded on each frame.

I.1 OPERATIONS: The following sequences will be affected:

Time	Frames	On/Off Commands
From Launch (L-1 min) to (L+30 min); MODE C*	7,440	Ground Command Thru Behavioral Electronics
Orbit, Every 10 minutes in Day Mode Only; MODE F*	12,960	Initiated By Behavioral Electronics
Orbit, Days 1, 7, 13, 19, 25, 31,... ....163, 169, 175, 180, for two minutes during first behavioral task session; MODE C*	14,400	Initiated By Behavioral Electronics
TOTAL FRAMES	34,800	

*MODE C (CINE): The camera shall operate at a frame rate of 4/second

*MODE F (FRAME): The camera shall operate for one frame only.

III. EXPERIMENT INTERFACE

J. HOUSE LIGHTING

The interior of the spherical chamber shall be maintained at lighting intensities throughout the day and night periods as specified in Section II J. This shall be accomplished by illuminating various triangular segments of the chamber wall in such a manner that no orientation cue is offered to the subject. The traingular segments will be uniformly illuminated over their entire surface area.

J.1 CONCEPT NO. 1

The required lighting intensity shall be accomplished by illuminating various traingular segments by means of electroluminescence sources. Electroluminescent lamps may be fabricated in any shape or form. The shape selected for this application would be a triangular spherical segment. A single triangular shaped sheet of electroluminescent material will be affixed to each lexan segment used for house lighting.

The physical dimensions of electroluminescent lamps, their low weight and power consumption, are among the advantages in favor of their use. Electroluminescent lamps are not subject to catastrophic failure as are incandescent lamps. The major disadvantage of electroluminescent lamps is their brightness degradation as a function of operating life. Since electroluminescence is the direct conversion of electrical energy to light, a uniform intensity may be maintained over a period of time by increasing the applied voltage with time. For a six month mission as proposed here, electroluminescent lamps at their present state of the art are marginal; however, the state of the art of electroluminescent lighting is advancing so rapidly, it seems highly likely that by the time the design of the spacecraft is frozen, electroluminescence would be adequate for its intended use.

CONCEPT NO. 2

The triangular wall segments utilized to light the primate chamber shall be illuminated by incandescent Halogen cycle lamps. Each triangular segment of the sphere deveoted to house lighting will house three incandescent lamps. Only one of the three lamps will be illuminated when a particular panel is energized. If the primary lamp fails, a sensing circuit will shunt the current to the secondary lamp and similarly to the third lamps should the secondary lamp fail. Each of the three lamps will be reflected so that uniform illumination of a segment is obtained (See Fig 50). The surface of the transparent panel which contains the house lights will be frosted on the side away from the primate to diffuse the light.

J.2 SPECIFICATIONS

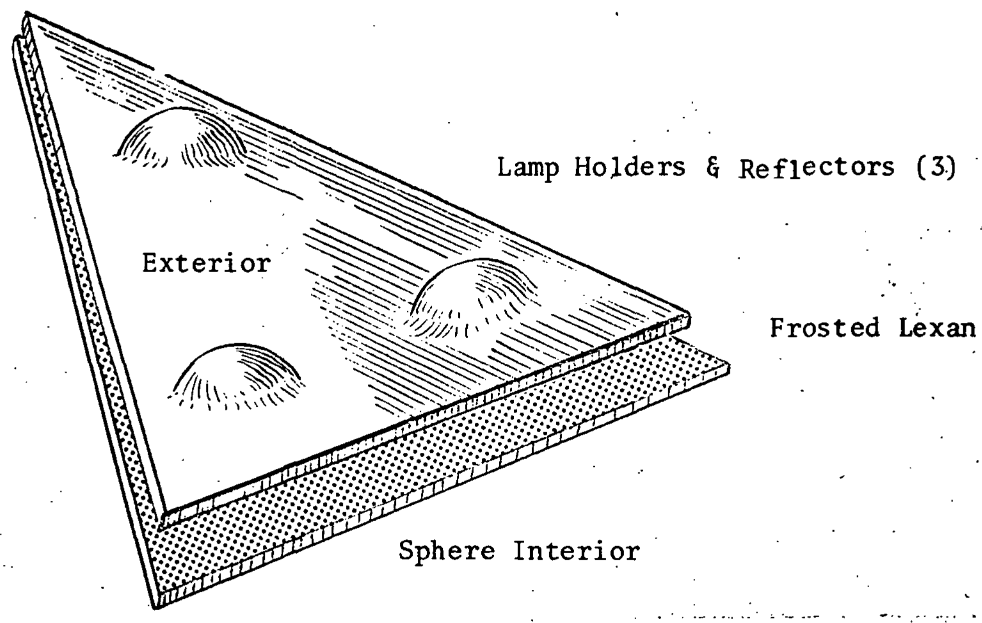
a) The lighting intensity within the capsule shall be uniform throughout the entire volume ±3%.

b) The illumination of a particular wall segment shall be uniform ±3%.

c) The lighting intensity within the capsule shall be as follows:

Nominal Values

Day time:	10 foot candles
Night time:	0.3 foot candles



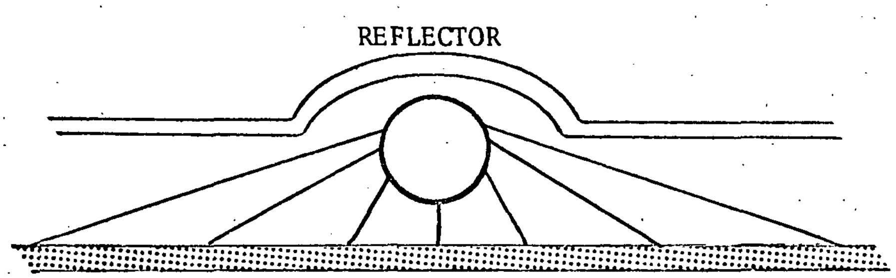


FIGURE 50

CONCEPT NO. 2

INCANDESCENT LIGHTING

III. EXPERIMENT INTERFACE

K. PRIMATE LIFE CELL

The life cell is the central element of the life support subsystem and serves as the living area for the primate. As the principal structural member of the spacecraft, it provides a shell which, in addition to the primate, encloses the food supply, waste management system, thermal and atmosphere control systems and other primate support equipment. Atmosphere, water and other tankage are mounted outside to the shell structure. The life cell is a pressure vessel which provides structural support for the internal equipment which is integrated into the spherical housing chamber.

To provide adequate living area for the primate while subjecting him to an orientation cueless environment, a spherical housing chamber of 1.524 meters inside diameter has been selected, providing an enclosed volume of 1.852 cubic meters.

The life cell's interior surface must be designed to resist scratching and chewing by the primate, and chemical attack from fresh or decomposing food, feces, and urine. It must be opaque to permit behavioral task presentation and to minimize interference with the on-board camera. For this purpose, we are considering polycarbonate (Lexan) as the material for the spherical chamber, coated with a thin polymer film. A "glass resin" polymer (a thermoset silicone) that is both transparent and tough, developed by Owens-Illinois, Toledo, called Sierracin 311 is under consideration as the inner coating of the Lexan surface.

The housing chamber must contain no components or fasteners that are accessible for removal by the primate and have a minimum of projections or obstacles capable of storing waste products.

K.1 CONCEPT

Polycarbonate (Lexan) and acrylic (Lucite) are materials being considered for the fabrication of the inner surface of the life cell. Polycarbonate is considerably stronger per unit weight than acrylic but has a slight purple color which is an optical consideration. Both materials may be cast, machined, and solvent welded. At this time, polycarbonate is favored over acrylic.

The sphere will be made by injection molding sixty identical triangular spherical segments (Fig 51) when fitted together from a complete sphere. Holes will be cast into the ribs on all three apexes of the triangular segments so that dowel pins may be inserted to precisely locate the relative positions of the sections during assembly. The segments will be fitted together with removable fasteners and will have a thin layer of complient material between them to provide a gas and water tight gasket and to allow for material expansion due to temperature variations.

The modular segments are to be fabricated so that they are interchangeable to facilitate exchange and repair.

A geometrical definition of a triangular spherical segment is presented below:

> On the circumference of a 5 feet inside diameter, 0.4 inch wall thickness, spherical shell, draw three great circles in such a manner that a small triangular section is located on the surface of the sphere where the circles intersect (See Fig 52). This triangular section is isosceles with planar dimensions of 22.68 inches opposite an angle of 68°37'8" and 20.12 inches opposite the two equal angles of 55°41'26". The segment represents 1/60 of the sphere's surface area.

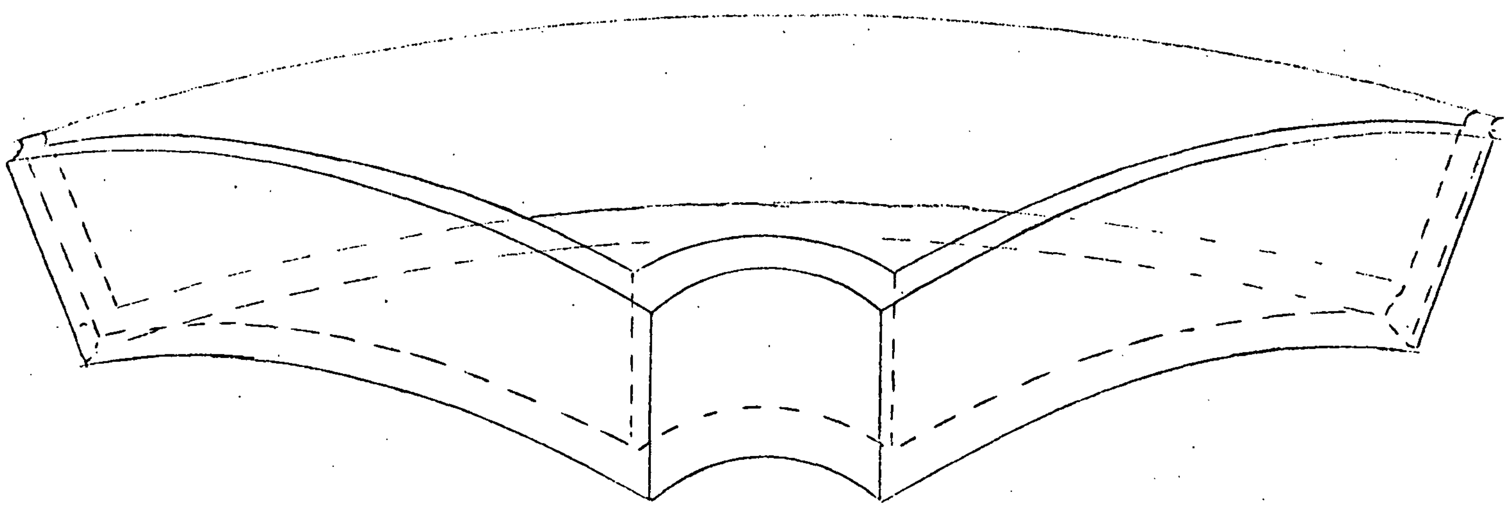


FIGURE 51

TRIANGULAR SHAPED WALL SEGMENT

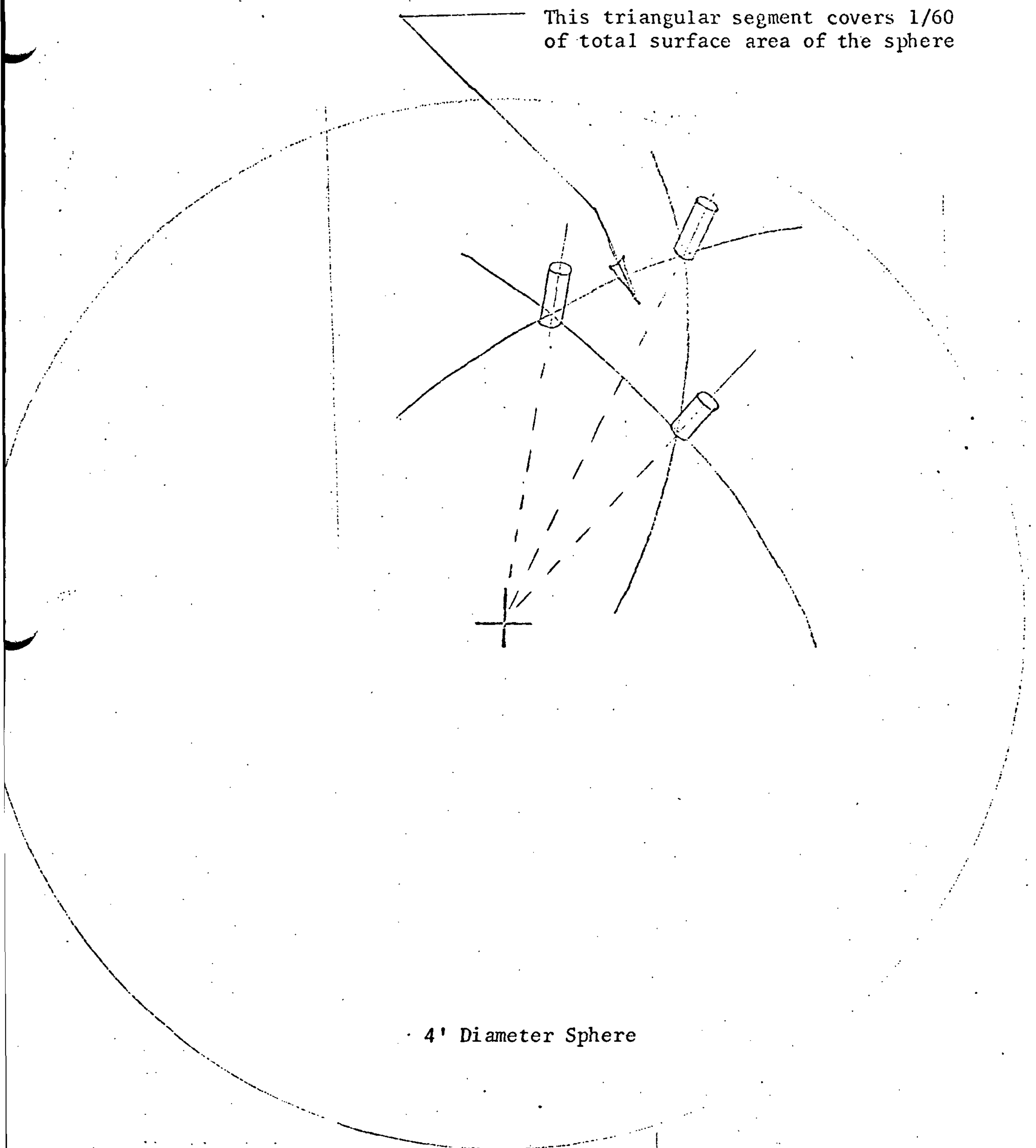


FIGURE 52

RELATIVE POSITION OF TRIANGULAR SEGMENT

IN RESPECT TO SPHERE AND CYLINDERS

Construct three hollow cylinders of 1 inch inside diameter with a wall thickness of 0.4 inches. The axis of each cylinder extends to the center of the sphere and intersects one of the three vertices of the triangular section. The inside ends of the cylinders are flush with the inside of the spherical surface and the outside ends of the cylinders are cut so that they would coincide with the surface of another larger and concentric imaginary sphere of approximately 5 feet and 8 inches in diameter. In addition to shaping the ends of the cylinders as described above, also remove that part of the three cylinders which lies outside the spherical segment formed by the great circles.

Now, connect to the figure three flat ribs, each 0.4 inches thick in the following manner: each rib is placed with one edge adjacent to the outside of the spherical shell, extending along one side of the triangular segment. The opposite edge is coincident with the surface of the larger imaginary sphere. The ribs extend along the surface of the sphere until it meets the surface of the cylinders where the segments are joined. This produces a shape consisting of a segment of a spherical shell, a segment of three hollow cylinders, and three rib segments all joined to form one rigid part (Fig 53). Sixty of these identical parts bonded together form a complete spherical shell.

K.2 SPECIFICATIONS

1. Dimensions: 1.524 meters ± 0.2 cm inside diamter.

2. The sphere must have sufficient structural integrity to withstand the forces imposed at launch.

3. The sphere must have sufficient structural integrity to withstand forces of up to 60 kg applied by the primate at any point and in any direction.

4. The triangular segments must be of the following planar dimensions:

   Long side: 57.61 cm $^{+.000}_{-.01}$ cm

   Short sides: 51.36 cm $^{+.000}_{-.01}$ cm

5. The sphere must have sufficient structural integrity to withstand a continuous pressure differential of 16.2 psia.

6. The sphere must have an easily removable hatch (6 triangular segments) to facilitate primate insertions.

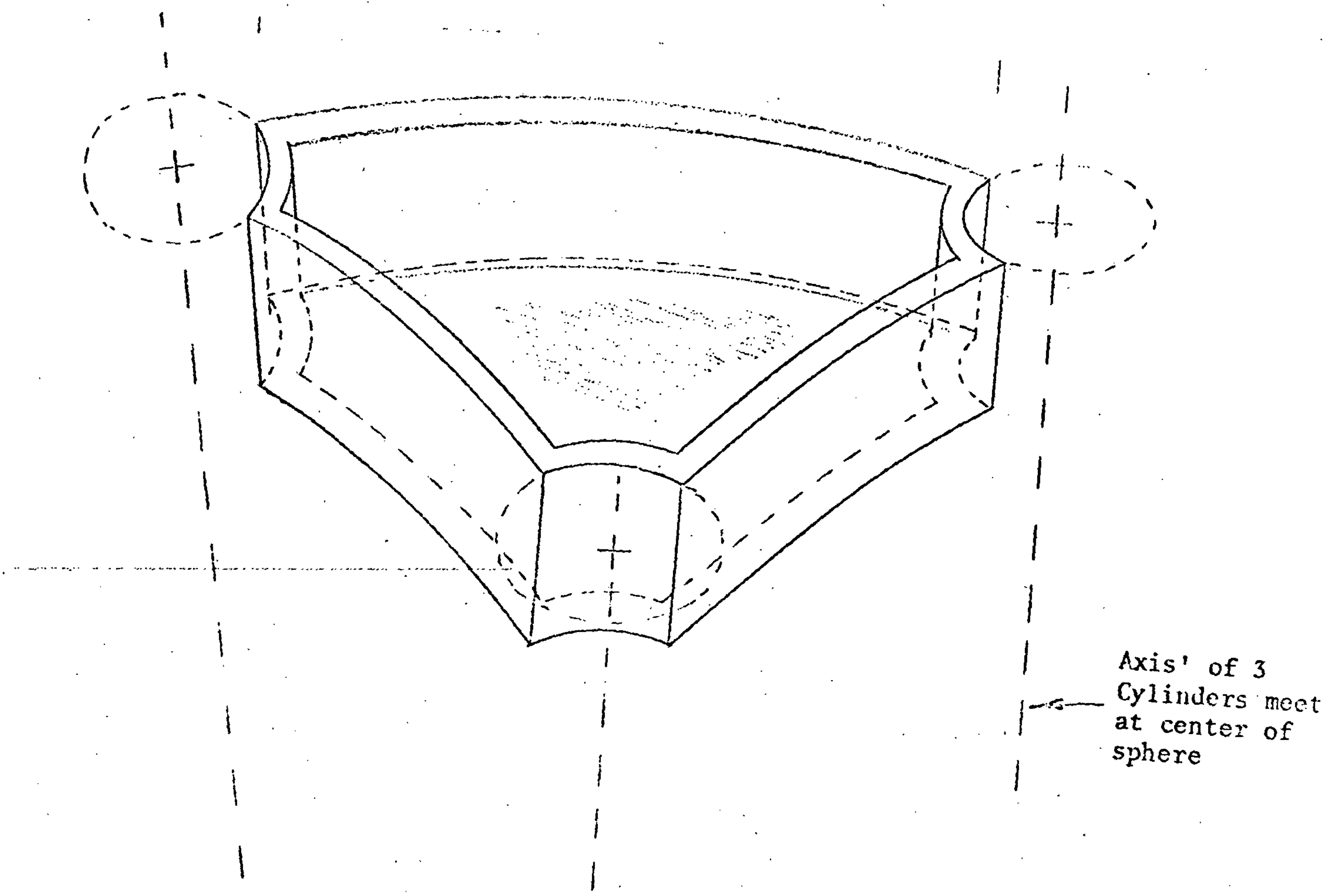


FIGURE 53

MODDED BOLYCARBONITE

TRIANGULAR SPHERICAL SEGMENT

K.3 LIFE CELL WALL SEGMENT DISPOSITION

In order to present an orientation cueless environment to the primate, the various components visible to the primate have been placed symmetrically about the sixty triangular wall segments. The geometrical constraints of a Solid Pentakis Dodecahedron (60 sided geodesic figure) necessitated the following quantity of components in order to establish an orientation cueless environement:

Behavioral Display Panels:	6
Feeder:	6
Water Dispenser:	6
Temperature Control Swith:	6
Light Intensity Control Switch:	6
Task Initiate Switch:	6
Camera Lens:	1
Tracking System Lens:	5
House Lighting Panel:	24

Each of sixty triangular shaped wall segments contain one or more of the above components. Presented in Table 11 is the disposition of these segments.

TABLE 11

WALL SEGMENT DISPOSITION

Quantity of Triangular Wall Segments	Function
12	Behavioral display panel (including secondary reinforcement switch and feeder)
24	House lighting

Quantity of Triangular Wall Segments	Function
6	House lighting on/off control switches
6	Temperature control switches
6	Water dispenser, dummy switch
1	Camera lens, task initiate switch
5	Tracking System lens, task initiate switch
60	TOTAL

III. EXPERIMENT INTERFACE

L. BEHAVIORAL ELECTRONICS

The behavioral electronics is a multi-purpose "mini computer" representing the "brains" of the behavioral system. A detailed description of the operation of each subsystem controlled by the behavioral electronics is included in their respective sections of this report and is not repeated here. The various functions controlled and monitored by this system are listed below:

1) Camera operation
2) Tape recorder operation
3) Ground commands
4) Feeder operation
5) Behavioral task presentation
6) Behavioral task progression
7) Behavioral task performance data and identity
8) Primate tracking system "lock"
9) Magnetometer data processing
10) Power switching
11) Mission Sequence
12) Primate "controlled" functions
13) Program time
14) Power supply regulation
15) Water dispenser
16) Life cell lighting

III. EXPERIMENT INTERFACE

M. MISSION SEQUENCE

The 180-day mission shall be divided into three equivalent trimesters consisting of three distinct phases as summarized below:

TRIMESTER I (Days 1-60)

<u>Phase A (Day 1 through 60)</u>

Day 1 through 10:
- a) 12 hr light, 12 hr dark
- b) three behavioral sessions of 100 trials each presented at scheduled times during the "day"
- c) temperature controlled by experimenter 76°F to 81°F

Day 11 through 20:
- a) 12 hr light, 12 hr dark
- b) behavioral sessions primate initiated during light (100 trials/session)
- c) temperature controlled by experimenter

<u>Phase B (Day 21 through 40)</u>

Day 21 through 30:
- a) primate lighting control
- b) behavioral sessions primate initiated
- c) temperature controlled by experimenter

Day 31 through 40:
- a) primate lighting control
- b) behavioral sessions primate initiated
- c) primate temperature control - 71°F to 81°F

<u>Phase C (Day 41 through 60)</u>

Day 41 through 50:
- a) 24 hr continuous light (at primate's desired intensity)
- b) behavioral sessions primate initiated
- c) primate temperature control

Day 51 through 60:
- a) 24 hr continuous light
- b) behavioral sessions primate initiated
- c) temperature controlled by experimenter (at primate's desired level)

Trimester II (Days 61-120) and Trimester III (Days 121-180) are identical to Trimester I. The mission sequence of one trimester is shown pictorially in Fig 54.

The behavioral task presented to the primate in each phase will proceed from very simple tasks up to and including 5 symbol MSS, dependent upon the animal's performance. The primate's performance during a particular session will determine his progression to a task of greater difficulty as specified in Section II E.6 of this document.

The system required to accomplish the experimental objectives as set forth in this report is shown in block diagram form in Fig 55.

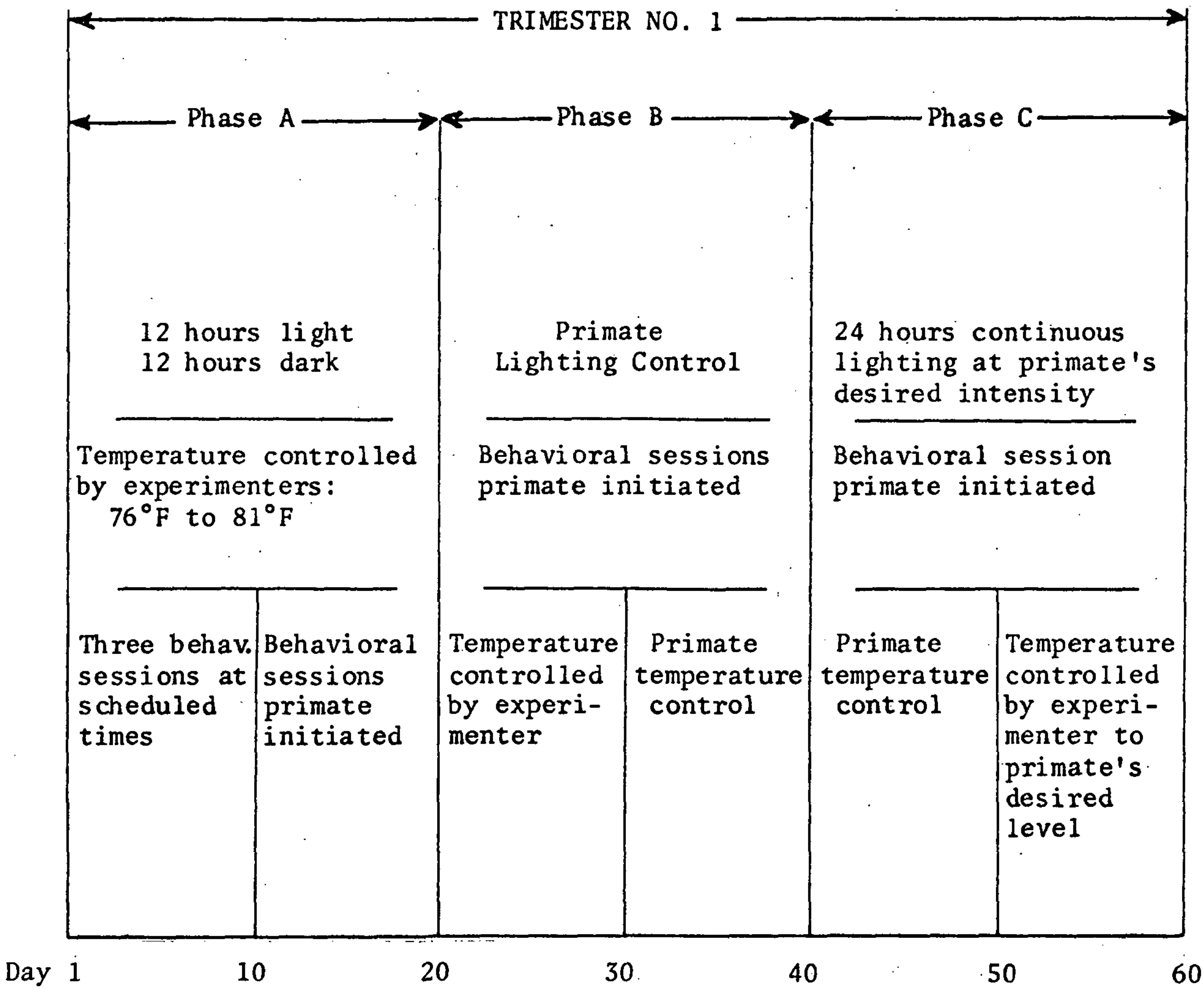
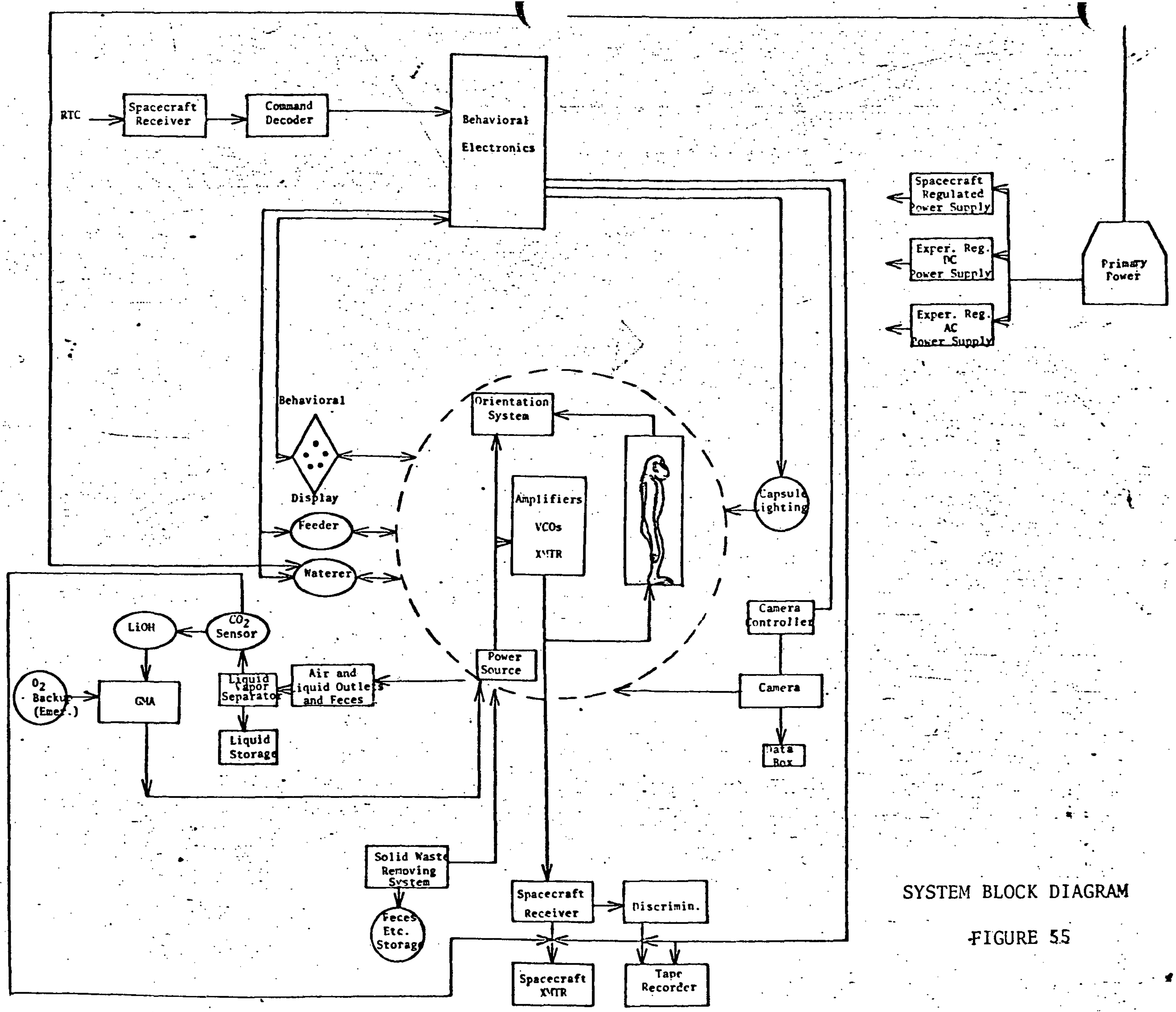


FIGURE 54

MISSION SEQUENCE

ONE TRIMESTER



SYSTEM BLOCK DIAGRAM

FIGURE 55

III. EXPERIMENT INTERFACE

N. FIVE YEAR PLAN FOR POCO DEVELOPMENT

This section of the report is devoted to the planning and scheduling of the development program. Presented in Fig 56 is a proposed development flow chart for the Physiology of Chimpanzees in Orbit program for the period January 1, 1970 through December 31, 1974. This 5 year program encompasses the hardware development, experiment definition, primate training, and system tests necessary to provide a design freeze.

Heavy emphasis has been placed on primate inserted tests which are envisioned to be conducted at one of the NASA field centers. Initial tests will determine primate adaptability to a closed life support system while demonstrating the feasibility of each support subsystem. Five system tests are proposed with a time block provided after each test to modify and upgrade the instrumentation and equipment as required. In parallel with system tests will be primate studies and stress evaluations to determine the effects of the individual and collective constraints imposed upon the primate to satisfy the mission objectives.

We feel that our experiences on the Biosatellite Program dictate the following order of major subsystem criticality:

1) Feces management
2) Implantable telemetry
3) Closed system primate tests
4) Medical monitoring and corrective action:
    a) On-board analysis of feces and urine
    b) Interpretation implanted telemetry data
    c) On-board measurement of O_2 consumption and CO_2 production

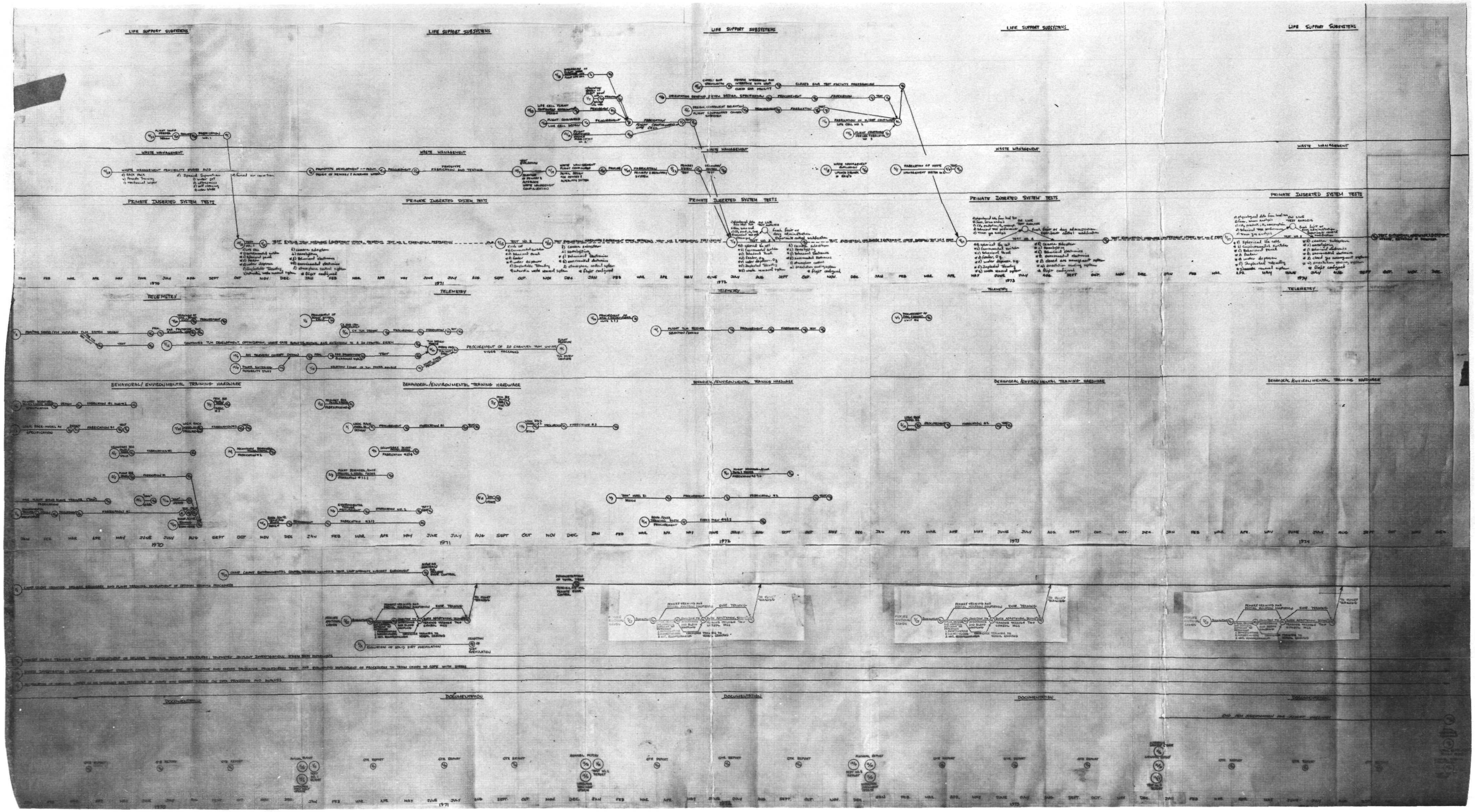


FIGURE 56
5 YEAR FLOW CHART FOR POCO DEVELOPMENT

5) MSS task feasibility

6) Cardiovascular system definition

7) Primate orientation sensing system.

The flow chart is summarized in Tables 12 and 13 consisting of a major milestone schedule and primate test summary respectively.

TABLE 12

MAJOR MILESTONE SCHEDULE

	Milestone Description	Completion Date
1.	Preliminary Interface Document	Complete
2.	End Item Specification for primary trainer	Complete
3.	End Item Specification for secondary trainer	Complete
4.	End Item Specification for flight trainer	Complete
5.	Start primate test number 1	10/15/70*
6.	Complete fabrication of spherical life cell	5/20/71
7.	Local TLM concept design freeze	6/16/71
8.	Go/No Go decision on primate control of temperature and lighting	6/17/71
9.	Start primate test number 2	9/15/71
10.	Definition of waste management system	11/19/71
11.	Review of primate MSSD task performance and design freeze	12/20/71
12.	Start primate test number 3	7/9/72
13.	Start primate test number 4	4/27/73
14.	Start primate test number 5	3/27/74
15.	Total experiment design freeze	12/31/74
16.	Interface definition and documentation complete	12/31/74

*Cancelled due to termination of program

TABLE 13

PRIMATE TEST SUMMARY

Test Number	Schedule Date	Operational Subsystem
1	10/15/70 to 11/15/70	Life Cell, Environmental Switches*, Behavioral Panel*, Feeder*, Water Dispenser*, Implantable Telemetry, Automatic Waste Removal System, Camera Subsystem, Houselighting, Behavioral Electronics*, Atmosphere Control System (open GMA)
2	9/15/71 to 11/15/71	Life Cell, Environmental Switches*, Behavioral Panel*, Water Dispenser*, Implantable Telemetry, Automatic Waste Removal System, Camera Subsystem, Houselighting, Behavioral Electronics*, Environmental Electronics*, Atmosphere Control System (open GMA)
3	7/9/72 to 10/9/72	Spherical Life Cell*, Environmental Switches*, Behavioral Panel*, Feeder*, Water Dispenser*, Implanted Telemetry*, Waste Removal System*, Camera Subsystem, Houselighting*, Behavioral Electronics*, Environmental Electronics*, Atmosphere Control, Orientation Sensing System
4	4/27/73 to 10/27/73	Spherical Life Cell*, Environmental Switches*, Behavioral Panel*, Feeder*, Water Dispenser*, Implanted Telemetry*, Waste Removal System*, Camera Subsystem*, Houselighting*, Behavioral Electronics*, Environmental Electronics*, Closed Gas Management System*, Orientation Sensing System*

*Flight Configured

TABLE 13 con't

PRIMATE TEST SUMMARY

Test Number	Schedule Date	Operational Subsystem
5	3/27/74	Spherical Life Cell*, Environmental Switches*, Behavioral Panel*, Feeder*, Water Dispenser*, Implanted Telemetry*, Waste Removal System*, Camera Subsystem*, Houselighting*, Behavioral Electronics*, Closed Gas Management System*, Orientation Sensing System*

*Flight Configured

APPENDIX A, PART I

POCO PRIMARY TRAINING PROTOCOL

1.0 Gross Observation

1.1 All candidates should be observed daily by animal trainers and all gross behavioral characteristics should be noted and logged. Of special interest here is each candidate's native resourcefulness, curiosity, dominance and dexterity.

1.2 All these notes and records should be continuously updated as the colony grows and the candidates age.

2.0 Deprivation

2.1 Twenty-four hours prior to commencement of button press training each candidate shall be totally deprived.

2.2 From this beginning phase as close to 100% as possible of the candidate's daily k/cal requirement should be earned by operant performance.

2.3 During non-training or terminal phases of training, the diet may be supplemented, if necessary, by a regime dictated by the project veterinarian.

3.0 Reinforcement Button Press Training

3.1 Upon presentation of the primary trainer display panel in the home cage, the reinforcement button is lighted and armed, and a 2000 Hz tone is emitted. A button press (BP) to the reinforcement button emits a BP click and activates the feeder, delivering one 150 to 180 mg food pellet.

3.2 Following 1000 reinforcements, reinforcement button press training is terminated. Opportunity button press schedules will commence on the following day.

4.0 Opportunity Button Press Schedules

4.1 CRF/CRF (opportunity button schedule/reinforcement button schedule) to satiation (7 days).

4.2 The opportunity button is armed (lighted). A response to the lighted button will extinguish the light and arm and light the reinforcement button. A response to the reinforcement button will dispense two 150-180 mg reward pellets, extinguish the reinforcement button, and arm the opportunity button.

4.3 CRF/CRF for daily food requirement (5 days).

4.4 DRL-10 sec/CRF: Standard method (10 days or until stable performance). (Group One)

4.4.1 400 reinforcements/day. Terminate daily sessions with CRF/CRF for daily food requirement. Onset of this CRF/CRF schedule will be cued by S^D Tone.

4.5 DRL-10 sec/CRF: Errorless method (10 days or until stable performance). (Group Two)

4.5.1 400 reinforcements/day. Terminate daily sessions with CRF/CRF to daily food requirement.

4.6 FR4/CRF 20 reinforcement; advance to 4.6.1

4.6.1 FR7/CRF 20 reinforcements; advance to 4.6.2

4.6.2 FR10/CRF 10 reinforcements; advance to 4.6.3

4.6.3 FR20/CRF 10 reinforcements; advance to 4.6.4

4.6.4 FR50/CRF 10 reinforcements; advance to 4.6.5

4.6.5 FR100/CRF reinforcements; terminate session with CRF/CRF to daily food requirement.

4.7 If characteristic pauses and ratio and effect occur at FR100/CRF, then begin session with FR100/CRF for 5 reinforcements; advance to VR100/CRF for 100 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.7.1 If no pause or ratio end effect occur at FR100/CRF, then begin session with FR100/CRF for 5 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.8 If 4.7, then begin session with VR100/CRF for 5 reinforcement; then advance to VI 3 min/CRF for 40 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.8.1 If 4.7.1 and pauses on ratio end effect occur at FR200, then proceed to VR200 for 50 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.8.2 If 4.7.1 and no pauses or ratio end effect occur, then begin session with FR200/CRF for 5 reinforcement; then advance to FR500/CRF for 20 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.8.3 (Option) If pauses and ratio and effect do not occur on the 5 reinforcements at that FR/CRF that began a session, when they did occur on the previous session, then advance to the next FR schedule for specified reinforcement.

4.9 If 4.8, then begin session with VI 3 min/CRF for 5 reinforcement; then advance to FI 3 min/CRF for 40 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.9.1 If 4.8.1, begin session with VR200/CRF for 5 reinforcement; then advance to VI 3 min/CRF for 40 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.9.2 If 4.8.2, begin session with FR500/CRF for 5 reinforcement; then advance to VR500/CRF for 20 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.10 If 4.9, begin session with FI 3 min/CRF for 50 reinforcements; terminate session with CRF/CRF for daily food requirement.

4.10.1 If 4.9.1, begin session with VI 3 min/CRF for 5 reinforcement; then advance to FI 3 min/CRF for 40 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.10.2 If 4.9.2, begin session with VR500/CRF for 5 reinforcement; then advance to VI 3 min/CRF for 40 reinforcements.

4.11 If 4.10, then repeat 4.10.

4.11.1 If 4.10.1, then begin session with FI 3 min/CRF for 50 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.11.2 If 4.10.2, then begin session with VI 3 min/CRF for 5 reinforcements; then advance to FI 3 min for 40 reinforcements.

4.12 Begin session with FI 3 min/CRF for 50 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.12.1 After 4 daily sessions of FI 3 min/CRF, if definite scalloping not present, then advance to FI 4 min/CRF. If still characteristic scallops are not present after 2 sessions of FI 4 min/CRF, advance to FI 5 min/CRF for 2 sessions. Advance to longer FI, if necessary, to produce stable scallops.

4.12.2 Tandem Schedules: BEgin session with DRL-10 sec/FR10/CRF for 400 reinforcements. Terminate session with CRF/CRF for daily food requirement.

4.12.3 The 4.12.2 schedule will prevail until the DRL histograms and the FR rates are stable.

4.13 Begin session with DRL 10 sec-Limited Hold 2 sec for 400 reinforcement. Terminate session with CRF/CRF for daily food requirement.

4.13.1 With stable histograms from this schedule, change LH contingency to 1 sec.

4.13.2 Additional tandem or mixed schedule combinations may be added to protocol to provide further tests of performance capabilities and to prepare S's for schedule requirements of MSS task (e.g., DRL 3 sec-FR4, and PEC task; DRH schedules).

5.0 Data Output and Recording

5.1 All button press responses will be accumulated in raw form on accumulative recorders, session by session. These shall be identified, dated, and stored in permanent training files.

5.2 All responses from all schedules performed will be counted on appropriate counters and logged to their respective schedule component in the individual training files.

5.3 Inter-response time (IRT) histograms will be drawn up and maintained for each session involving DRL performances.

5.4 All reinforcements will be recorded on a daily session-by-session basis and will be logged in the training charts and converted to k/cal and entered in the colony feeding charts. All k/cal supplements will also be entered in the training and feeding records.

5.5 Response rates and schedule efficiency charts will continually be updated for each subject and maintained in individual training records.

5.6 As criteria for candidate selection becomes more refined, quantitative proficiency graphs relative to these criteria will be maintained for progress evaluation and selection. Further detailed instructions may by added periodically to this protocol as candidate proficiency requirements become more stringent.

APPENDIX A, PART II

SEQUENTIAL BUTTON PRESS AND MSS

1. OS1C One sample-One choice task.

   a. The logic of this and every other display will be tested before presenting task to the S. A trial orientation tone (TOT) (1000 Hz) of 1 sec duration will cue the subject to the onset of a trial. The TOT will be followed by a variable interval (1/4 to 2 sec). A button press (BP) to the sample switch by the S during this interval will initiate the inter-trial interval (ITI) of 0 to 60 sec, tentatively 4 sec. If no BP occurs, the interval will be followed by the appearance of a randomly selected symbol Δ, +,□, 0, or Z on the sample switch. Completion of the tandem response schedule (initially DRL 4 sec: FR3 in LH of 5 sec) will extinguish sample and initiate the delay period (1/4 sec). Unsuccessful completion of the tandem response schedule initiates ITI. A choice orientation tone (COT) of 1/4 sec will occur simultaneously with the delay period. Following the delay period the sample symbol will reappear on the sample switch and on one of the two choice switches selected randomly. BPs to the sample switch has no consequence while a BP to the unlighted switch will lead to a time out period and the concomitant sounding of a buzzer (TO) of 0 to 20 sec (tentatively 10 sec). The TO will be followed by ITI. A BP to the lighted choice switch will extinguish the symbols and initiate the reinforcement cues (S^{rs}), lighting of the red reinforcement button and onset of the reinforcement tone (2000 Hz), which signals the availability of reinforcement (S^R). A BP to the reinforcement button will terminate the S^{rs} and deliver a primary S^R, and initiate the ITI.

   b. This task will remain in effect until the S displays a criterion performance of 90% correct on two successive sessions of 100 trials.

2. OS2C (+,0) Matching to one sample-two choice task.

   a. Sample phase of trial-(from onset of TOT to onset of COT) is same as in OS1C task, except that the sample symbol on each trial will be selected randomly from two preselected symbols, in this case form + and 0.

   b. At the termination of the delay period and COT the symbol which appeared as sample will reappear on the sample switch as a "redisplay symbol." A BP to the redisplay symbol switch has no consequence. Concomitant to the onset of the redisplay symbol is the appearance of both preselected symbols as choice symbols, randomly positioned from trial to trial on the choice switches. The correct choice symbol (the symbol that appeared as the sample symbol) will appear at maximum brightness. The incorrect choice symbol will appear on the other choice switch attenuated in brightness near or below visual threshold. The incorrect choice symbol attenuator will initially be set such that the correct and incorrect choices will increment and decrement respectively, the brightness of the incorrect choice symbol on the subsequent trial by a step of approximately 1/60 of the brightness scale, 0 to maximum. This step setting will be reset below just noticeable difference (JND) threshold level once the brightness of the incorrect symbol reaches mid-point of the brightness continuum. A BP to the incorrect choice symbol extinguishes all symbols, terminates the trial, and initiates a TO. The TO is followed by ITI. A BP to the correct choice symbol extinguishes all symbols and initiates the reinforcement phase of trial followed by ITI. A trial repeat option will be included in order to break position habits of S if necessary.

c. Scores will be recorded in banks of 25 trials. Correct and incorrect counters are to be reset after each session. Attenuation level of the incorrect symbol is to be noted.

d. When the S first attains a score of 20 correct choices/25 trials after the incorrect choice symbol intensity has reached maximum, the attenuator will be inhibited, counters reset and scores will be recorded in banks of 25 trials. The S will be allowed to perform without choice attenuation unless the score for any bank falls below 18 correct/25 trials.

e. After eight consecutive banks of 25 trials where choice attenuation has been inhibited, the session length will be increased to 100 trials/session without the choice attenuation parameter. With 90% correct performance on 2 consecutive sessions of 100 trials, then the S will be advanced to task OS2C with redisplay dimming.

3. OS2C (+,0) with redisplay dimming:

a. This task is identical to OS2C (+,0) task with the exceptions that there is 1) no attenuation of the incorrect choice symbol and 2) there is trial by trial attenuation of the sample redisplay symbol. Each session will be composed of 100 trials. Every correct trial in this phase will be followed by an intensity reduction of the sample redisplay for the subsequent trial by a step setting less than 1/2 JND threshhold while every incorrect trial will be followed by an intensity increment of the sample redisplay by a step setting less than 1/2 JND threshold intensity level.

b. Following two successive sessions of 90% correct performance, the task will be advanced to OS2C (+,Δ) 1/4 sec delay.

c. OS2C (+,Δ) 1/4 sec delay is identical to previous task; however, there is no redisplay symbol appearance and the symbol 0 has been replaced by the symbol Δ. Following criterion performance of 90% correct/100 trial session the task will be advanced to OS2C (Z, Δ) 1/4 sec delay:

NOTE: On all phases of matching to successive sample training E will have the option of using the sample redisplay parameter.

d. OS2C (Z, Δ) 1/4 sec delay. Same as previous task except + symbol replaced by Z symbol. After criterion performance task will be advanced to OS2C (□, Δ) 1/4 sec delay.

e. OS2C (□, Δ) 1/4 sec delay; same as preceding task excepting replacement of the Z symbol with the symbol. With criterion performance the task will be advanced to OS2C (+, 0, Δ, Z, □).

f. OS2C (+, 0, Δ, Z, □). This task is similar to the above tasks with the exception that the sample and the choice confusion symbol will be selected randomly from trial to trial from the symbols +, 0, Δ, Z, □.

g. With criterion performance the task progression will be repeated beginning with OS2C (+, 0) 1/4 sec delay thru OS2C (+, 0, Δ, Z, □) on the flight configured panel. The sample and choice symbols will be positioned randomly on the display switches. With 40/50 correct, the task will be advanced to OS3C 1/4 sec delay.

4. OS3C (+, 0, Δ, Z, □) 1/4 sec delay: Delayed matching to single sample with three choice symbols. This task is like the previous task. One of five symbols will appear randomly from trial to trial as the sample. The sample symbol and two additional confusion symbols, selected randomly from the remaining four symbols, will appear as choice symbols. 37 correct trials in block of 50 will advance the task to OS4C 1/4 sec delay.

5. OS4C (+, 0, Δ, Z, □) 1/4 sec delay. Matching to single sample with four choice symbols. This task is similar to the previous task except during the choice phase of the trial the symbol that appeared as the sample will reappear along with three additional symbols. 35 correct out of a block of 50 trials will advance the task to OS5C (+, 0, Δ, Z, □) 1/4 sec delay.

6. OS5C (+, 0, Δ, Z, □) delayed matching progression. This task is similar to the preceding task, however, the COT will occur following the delay and before the onset of the choice symbols. There will be an option to increase the duration of the COT to 1 sec. A performance of 22 correct during a block of 25 trials will advance the delay between the sample phase and choice phase of the trial through the following time increment progression 0, 1/4, 1/2, 3/4, 1.0, 1.5, 2.0, 3.0, 5.0, 7.0, 10.0 sec. With an 80% correct performance during a 100 trial session with a 5 sec delay the progression will be repeated with the response schedule requirement on the sample changed to CRF. With criterion performance at a 5 to 10 sec delay the S will advance to the next task.

7. TWS2C (+, 0) with white light as "interference" sample: two symbol matching task with white light as an interference sample. This task is similar to

the OS2C (+, 0) 1/4 sec delayed matching task but with an added "retroactive" interference sample in the sample phase. One quarter sec after the response schedule (tandem DRL 4"/FR3 in LH 5 sec) to the first sample symbol is completed, a white light sample appears on the sample key. A single press to this interference sample extinguishes the light and produces the 1/4 sec COT followed by the onset of choice symbols +, 0, randomly positioned on the five choice switches. No white light appears in choice phase of trial. 22 correct trials/25 trial block will advance S to TWS2 (+, 0) 1/4 sec delay. NOTE: The white light interference variable will be replaced by sample focus attenuation variable when available.

9. TWS2C (+, 0) 1/4 sec delay:

   a. The white light interference sample is replaced in this task by the second or alternate symbol so that both symbols (+, 0) are presented randomly in sequence during the sample phase. All other events are as in the above task. A 90% performance during a 100 trial session will advance the S to the next task.

   b. Reinforcement following the second correct choice: The sample phase of the task is like the TWS2C task above, however, during the choice phase of the paradigm the correct BP to the choice symbol which appeared previously as the first sample symbol of the sequence extinguishes only that symbol. The second choice symbol remains lighted. A BP to this symbol extinguishes it and initiates the reinforcement phase of the trial. Following three sessions of 100 trials/session with 90% correct performance, the S will be advanced to TWS2C (Δ, 0), (Δ, Z), (□, 0).

   c. TWS2C (Δ, 0), (Δ, Z), (□, 0). A 90% correct performance level for 100 trial sessions on each of these symbol configurations will advance the S to the TWS2C (+, 0, Δ, Z, □) task.

   d. TWS2C (+, 0, Δ, Z, □): This task is identical to the above tasks except that the symbol configurations used on each trial will be selected randomly from the five symbols +, 0, Δ, Z, □. 90% correct performance on two successive sessions of 100 trials each will advance the subject to the TWS3C task.

10. TWS3C (+, 0, Δ, Z, □) 1/4 sec delay: This task (delayed matching to two symbols with three choice symbols) is identical to the above task except that a third symbol (a confusion symbol) now appears in the choice phase though it has had no mate in the sample phase. A FR response schedule may be an added requirement to extinguish the second sample and the choice brightness attenuation procedures may be used for the confusion choice symbol. Reinforcement contingencies still occur at the BP emitted correctly to the second choice symbol and the confusion choice symbol extinguishes simultaneously. 90% correct performance on two successive sessions of 100 trials where no attenuation is used will advance the S to TWS4C task.

11. TWS4C (+, 0, Δ, Z, □) 1/4 sec delay: This task (delayed matching to two sample with four choice symbols) is as the above task except two confusion choice symbols are present in the choice phase of the trial. No attenuation procedures are used. 90% correct performance on one session of 100 trials will advance the S to TWS5C.

12. TWS5C (+, 0, Δ, Z, □) 1/4 sec delay: This matching to two sample with five choice symbols task is as the above task except three confusion symbols are used in the choice phase. 90% correct performance on a session of 100 trials to TWS5C with a delay progression.

13. TWS5C delayed matching progression: This task is similar to the preceding task; however, the COT will occur following the delay and before the onset of the choice symbols. There will be an option to increase the duration of the COT to 1 sec. A performance of 22 correct during a block of 25 trials will advance the delay between the sample phase and the choice phase of the trial through the following time increment progression: 0, 1/4, 1/2, 3/4, 1.0, 1.5, 2.0, 3.0, 5.0, 7.0, 10.0 sec. With 80% correct performance during a 100 trial session with a 5 to 10 sec delay the task delay progression will be repeated with the response schedule requirements changes to CRF and the 1/4 sec ISI increase to 1/2 sec of 1 sec. Criterion performance with the longer delays will advance S to the next task.

14. THS5C, F6S5C, F1S5C: The training paradigms to acquire the delayed matching to three, four and five samples will follow the same logical progression as the OS5C, and the TWS5C tasks. However, additional response schedule requirements to the sample symbols and lower criterion performance requirements may be used.

APPENDIX A, PART III

PRELIMINARY ENVIRONMENTAL CONTROL TRAINING PROTOCOL

I. HOUSELIGHT CONTROL

1.0 Button-pressing established; begin deprivation. Deprive subjects for two (2) days prior to commencement of booth training.

1.1 During initial button-pressing and simple operant schedule phases of this training at least 75% of the subject's daily kcal requirement shall be earned through performance.

1.2 Following criterial phases of self-control of environmental parameters a selective decrease in the amount of deprivation can proceed to a point ultimately where no food is earned by the performance of environmental control.

2.0 Set environmental parameters and feeder schedule.

2.1 Preselect light task only; set feeder schedule at CRF.

2.2 Set light level manually at minimum.

2.3 Set light increment/decrement at maximum step size.

2.4 Arm light and reinforcement switches for two immediate reinforcements.

2.5 Allow subject to perform light/feeder task chain CRF/CRF (this is called a simple chained schedule). A response to either lighted light-control switches, arms the feeder switch (red light on) and a response to this switch dispenses a pellet. After the light level steps from minimum both increase and decrease colors should be on and switches armed.

2.6 When the light level reaches maximum, the increase switch should go off automatically leaving only the decrease switch armed.

3.0 Light/feeder schedule changes.

3.1 Once the subject has traversed the house light range four times <u>OR</u> has elected to alternate between light levels to arm the feeder the increment/decrement steps should be reduced one-half of maximum and the light/feeder schedule changed to ch. (FR2/CRF). This chained schedule requires that any combination of two responses on one or both light switches alters the light level and arms the feeder light.

3.2 Twenty (20) reinforcements (S^R) from this schedule advances the subject to one-fourth maximum step setting on the light scale and alters the schedule to ch. (FR4/FR4).

3.2.1 The next schedule following 20 reinforcements from the schedule of 3.2 is: ch. (FR10/FR10) step setting 1/8 scale. 20 reinforcements advances subject to:

3.2.2 CH (FR10/VI30") step setting 1/16th scale. 20 S^R advances to:

3.2.3 CH. (FR10/VI 1 min) 1/16th step setting.

4.0 Houselight readjustment following stable baseline.

4.1 If within section 3.2.3, the subject has maintained a light level within 10% of the full light range, the operator should manually reduce the light level to the minimum, switch the feeder schedule VI 3 min and allow the subject to readjust the light level to its desired baseline level for at least 10 reinforcements.

4.2 After two such operations, the operator should manually switch the house light level to maximum on the same feeder schedule and again allow the subject to return to baseline.

5.0 Feeder schedule phaseout.

5.1 After the subject has completed a satisfactory baseline of 10% of light range on the foregoing schedules, he should be advanced gradually to:

5.2 A feeder schedule of VI 10'. If the light level baseline is still nominal for 20 min, the feeder schedule and button should be inhibited.

5.3 This program should prevail for repeat operations of 4.1 without the feeder schedule.

NOTE: The light control switches shall always be armed even while the feeder switch is armed.

II. TEMPERATURE CONTROL

1.0 Temp./feeder schedules.

1.1 Ch. FR5/VI 1 min step setting at maximum increment and decrement. 10 reinforcements advance to:

1.2 Ch. FR10/VI 1 min. Step setting 1/2 max. 10 reinforcements advance to:

1.3 Ch.FR10/VI 1 min. Step setting 1/4 max. 10 reinforcements advance to:

1.4 Ch. FR10/VI 1 min. Step setting 1/8 max. 10 reinforcements advance to:

1.5 Ch. FR10/VI 3 min. Step setting 1/16 max. 4 reinforcements advance to:

1.6 Ch. FR10/VI 10 min. Step setting 1/16 max. 4 reinforcements.

2.0 The subject should proceed from this point to section 4.0 of the house light control procedure with the replacement of light changes by temperature changes. This should follow to the end of section 5.0.

APPENDIX B

PRIMATE INSERTED SYSTEM TEST SPECIFICATIONS

PRIMATE INSERTED SYSTEM TEST SPECIFICATION

I. TEST DESCRIPTION

The primary purpose of the test is to determine primate adaptability to the proposed experimental conditions while demonstrating the feasibility of each available flight configured support subsystem. For this purpose, one complete trimester of the flight will be simulated, adhering as closely as possible to the experiment definition and mission sequence specified in the interface document.

II. TEST LOCATION

The test will be conducted in the isolation chamber located in the basement of Slichter Hall. Total primate isolation throughout the system test is planned.

III. TEST DURATION

The duration of the test is scheduled to be no less than 30 days. If conditions exist to allow test continuation, the test will be extended on a day by day basis contingent upon approval by the Project Scientist, Project Engineer and Research Manager.

IV. PRIMATE INTERFACE

A. Test Subject

The chimpanzee named Charlie has been designated as the test subject (head electrode implantation and headcap structure are complete). This chimpanzee was also the subject of the system test conducted in October of 1969.

B. Food

There will be a singular diet formulation supplied in the form of dry pellets to the primate. At the successful completion of a behavioral task, one pellet will be dispensed to the primate. The diet to be utilized in this test will be Purina Monkey Chow; the ingredients of which are presented below:

<u>Ingredients</u>

Ground wheat

Dehydrated alfalfa meal preserved with ethoxyquin

Ground yellow corn

Dried skimmed milk

Soybean meal

Sucrose

Animal fat preserved with BHA

Fish meal

Brewers' dried yeast

Vitamin B_{12} supplement

Riboflavin supplement

Methionine hydroxy analogue calcium

Calcium pantothenate

Niacin

Folic acid

Pyridoxine hydrochloride

Thiamin

Ascorbic acid

Vitamin A supplement

D activated animal sterol (source of Vitamin D)

Steamed bone meal

Vitamin E supplement

Calcium carbonate

Dicalcium phosphate

Iodized salt

Iron oxide

Manganous oxide

Copper oxide

Cobalt carbonate

Zinc oxide

Guaranteed Analysis

Crude protein not less than 15.0%

Crude fat not less than 5.0%

Crude fiber not more than 3.0%

Added minerals not more than 3.0%

The pellets shall conform to the following specifications:

Weight : 1.3 grams

Caloric Content : 5.4 Kcals/pellet

Dimensions : 0.62 inch, spherical diameter

The feeder capacity shall be no less than 12,000 pellets.

C. Water

The only liquid to be available for primate consumption during the test shall be water. Water will be presented on an ad lib basis requiring primate switch depression and suction for delivery. Water may be obtained by the primate only for the duration of the water switch depression.

The quantity of water consumed by the primate will be monitored hourly to within ±5 ml. In addition, the water activation event signal will be recorded continuously.

The temperature of the water delivered to the primate shall be between 55°F and 80°F. The suction required for operation of the water dispenser shall be between 22 and 40 torrs. The water flow rate over the range of required suctions will be no less than 0.2 ml/sec and no greater than 0.7 ml/sec.

D. Atmosphere

The test will be conducted in a controlled, open, non-recirculated atmosphere. The environmental control limits shall be as follows:

1. Relative Humidity : 35 - 70 percent

2. Temperature in Life Cell : 76°F $^{+5}_{-1}$°F

76°F ±5°F when primate controlled

3. Gas Flow Rate into Life Cell : 160 ft^3/min

E. Behavioral Tasks

A variety of behavioral tasks will be presented to the primate of varying degree of difficulty. Behavioral Task sessions of 100 trials each will be monitored and scored in banks of 25 trials to determine the particular task to be presented to the primate in the subsequent 25 trial bank. For detail task description, please refer to the interface document.

Table I - Behavioral Task Nomenclature*

Nomenclature	Description
R1	Reinforcement Button Task: Event I Duration = 60 secs
R2	Reinforcement Button Task: Event I Duration = 50 secs
R3	Reinforcement Button Task: Event I Duration = 40 secs
R4	Reinforcement Button Task: Event I Duration = 30 secs
R5	Reinforcement Button Task: Event I Duration = 20 secs
R6	Reinforcement Button Task: Event I Duration = 10 secs
OS1	One Symbol Random Task: Event III Duration = 1 sec
OS2	One Symbol Random Task: Event III Duration = 2 secs
OS3	One Symbol Random Task: Event III Duration = 5 secs

*MSS behavioral tasks may have one through five choice symbols; nomenclature in Table I refers to number of sample symbols in task.

TABLE 1 (cont)

Nomenclature	Description
TWS1	Two symbol Random, Matching to Successive Sample Task: Intersymbol Interval = 1/4 sec; Delay Between Sample Presentation "OFF" and Response Orientation Cue = 50 msecs
TWS2	Intersymbol Interval = 0.5 sec; Delay = 0.5 sec
TWS3	Intersymbol Interval = 1.0 sec; Delay = 1.0 sec
TWS4	Intersymbol Interval = 1.0 sec; Delay = 2.0 secs
TWS5	Intersymbol Interval = 1.0 sec; Delay = 3.0 secs
TWS6	Intersymbol Interval = 1.0 sec; Delay = 4.0 secs
TWS7	Intersymbol Interval = 1.0 sec; Delay = 5.0 secs
TWS8	Intersymbol Interval = 1.0 sec; Delay = 6.0 secs
TWS9	Intersymbol Interval = 1.0 sec; Delay = 7.0 secs
TWS10	Intersymbol Interval = 1.0 sec; Delay = 8.0 secs
TWS11	Intersymbol Interval = 1.0 sec; Delay = 9.0 secs
TWS12	Intersymbol Interval = 1.0 sec; Delay = 10.0 secs
THS1	Three Symbol Random, Matching to Successive Sample Task: Intersymbol Interval = 1/4 sec; Delay Between Sample Presentation "OFF" and Response Orientation Cue = 50 msecs
THS2	Intersymbol Interval = 0.5 sec; Delay = 0.5 sec
THS3	Intersymbol Interval = 1.0 sec; Delay = 1.0 sec
THS4	Intersymbol Interval = 1.0 sec; Delay = 2.0 secs
THS5	Intersymbol Interval = 1.0 sec; Delay = 3.0 secs
THS6	Intersymbol Interval = 1.0 sec; Delay = 4.0 secs
THS7	Intersymbol Interval = 1.0 sec; Delay = 5.0 secs
THS8	Intersymbol Interval = 1.0 sec; Delay = 6.0 secs

TABLE 1 (cont)

Nomenclature	Description
FIS6	Intersymbol Interval = 1.0 sec; Delay = 4.0 secs
FIS7	Intersymbol Interval = 1.0 sec; Delay = 5.0 secs
FIS8	Intersymbol Interval = 1.0 sec; Delay = 6.0 secs
FIS9	Intersymbol Interval = 1.0 sec; Delay = 7.0 secs
FIS10	Intersymbol Interval = 1.0 sec; Delay = 8.0 secs
FIS11	Intersymbol Interval = 1.0 sec; Delay = 9.0 secs
FIS12	Intersymbol Interval = 1.0 sec; Delay = 10.0 secs

1. Behavioral Task Presentation Criteria

The first behavioral task presented to the primate at the start of each phase of the test is the reinforcement button press task (R1). The task progression from task R1 through R6 to OS1C1 will be contingent on the primate's response latency scores, defined as the time from trial onset to reinforcement switch depression. During the initial bank of trials, task R1 will be presented to the primate (Event I, duration = 60 seconds). The criteria for determining the subsequent tasks are as follows:

a. If the primate performs successfully (latency scores equal to or less than Event I duration) on 22 or more of the 25 trials, he shall advance to the reinforcement task that has an Event I duration within which have occurred no less than 15 of 25 of his response latency scores.

b. If on any given R task the primate successfully performs on 15 to 21 of 25 trials, then the same R task will be presented on the subsequent bank of trials.

c. If the primate performs successfully on less than 15 of 25 trials for any R task, R2 through R6, then on the next bank of trials, he shall revert to an R task that has an Event I duration 10 seconds longer than the previous R task. (60 seconds is maximum Event I duration, 10 seconds is the minimum Event I duration).

d. The performance criterion to advance the task to OS1C1 with a switch depression opportunity time of 10 seconds will be 12 successive banks of 25 trials where the animal has averaged greater than 90 percent successful responses to the reinforcement switch on task R6. If the subject does not meet the above criterion within 108 banks then he will be presented successive banks of task R5. The subject will advance to task OS1C1 with a switch depression opportunity time of 20 seconds only if he averages on 12 successive banks greater than 90 percent successful responses and that his latency scores on 75 percent of the trials of the banks are equal to or less than 10 seconds. The subject will remain on task R5 until criterion is reached or unless performance is such to warrant the presentation of task R4 to R1.

Table II - Task Presentation Criterion

Behavioral Task	Performance - Subsequent Behavioral Task 22/25	17 to 21/25	0 to 16/25
OS1C1	OS1C2	OS1C1	OS1C1
OS1C2	OS1C3	OS1C2	OS1C1
OS1C3	OS5C1	OS1C3	OS1C2
OS2C1	OS2C2	OS2C1	OS1C3
OS2C2	OS2C3	OS2C2	OS2C1
OS2C3	OS5C1	OS2C3	OS2C2
OS5C1	OS5C2	OS5C1	OS2C1
OS5C2	OS5C3	OS5C2	OS5C1
OS5C3	TWS2C1	OS5C3	OS5C2

Behavioral Task	Performance - Subsequent Behavioral Task 21/25	16 to 20/25	0 to 15/25
TWS2C1	TWS2C3	TWS2C1	OS5C3
TWS2C2	TWS2C3	TWS2C2	TWS2C1
TWS2C3	TWS2C5	TWS2C3	TWS2C2
TWS2C4	TWS2C5	TWS2C4	TWS2C3
TWS2C5	TWS2C7	TWS2C5	TWS2C4
TWS2C6	TWS2C7	TWS2C6	TWS2C5
TWS2C7	TWS2C9	TWS2C7	TWS2C6
TWS2C8	TWS2C9	TWS2C8	TWS2C7
TWS2C9	TWS2C12	TWS2C9	TWS2C8
TWS2C10	TWS2C11	TWS2C10	TWS2C9
TWS2C11	TWS2C12	TWS2C11	TWS2C10
TWS2C12	TWS5C1	TWS2C12	TWS2C11
TWS3C1	TWS3C3	TWS3C1	TWS2C12
TWS3C2	TWS3C3	TWS3C2	TWS3C1
TWS3C3	TWS3C5	TWS3C3	TWS3C2
TWS3C4	TWS3C5	TWS3C4	TWS3C3
TWS3C5	TWS3C7	TWS3C5	TWS3C4
TWS3C6	TWS3C7	TWS3C6	TWS3C5
TWS3C7	TWS3C9	TWS3C7	TWS3C6
TWS3C8	TWS3C9	TWS3C8	TWS3C7
TWS3C9	TWS3C12	TWS3C9	TWS3C8
TWS3C10	TWS3C11	TWS3C10	TWS3C9

Behavioral Task	Performance - Subsequent Behavioral Task 21/25	16 to 20/25	0 to 15/25
TWS3C11	TWS3C12	TWS3C11	TWS3C10
TWS3C12	TWS5C1	TWS3C12	TWS3C11
TWS5C1	TWS5C3	TWS5C1	TWS3C12
TWS5C2	TWS5C3	TWS5C2	TWS5C1
TWS5C3	TWS5C5	TWS5C3	TWS5C2
TWS5C4	TWS5C5	TWS5C4	TWS5C3
TWS5C5	TWS5C7	TWS5C5	TWS5C4
TWS5C6	TWS5C7	TWS5C6	TWS5C5
TWS5C7	TWS5C9	TWS5C7	TWS5C6
TWS5C8	TWS5C9	TWS5C8	TWS5C7
TWS5C9	TWS5C12	TWS5C9	TWS5C8
TWS5C10	TWS5C11	TWS5C10	TWS5C9
TWS5C11	TWS5C12	TWS5C11	TWS5C10
TWS5C12	TWS3C1	TWS5C12	TWS5C11

Behavioral Task	Performance - Subsequent Behavioral Task 19/25	14 to 18/25	0 to 13/25
THS3C1	THS3C3	THS3C1	TWS5C12
THS3C2	THS3C3	THS3C2	THS3C1
THS3C3	THS3C5	THS3C3	THS3C2
THS3C4	THS3C5	THS3C4	THS3C3
THS3C5	THS3C7	THS3C5	THS3C4
THS3C6	THS3C7	THS3C6	THS3C5
THS3C7	THS3C9	THS3C7	THS3C6
THS3C8	THS3C9	THS3C8	THS3C7
THS3C9	THS3C12	THS3C9	THS3C8
THS3C10	THS3C11	THS3C10	THS3C9
THS3C11	THS3C12	THS3C11	THS3C10
THS3C12	THS5C1	THS3C12	THS3C11
THS4C1	THS4C3	THS4C1	THS3C12
THS4C2	THS4C3	THS4C2	THS4C1
THS4C3	THS4C5	THS4C3	THS4C2
THS4C4	THS4C5	THS4C4	THS4C3
THS4C5	THS4C7	THS4C5	THS4C4
THS4C6	THS4C7	THS4C6	THS4C5
THS4C7	THS4C9	THS4C7	THS4C6
THS4C8	THS4C9	THS4C8	THS4C7
THS4C9	THS4C12	THS4C9	THS4C8
THS4C10	THS4C11	THS4C10	THS4C9

Behavioral Task	Performance - Subsequent Behavioral Task 19/25	14 to 18/25	0 to 13/25
THS4C11	THS4C12	THS4C11	THS4C10
THS4C12	THS5C1	THS4C12	THS4C11
THS5C1	THS5C3	THS5C1	THS4C12
THS5C2	THS5C3	THS5C2	THS5C1
THS5C3	THS5C5	THS5C3	THS5C2
THS5C4	THS5C5	THS5C4	THS5C3
THS5C5	THS5C7	THS5C5	THS5C4
THS5C6	THS5C7	THS5C6	THS5C5
THS5C7	THS5C9	THS5C7	THS5C6
THS5C8	THS5C9	THS5C8	THS5C7
THS5C9	THS5C12	THS5C9	THS5C8
THS5C10	THS5C11	THS5C10	THS5C9
THS5C11	THS5C12	THS5C11	THS5C10
THS5C12	FOS4C1	THS5C12	THS5C11

Behavioral Task	Performance - Subsequent Behavioral Task 16/25	10 to 15/25	0 to 9/25
FOS4C1	FOS4C3	FOS4C1	THS5C12
FOS4C2	FOS4C3	FOS4C2	FOS4C1
FOS4C3	FOS4C5	FOS4C3	FOS4C2
FOS4C4	FOS4C5	FOS4C4	FOS4C3
FOS4C5	FOS4C7	FOS4C5	FOS4C4
FOS4C6	FOS4C7	FOS4C6	FOS4C5
FOS4C7	FOS4C9	FOS4C7	FOS4C6
FOS4C8	FOS4C9	FOS4C8	FOS4C7
FOS4C9	FOS4C12	FOS4C9	FOS4C8
FOS4C10	FOS4C11	FOS4C10	FOS4C9
FOS4C11	FOS4C12	FOS4C11	FOS4C10
FOS4C12	FOS5C1	FOS4C12	FOS4C11
FOS5C1	FOS5C3	FOS5C1	FOS4C12
FOS5C2	FOS5C3	FOS5C2	FOS5C1
FOS5C3	FOS5C5	FOS5C3	FOS5C2
FOS5C4	FOS5C5	FOS5C4	FOS5C3
FOS5C5	FOS5C7	FOS5C5	FOS5C4
FOS5C6	FOS5C7	FOS5C6	FOS5C5
FOS5C7	FOS5C9	FOS5C7	FOS5C6
FOS5C8	FOS5C9	FOS5C8	FOS5C7
FOS5C9	FOS5C12	FOS5C9	FOS5C8
FOS5C10	FOS5C11	FOS5C10	FOS5C9
FOS5C11	FOS5C12	FOS5C11	FOS5C10
FOS5C12	FIS5C1	FOS5C12	FOS5C11

Behavioral Task	Performance - Subsequent Behavioral Task 12/25	6 to 11/25	0 to 5/25
FIS5C1	FIS5C3	FIS5C1	FOS5C12
FIS5C2	FIS5C3	FIS5C2	FIS5C1
FIS5C3	FIS5C5	FIS5C3	FIS5C2
FIS5C4	FIS5C5	FIS5C4	FIS5C3
FIS5C5	FIS5C7	FIS5C5	FIS5C4
FIS5C6	FIS5C7	FIS5C6	FIS5C5
FIS5C7	FIS5C9	FIS5C7	FIS5C6
FIS5C8	FIS5C9	FIS5C8	FIS5C7
FIS5C9	FIS5C12	FIS5C9	FIS5C8
FIS5C10	FIS5C11	FIS5C10	FIS5C9
FIS5C11	FIS5C12	FIS5C11	FIS5C10
FIS5C12	FIS5C12	FIS5C12	FIS5C11

At the completion of each test phase, the behavioral task program will re-cycle and start again at task R1. The automatic task progression criteria will be supplemented by an overriding capability of the test control center to initiate any of the tasks or terminate any behavioral session.

F. Environmental Tasks

At select periods during the test, certain environmental controls will be given to the subject as specified in the test sequence. These controls are summarized below:

1. Life Cell Temperature : 71°F to 81°F (fixed ratio to initiate)
2. Lighting Intensity : 0 to 35 foot-candles (fixed ratio to initiate)
3. Behavioral Session Self Initiate (fixed ratio to initiate)
4. Auditory Reinforcement (DRH to initiate)

G. Physiological Data Acquisition Requirements

1. Lt. Occ. - Rt. Occ. EEG
2. Lt. Occ. - Lt. Par. EEG
3. Lt. Red Nucl. EEG
4. Rt. Hipp. EEG
5. RCM EEG
6. Rt. Amyg. EEG
7. EOG
8. EMG
9. Core Temp.
10. Heart Rate

Totally implantable telemetry systems will be used to gather information from the central and peripheral nervous system and cardiovascular system. The telemetry system will be divided into two separate independent units; one attached to the subject's existing headcap to obtain nervous system data, and the other surgically implanted in the animal to obtain cardiovascular data. The University of Southern California will be responsible for the cardiovascular telemetry unit.

H. Acoustic Considerations

The primate inserted system test will be conducted in a totally isolated environment. The primate will be subjected to only those sounds associated with the behavioral tasks and life support equipment.

The total continuous sound pressure level during the test at any point within the life cell shall not be greater than 75 dB (not including behavioral task tones). Excursions not lasting more than 30 seconds may reach a sound pressure level of 100 dB during the "day" cycle only.

I. Test Sequence

The test sequence will follow the proposed mission sequence as specified in Revision I of the interface document with a time scaling of one-half (60 day trimester to be simulated in 30 days).

The simulated flight trimester is divided into 3 phases as summarized below:

<u>Phase A (Day 1 through 10)</u>

Day 1 through 5 : a) 12 hours light, 12 hours dark

b) three behavioral sessions of 100 trials each presented at scheduled times during the "day"

Day 1 through 5 : c) temperature controlled by experimenter 76°F to 81°F

Day 6 through 10 : a) 12 hours light, 12 hours dark

b) behavioral sessions primate initiated during light (100 trials/session)

c) temperature controlled by experimenter

Phase B (Day 11 through 20)

Day 11 through 15 : a) primate lighting control

b) behavioral sessions primate initiated

c) temperature controlled by experimenter

Day 16 through 20 : a) primate lighting control

b) behavioral sessions primate initiated

c) primate temperature control - 71°F to 81°F

Phase C (Day 21 through 30)

Day 21 through 25 : a) 24 hours continuous light (at primate's desired intensity)

b) behavioral sessions primate initiated

c) primate temperature control

Day 26 through 30 : a) 24 hours continuous light

b) behavioral sessions primate initiated

c) temperature controlled by experimenter (at primate's desired temperature)

Figure 1 represents the test sequence.

Should the test duration be extended beyond 30 days, the second trimester of the flight will be simulated beginning with Phase A of trimester II. A more

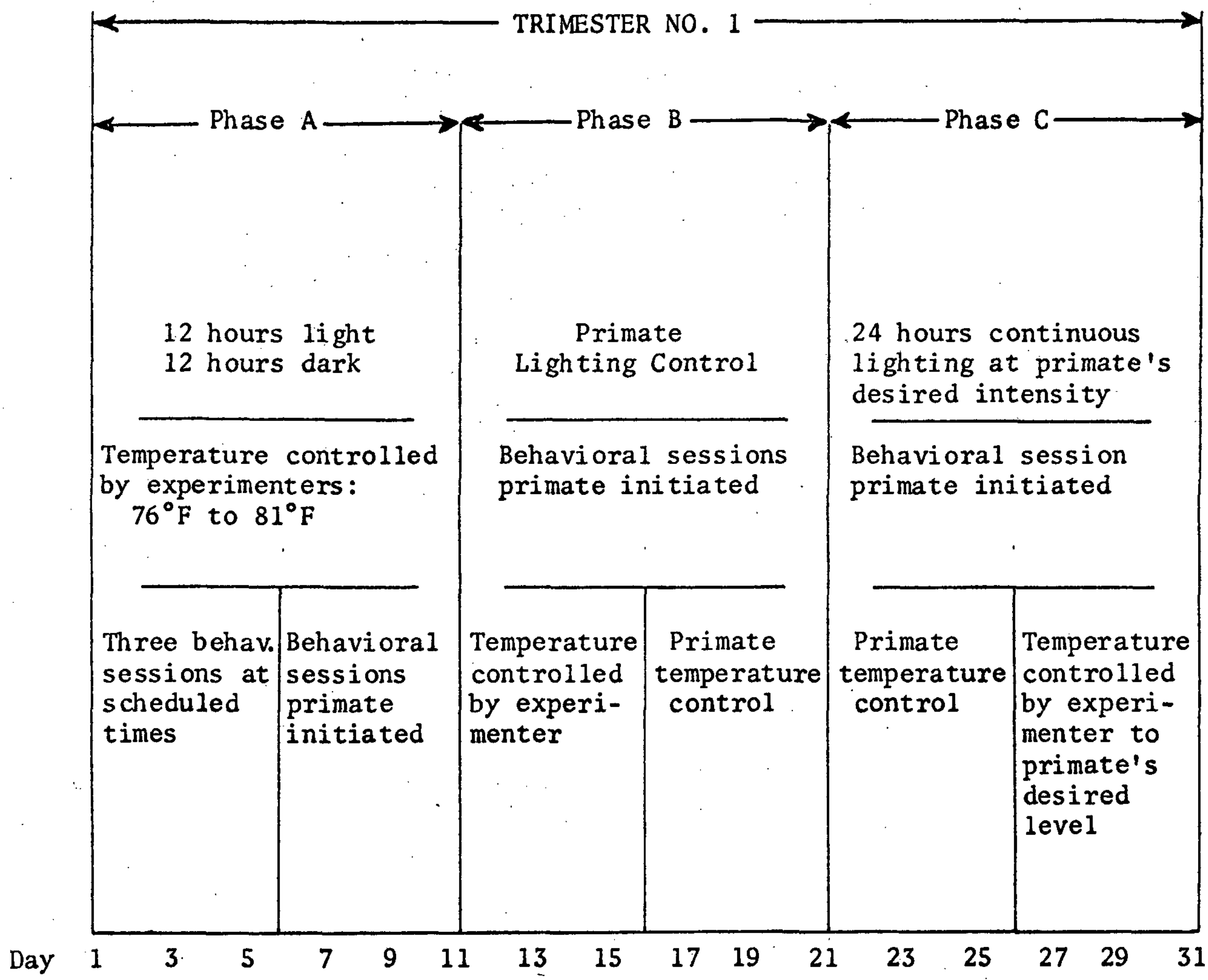


Figure 1

TEST SEQUENCE

detailed description of the test sequence is shown below:

Day 1 through 5

PDT

0700 Lights on

0900 Behavioral session #1

Waste management flush, 5 minutes after behavioral session completion

1200 Behavioral session #2

1500 Behavioral session #3

1900 Lights off

Day 6 through 10

0700 Lights on; primate behavioral session initiate switch on

Waste management flush, 5 minutes after completion of first behavioral session during which behavioral session initiate switch is off

1900 Lights off; primate behavioral session initiate switch off (behavioral session initiate switch is automatically turned off at beginning of third behavioral session). If three sessions are not initiated by 1900, then switch is extinguished at 1900.

Day 11 through 15

0700* Primate lighting control switches on; primate behavioral session initiate switch on (no longer limited to three sessions/day).

Waste management flush; 5 minutes after completion of first behavioral session during which behavioral session initiate switch is off

Day 16 through 20

** At onset of 16th circadian day, defined as subject's mid-activity point plus one-half of the circadian cycle, primate temperature control switches on

Waste management flush: 5 minutes after completion of first behavioral session during which behavioral session initiate switch is off

*Day 11 only
**Day 16 only

Day 21 through 25

PDT

* At onset of 21st circadian day, lights on; primate lighting control switches off

Waste management flush; 5 minutes after completion of first behavioral task during which behavioral session initiate switch is off

Day 26 through 30

** At onset of 26th circadian day, temperature controlled by experimenter; primate temperature control switches off

Waste management flush; 5 minutes after completion of behavioral session during which behavioral session initiate switch is off

In addition to the automatic data acquisition system, the following items will be manually recorded as described below:

1. Water intake - hourly
2. Subject position
3. Gross subject activities
4. Behavioral session times

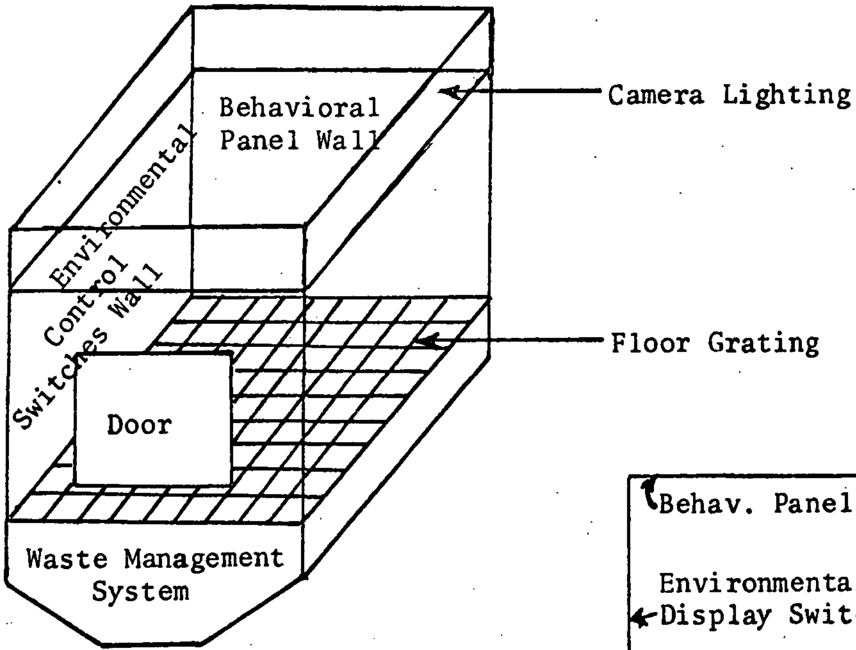
---

*Day 21 only
**Day 26 only

V. HARDWARE & INSTRUMENTATION

A. Life Cell

A cubical housing chamber with sides of 4 feet will be used for the test, providing an enclosed volume of 64 cubic feet. One wall of the life cell contains environmental control switches and water dispensers; an adjacent wall contains a flight configured behavioral panel and feeder, the bottom of the life cell consists of a supporting grate below which is located the waste management system, incorporated in the ceiling of the cell is the lighting and camera system (see Figure 2).



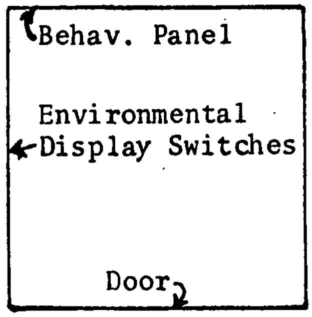


Figure 2

LIFE CELL

Top View

B. Environmental Control Display Switches

One wall of the life cell (see Figure 2) will be utilized to mount the environmental display switches. There shall be 18 circular switches, 2 for each of the 9 environmental control functions positioned on the mounting wall as shown in Figure 3. The switches functions, dimensions, and color are presented in Table III.

Table III

Switch Designation	Function	Color	Diameter	Shinkolite A Color Number
1	Decrease lighting intensity	Dark Blue	2.00 inches	302*
2	Increase lighting intensity	Yellow	2.00 inches	993*
3	Water dispenser	White	2.25 inches	432
4	Auditory enrichment	Purple	2.00 inches	375
5	Decrease temperature	Light Blue	2.00 inches	300*
6	Increase temperature	Orange	2.00 inches	264
7	Behavioral session initiate	Green	2.00 inches	343*
8	Not connected	Black	2.00 inches	502
9	Food reinforcement**	Red	2.25 inches	136

*colors are transparent and require the addition of a white translucent background
**to be non-operative during system test

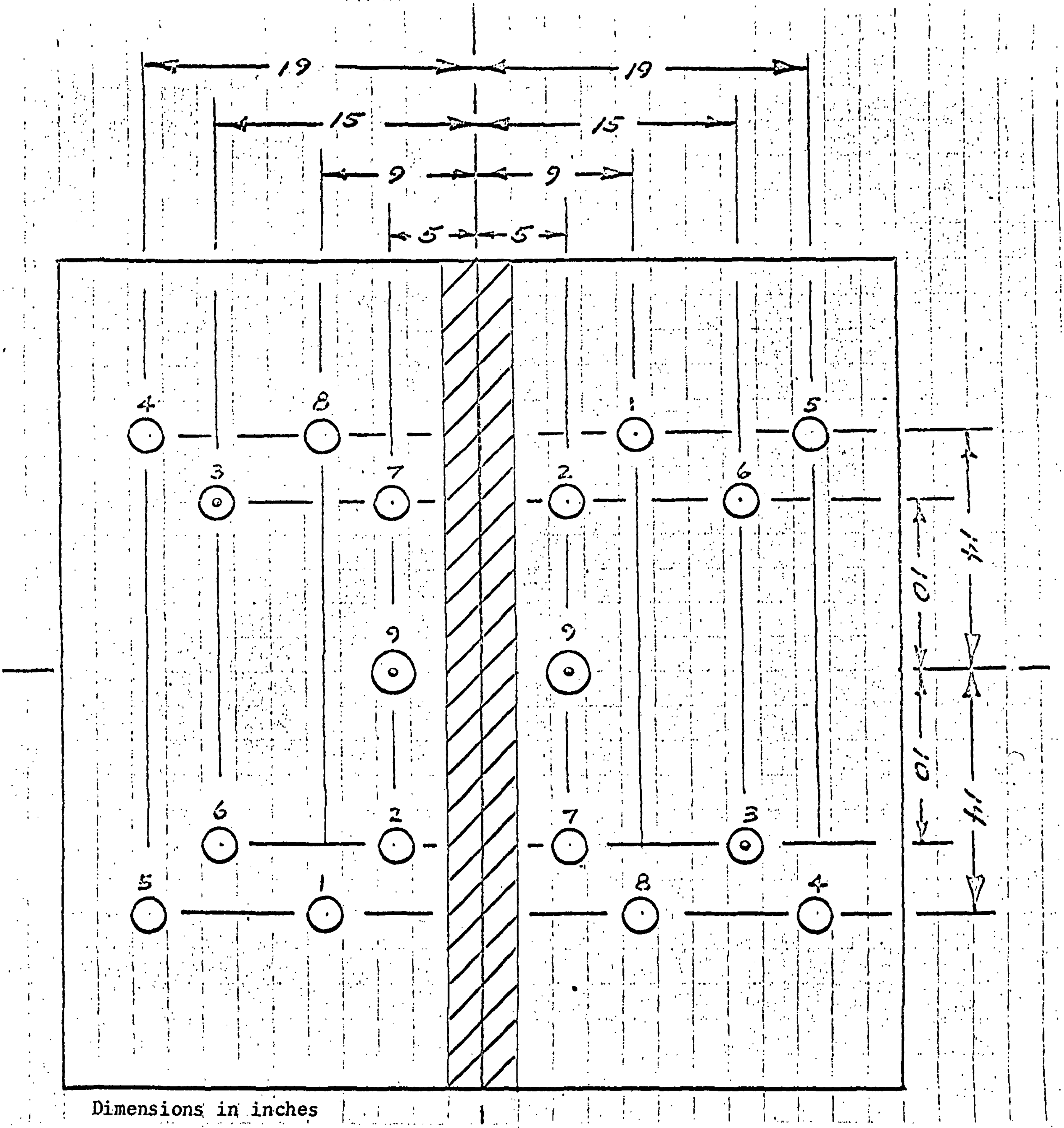


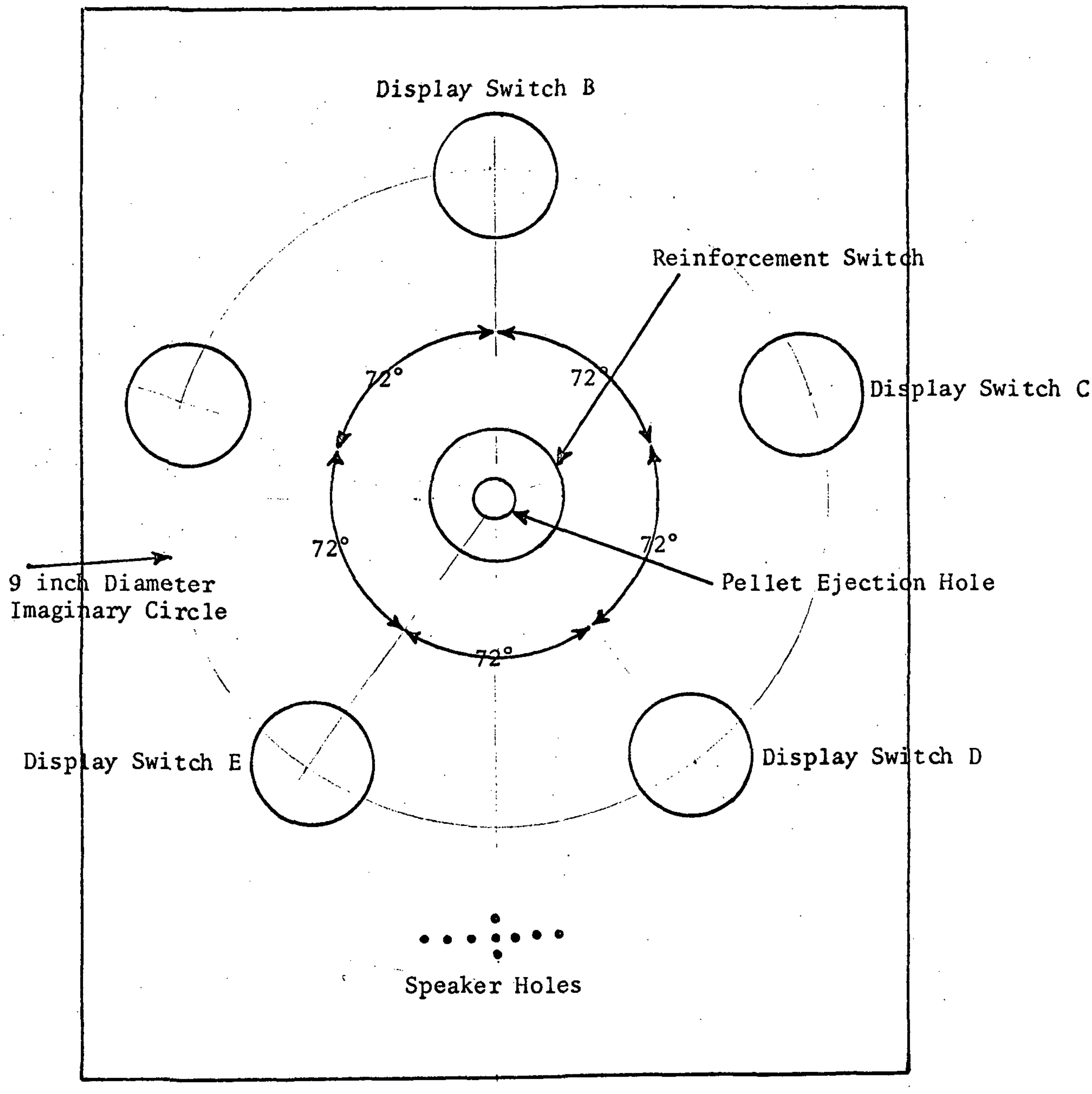
Figure 3

ENVIRONMENTAL CONTROL DISPLAY SWITCH LOCATION

C. Behavioral Display & Feeder

The mechanical configuration of the behavioral display panel is shown in Figure 4. The panel consists of five circular symbol display switches equally spaced along the circumference of an imaginary 9 inch diameter circle. A pellet ejection hole is located at the center of the imaginary 9 inch diameter circle and is surrounded by a circular reinforcement switch.

1. Switch size (non-displacement proximity)
   a. Display switch : 5.08 cm ±.051 cm
   b. Reinforcement switch : 5.715 cm ±.051 cm
2. Switch color
   a. Display switches : Clear (symbol projector to mount behind display switch)
   b. Reinforcement switch : Red (same as primary trainer)
3. Pellet ejection hole
   a. 2.0 cm ±0.1 cm diameter
4. Display symbols :
   a. Symbol size : 1 inch - IEE Projection Symbols
5. Panel mounting
   a. The panel shall be mounted in the life cell in place of the existing behavioral panel



Surface Color : Black

On back side of behavioral panel mount 1-45 pin male connector part no. FK-46-32S

Figure 4

BEHAVIORAL PANEL CONFIGURATION

D. Water Dispenser

Water will be available for primate consumption on an ad lib basis in response to a depression of either "water dispensation" switch. Water shall be available to the primate for the duration of switch depression.

There will be three containers for drinking water storage; a 5 gallon primary storage container and two 250 ml secondary storage containers. From primary storage, water enters the secondary containers via gravity feed from which the water is delivered to the two dispensing devices.

Once each hour, a test attendant will observe and document the water level in the two secondary containers (graduated cylinders), and fill the cylinders by opening a valve from the primary storage container. The primary and secondary containers will be located outside the isolation chamber so that acoustical isolation is maintained. The water from the secondary storage will be delivered to the dispensing nipples via tygon tubing. A solenoid valve will be actuated when the primate touches the "water dispensation" switch which will allow water to be delivered to the dispenser. The water level in the graduated cylinders will be slightly lower than the elevation of the two dispensers requiring suction from the animal for water delivery. (See Figure 5).

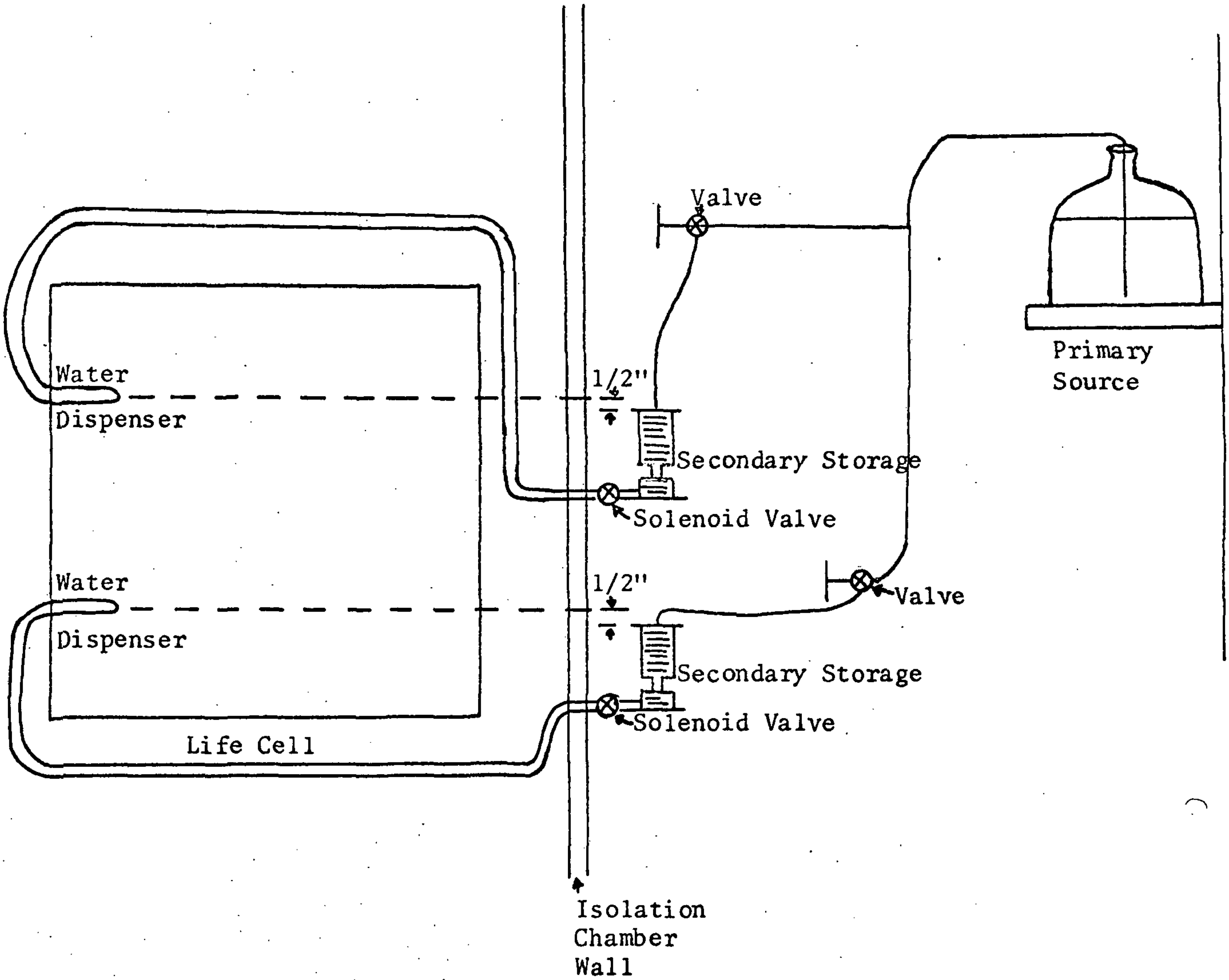


Figure 5

WATER DISPENSATION SYSTEM

E. Implantable Telemetry

1. Nervous System

An eight channel micropowered PAM/TIME SHARED/FM TELEMETRY SYSTEM shown in block diagram form in Figure 6 will be used for nervous system data acquisition.

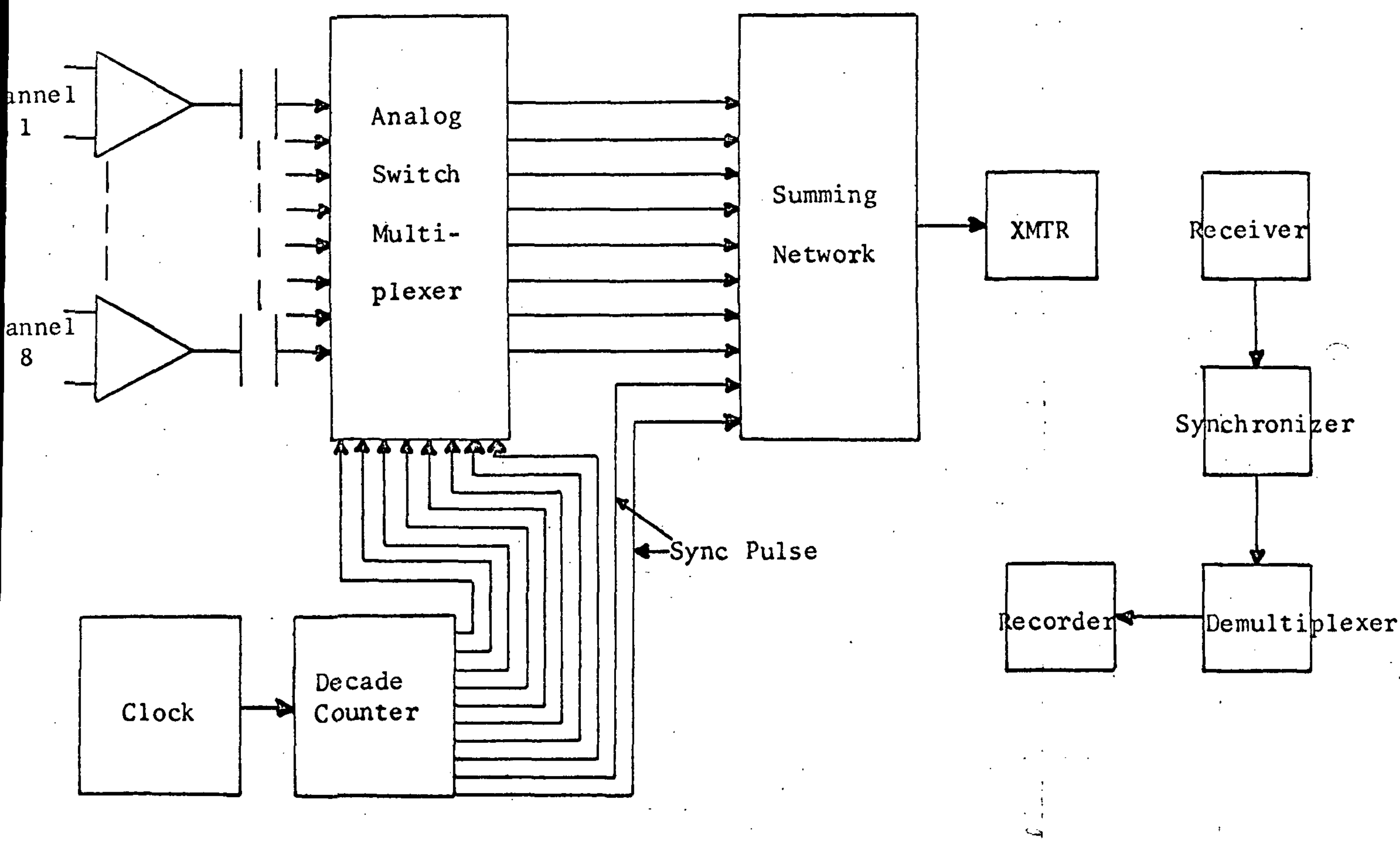


Figure 6

SYSTEM CONFIGURATION

Each differential amplifier is comprised of two Fairchild μA735 operational amplifiers connected in a voltage follower configuration, providing unity gain whose outputs are connected to a third Fairchild μA735 operational amplifier to provide the required channel amplification. The amplified outputs are AC coupled into an analog multiplexing unit being switched at a rate of 256 samples/second/channel via clock and decade counter. The multiplexer, clock and decade counter are micropowered complimentary metal oxide semiconductors manufactured by RCA. The outputs of the multiplexer are summed and fed into a FM transmitter. The signal is then received, synchronized, demultiplexed and recorded. The telemetry system fabricated for the system test shall conform to the following specifications:

1. Gain	:	1000 (variable)
2. Frequency Response	:	3 dB cutoff $\leq$0.65 Hz to 50 Hz (Limited by sampling rate of 256 sps)
3. Output Noise Referenced to Input (input shorted)	:	$\leq$3 μv peak-to-peak
4. Common Mode Rejection Rate	:	$\geq$82 dB
5. Input Impedance	:	$\geq$50 MΩ
6. Power Consumption	:	$\leq$550 μwatts from -2.5 v; $\leq$1550 μwatts from +2.5 v (220 μA @ neg. supply, 620 μA @ pos. supply)
7. Supply Voltage	:	$\pm$2.5 VDC (transmitter: +2.5 VDC only)
8. Frequency of Transmission	:	86 MHz
9. Transmitted Field Intensity (1 meter referred to 1μv, 50 Ω)	:	$\geq$60 dB

10. Transmitter Deviation Sensitivity : 15 μv/kHz

11. Adjacent Channel Crosstalk Isolation : ≥40 dB

The telemetry unit will be packaged to mate with the headcap configuration existing on the test subject (see Figure 7). The package configuration and dimensions are to be determined at a later date.

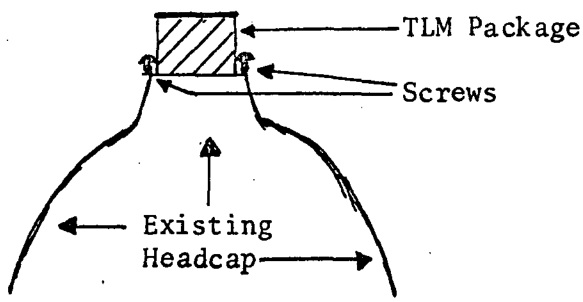


Figure 7

2. Cardiovascular System

The data acquisition from the cardiovascular system is the responsibility of the University of Southern California and will be integrated into the test specification at a later date. The system will be surgically implanted and will monitor heart rate and core temperature.

F. Waste Removal System

The waste removal system will be a gravity feed, water - disinfectant flushed unit. The existing floor grates in the isolation test booth will be replaced with a new grate having sufficiently wide spacing to allow solid fecal matter to drop through and fall upon the sloping sides of the waste collector. Two waste collector canisters will be located below the grate. At the bottom of the canisters will be 3 inch holes. Directly below these holes will be a stainless steel sheet metal funnel; the small end of which is connected to a 3 inch diameter plastic (vinyl) soil pipe.

The pipe will penetrate the wall of the isolation booth with a downward slope. A rubber stopper will be used to plug the soil pipe.

A sprinkler-type flushing system will be activated once a "day", synchronized with completion of the first behavioral session. Around the perimeter of the waste collection canisters, immediately below the floor grate will be a metal tube with an array of holes placed approximately an inch apart. The holes will be located so that the water emerging from them (under pressure) will impinge upon the surfaces of the waste collection canisters and carry feces and residual urine down the sloping sides and into the soil pipe. During system flushing, the stopper will be removed from the soil pipe and the waste will be collected.

G. Camera Subsystem

A television camera will be located above the life cell ceiling looking down at a rotatable mirror. The mirror shall be capable of rotating in two perpendicular axes so that all four walls and the floor may be observed, depending upon the position of the mirror. Camera operation is planned 24 hours per day.

H. Houselighting

Houselighting for the primate inserted system test will consist of four evenly spaced 50 watt incandescent bulbs. Below each bulb is a lucite window mounted on the ceiling of the life cell. The four lamps are to be connected in parallel and powered by a variac (variable transformer) to provide a variable level of illumination. The variac shaft is belt driven to a DC gear-motor which is driven by signals from the control console.

I. Behavioral Electronics

1. Behavioral Tasks

A combination of two existing major systems, the MSS console and the logic rack, plus additional interface hardware are required to present the full complement of behavioral tasks.

The logic rack will be used primarily for the following functions:

a. Reinforcement task presentation (task R1 through R6) with automatic task progression.

b. Test timer.

c. Behavioral task success monitor.

d. Test equipment status monitor and event coder.

The MSS console will be used to present behavioral tasks OS1C1 through FIS5C12 without automatic task progression, that is, an 100 trial behavioral session will be divided into four 25 trial "sessions" with the subsequent behavioral task definition manually entered into the MSS console after which the next session is immediately initiated. This will cause approximately a 1 minute delay between banks of 25 trials within the 100 trial session.

Design changes to the MSS console plus some additional interface hardware will be necessary to make the electronics compatible with the flight configured behavioral panel.

The system is shown in block diagram form in Figure 8a and 8b.

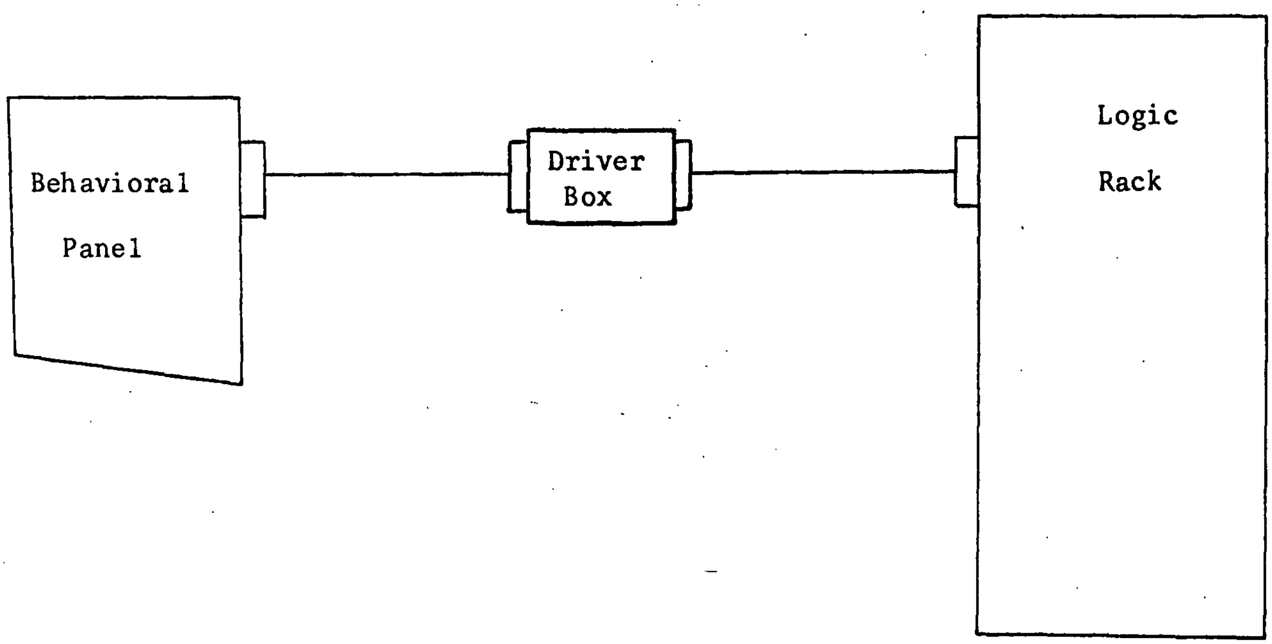


Figure 8a

BEHAVIORAL ELECTRONICS

BLOCK DIAGRAM TASKS R1 THROUGH R6

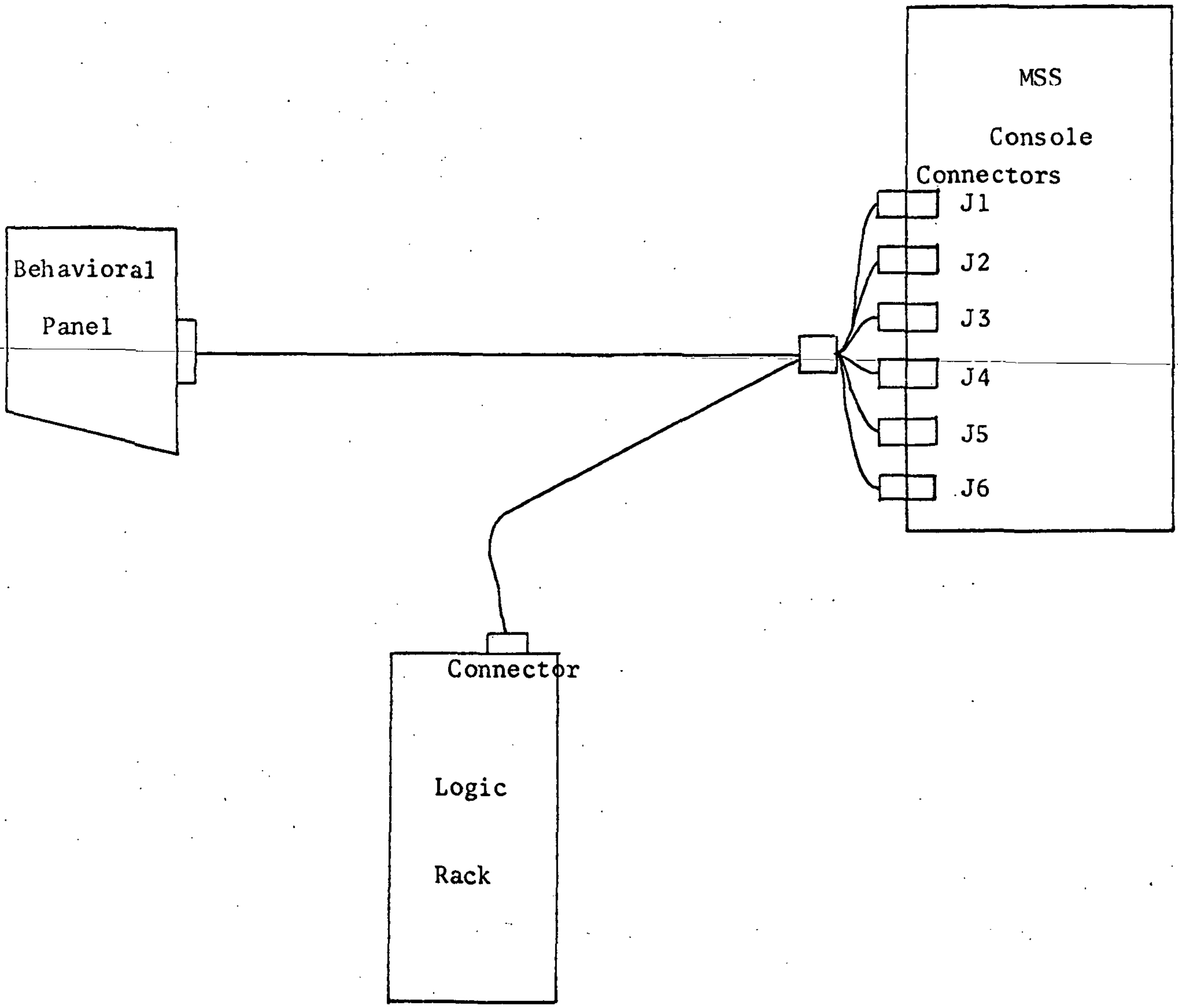


Figure 8b

BEHAVIORAL ELECTRONICS

BLOCK DIAGRAM TASKS OS1C1 THROUGH FIS5C12

2. Environmental Tasks

A separate independent unit known as the Environmental Console will be utilized to offer the primate temperature, lighting intensity and audio control. The events occurring in the environmental electronics as well as events from other support subsystems will be monitored by use of the logic rack.

VI. DATA ACQUISITION

A. Data Acquisition Parameters

The following parameters will be monitored throughout the system test:

1. Telemetry
   - a. Lt. Occ. - Rt. Occ. EEG
   - b. Lt. Occ. - Lt. Par. EEG
   - c. Lt. Red Nucl. EEG
   - d. Rt. Amyg. EEG
   - e. Rt. Hipp. EEG
   - f. RCM EEG
   - g. EOG
   - h. EMG
   - i. Heart Rate
   - *J. Core Temp
2. Hardwire
   - a. Time Code
   - b. Life Cell Temperature

*Optional - may not be implemented for this system test

c. Life Cell Lighting Intensity

d. Water Intake (hourly)

e. Life Cell Humidity

f. Urination Occurrence/Duration

g. Behavioral Task Event Code

h. Life Cell Auditory Level

i. Environmental Task Event Code

   1. Temperature "Up" Change

   2. Temperature "Down" Change

   3. Light Intensity "Up" Change

   4. Light Intensity "Down" Change

   5. Self Behavioral Task Initiate

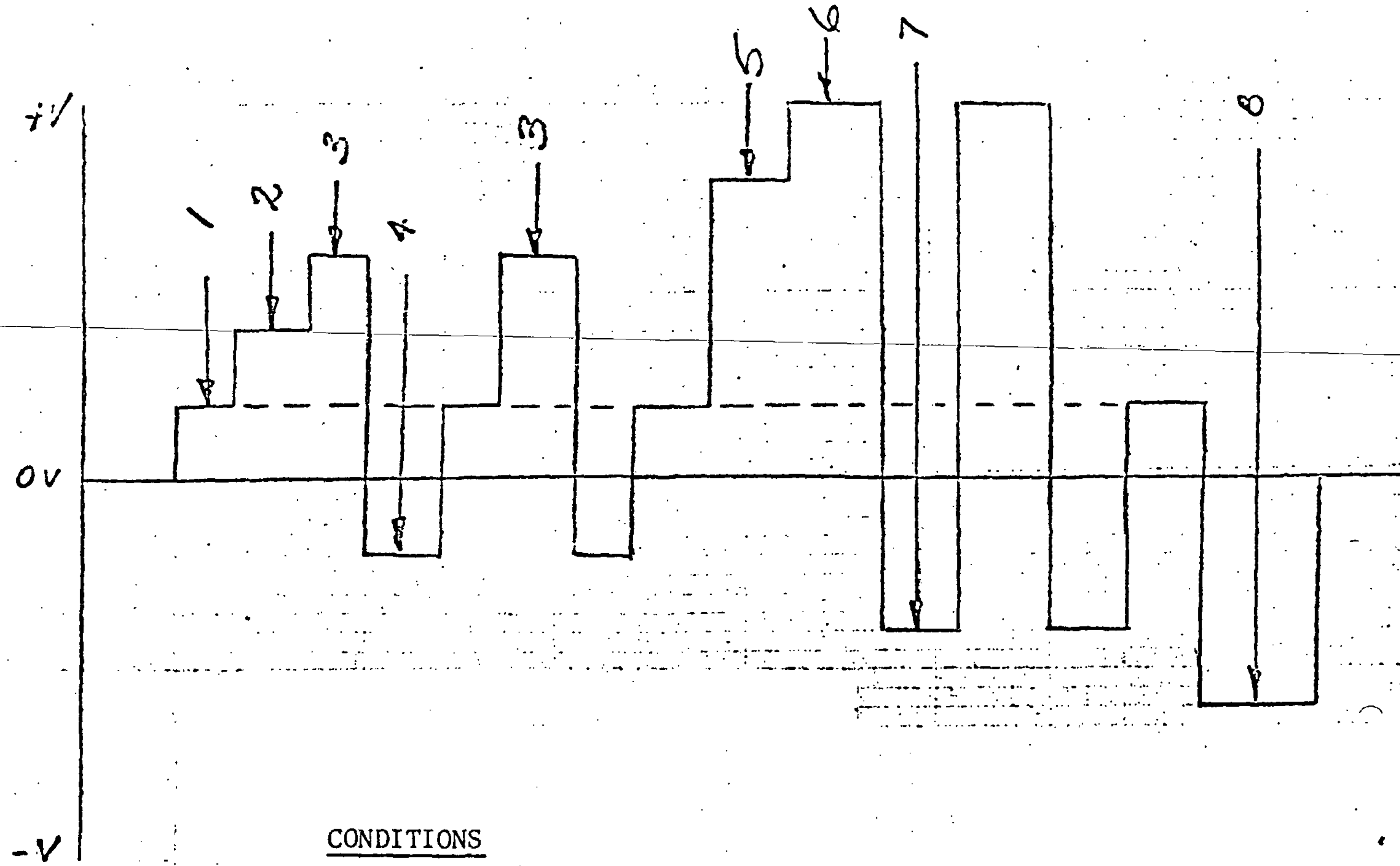
   6. Auditory Reinforcement Initiate

   7. Water Intake Initiate

B. Behavioral Task Event Code

The behavioral task event code is shown in Figure 9. The code provides eight different voltage levels between ±1.4 VDC to indicate the following conditions:

1. Trial in progress: +0.28 V
2. Trial orientation tone: +0.56 V
3. Sample time: +0.84 V
4. Sample switch depressed: -0.28 V
5. Choice orientation tone: +1.12 V
6. Choice time: +1.40 V



CONDITIONS

1. Trial In Progress
2. Trial Orientation Tone
3. Sample Time
4. Sample Switch Depressed
5. Choice Orientation Tone
6. Choice Time
7. Choice Switch Depressed
8. Time Out Interval (Void)

Figure 9

BEHAVIORAL TASK EVENT CODE

7. Choice switch depressed: -0.56 V

8. Time out interval (void): -0.84 V

C. Data Acquisition Facility

The data acquisition facility is shown in block diagram form in Figure 10. The proposed facility features both oscillograph and magnetic tape recording of physiological and life support system parameters using Beckman 16 channel and 6 channel oscillograph recorders and two FR 1300 magnetic tape recorders.

The physiological signals to be displayed on the 16 channel dynograph are to be recorded on FR 1300 #1. The FR 1300 inputs are thus derived from the oscillograph preamp outputs. This avoids coupling the decommutator and other signals to the relatively low input impedance of the FR 1300. The FR 1300 will be run at a speed of 1 7/8 ips.

D. Data Acquisition Schedule

The recording times and durations relating to the chart recordings and magnetic tape recordings are to be determined at a later date.

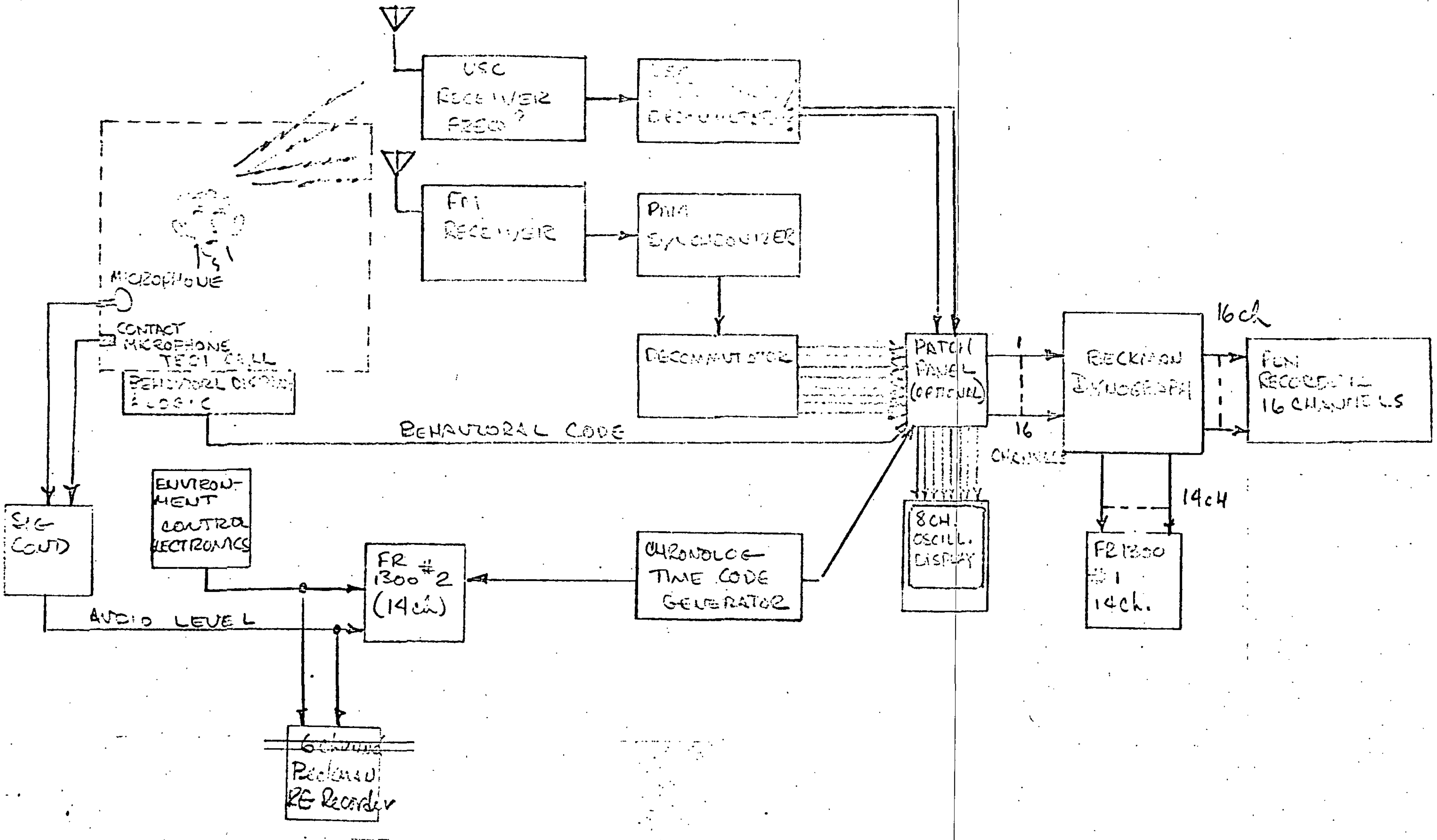


Figure 10

BLOCK DIAGRAM 30 DAY TEST DATA ACQUISITION FACILITY