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**NOTE**

**MONKEY PERFORMANCE  
TESTING APPARATUS (MAZE)**

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**ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE**  
**Defense Atomic Support Agency**  
**Bethesda, Maryland**

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MONKEY PERFORMANCE TESTING APPARATUS (MAZE)

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## ABSTRACT

A description is presented of a special performance testing device, the Kaplan-AFRRI Maze (KAM), designed for studying radiation effects upon the monkey. The structure and functions of this automated maze are provided. The material covered in this report also includes the environmental chamber for the KAM, manual and automatic operation, programming for automatic control, the data acquisition system and the data processing procedures.

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## I. INTRODUCTION

The Armed Forces Radiobiology Research Institute (AFRRI) is conducting studies on the effect of ionizing radiation upon learning, retention and cognition of the monkey (Macaca mulatta). The Kaplan-AFRRI Maze (KAM) has been developed to permit measurement of aspects of these parameters. It is a modification of previously developed devices<sup>6,8,9,10</sup> and is essentially an automated version of the original Shock Avoidance Apparatus Maze.<sup>9</sup> The predecessors of the KAM were successfully employed in radiation studies in the 1950's<sup>6,8,9</sup> and proved to be of value in permitting the experimenter to follow the gross motor behavior of the subject as well as its decision-making processes.

Monkey performance testing devices of the maze type were expressly developed for studying postirradiation psychomotor performance. Originally, monkeys were trained to work for food reward in the Wisconsin General Test Apparatus<sup>2-5,7,11,13</sup> after exposure to at least 1000 rad of x or gamma radiation. The monkeys did not work continuously following exposure and inconclusive data were obtained on their retentive capability. Whether nonresponse to stimuli represented loss of memory or loss of motivation was not established. It was felt, therefore, that a shock avoidance stimulus would be required to obtain a response and answer this question.

Ascertaining the integrity of the motor apparatus of a postirradiated animal was of interest in the early studies and also in recent work.<sup>12</sup> Tremors and ataxic signs in subjects, particularly those exposed to massive radiation doses (1000 to 100,000 rad) had been reported.<sup>12</sup> This information suggested that the organism's

capacity to efficiently perform motor acts had been damaged. It was of particular interest, therefore, to ascertain not only whether the subject could recall previously learned materials following irradiation but also the extent of depreciation of its performance efficiency.

The KAM was designed and constructed to obtain this additional information on postirradiation monkey performances. The details of its design and operation are the subject of this report.

## II. THE KAPLAN-AFRRI MAZE

The KAM is constructed of 1/4 inch Plexiglas, with overall dimensions of 48 inches x 72 inches x 24-1/2 inches (Figure 1). The floor is a shock grid made of 3/8 inch aluminum rods, spaced 1-1/4 inches apart. The entire device is mounted on a metal platform 18-3/4 inches off the floor. The KAM contains six compartments labeled A through F. The schematic of the KAM is shown in Figure 2 with a description of a simple conditioned traffic pattern which may be developed for the subject as one form of performance problem. In this problem the monkey is expected to run from compartment A, clockwise through B, C, D, E, F to A, respectively. The monkey's requirement is simply to run through exits, the doors of which are automatically opened or unlocked upon onset of visual stimuli in checkback switches shown at points (A), (B), (C), (D), (E), and (F) in Figure 2 and in Figure 3F. As the monkey presses the switch, he eliminates a visual and auditory signal and relocks the door behind him. A bell sounds at the start of each task, and an incorrect response results in a shock from the grid.

The KAM employs two types of doors (Figure 1). Doors A and D, identified in Figure 2, are guillotine doors raised by two air cylinders, one housed on each side of the door out of view of the subject. This door is opened by energizing an electric valve, and will remain open as long as the valve is energized. The speed with which the door opens is controlled by adjusting the pressure of the air to the cylinders with a pressure regulator. The door is closed by gravity and its closing speed is controlled by a valve which regulates the flow of air bleeding out of the cylinders. Doors B, B1, C, E, E1 and F are hinged and have solenoid locks.

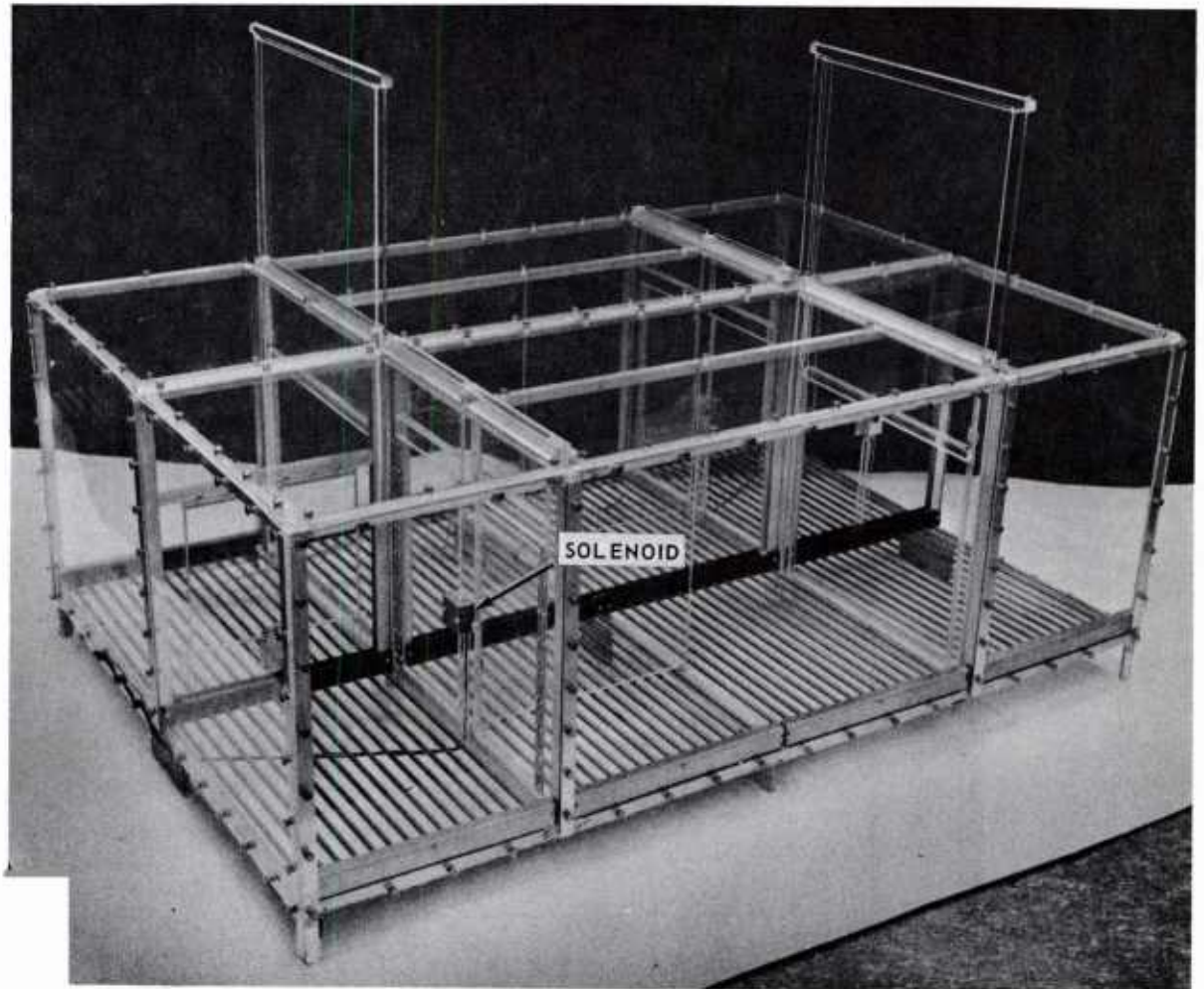


Figure 1. The Kaplan-AFRRI Maze (KAM)

These solenoids, which operate remotely by a 115-volt pulse, are shown in position in Figure 1. Doors C and F are placed in a low and high position 4 inches and 12 inches off the shock grid respectively to require a "low and high hurdle" type of motor response by the monkey. These doors are spring loaded to return to the closed position after entry.

Each compartment in the KAM is equipped with removable manipulanda and discriminanda permitting various test problems to be presented to the subject. In the simple traffic pattern previously mentioned, the manipulanda and discriminanda are the checkback switches consisting of a lighted plate which, when pressed, close

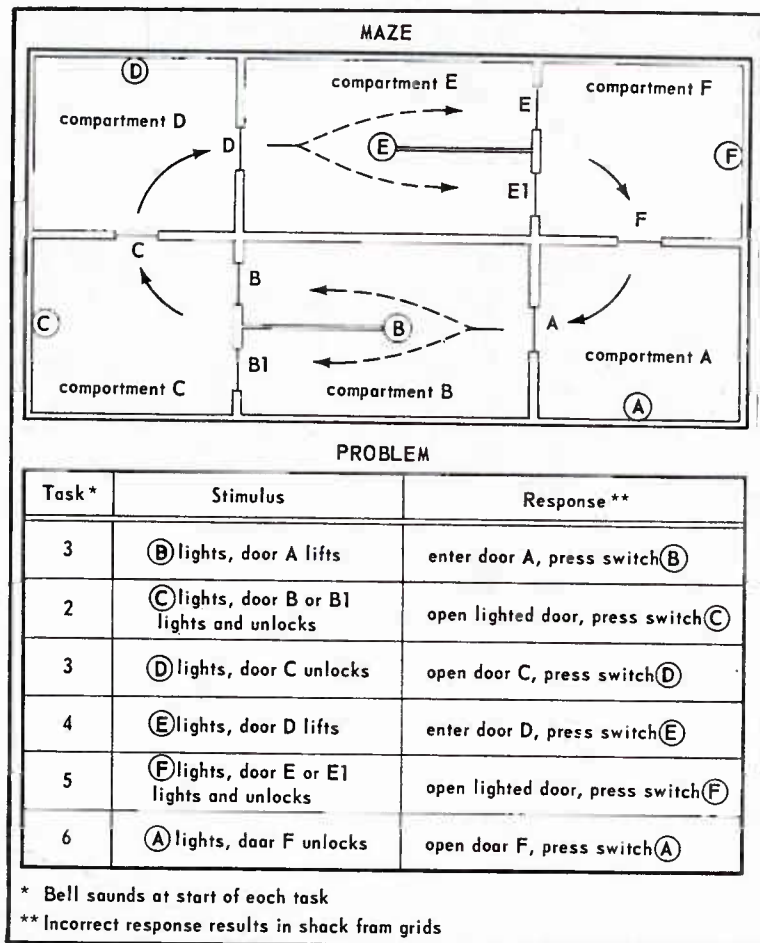


Figure 2. Diagram of a problem in the Kaplan-ARRI Maze (KAM)

a microswitch. These and other types of manipulanda-discriminanda are shown in Figure 3. The aforementioned devices can be viewed as conditioned stimuli, and the shock on the grids as the unconditioned stimuli. Each of the devices shown in Figure 3 requires a different muscle movement (e.g., linear or rotary motion), and/or a different sensory acuity (e.g., visual for observing the stimulus lights or kinesthetic for sensing the tension on the spring resistance of the levers). The types of problems employable in the KAM with these instruments are described under Automatic Operation of KAM.

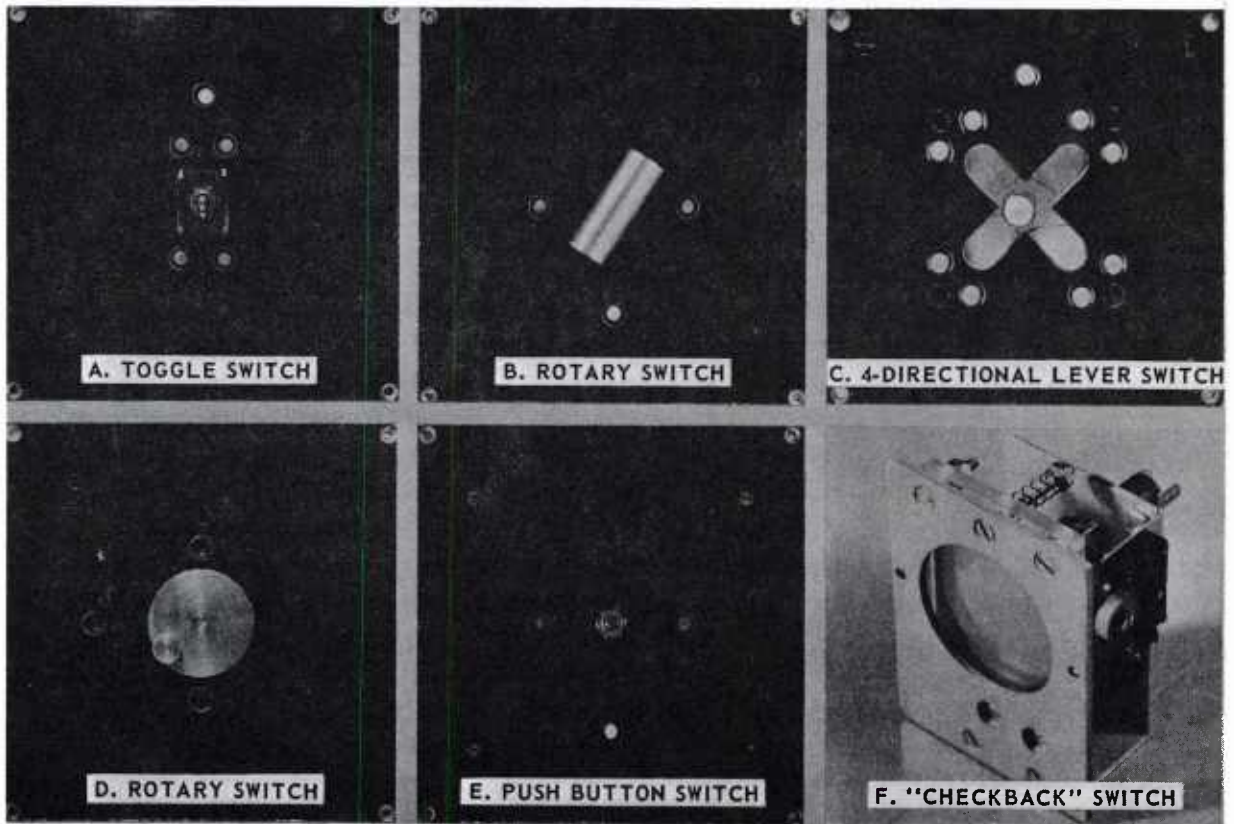


Figure 3. Manipulanda used in the Kaplan-AFRRI Maze (KAM)

The KAM is under surveillance of a television camera placed in the left front of the environmental chamber (Figure 4). The television is monitored by a viewing

screen in the control room. The camera may also be used for video tape recording.

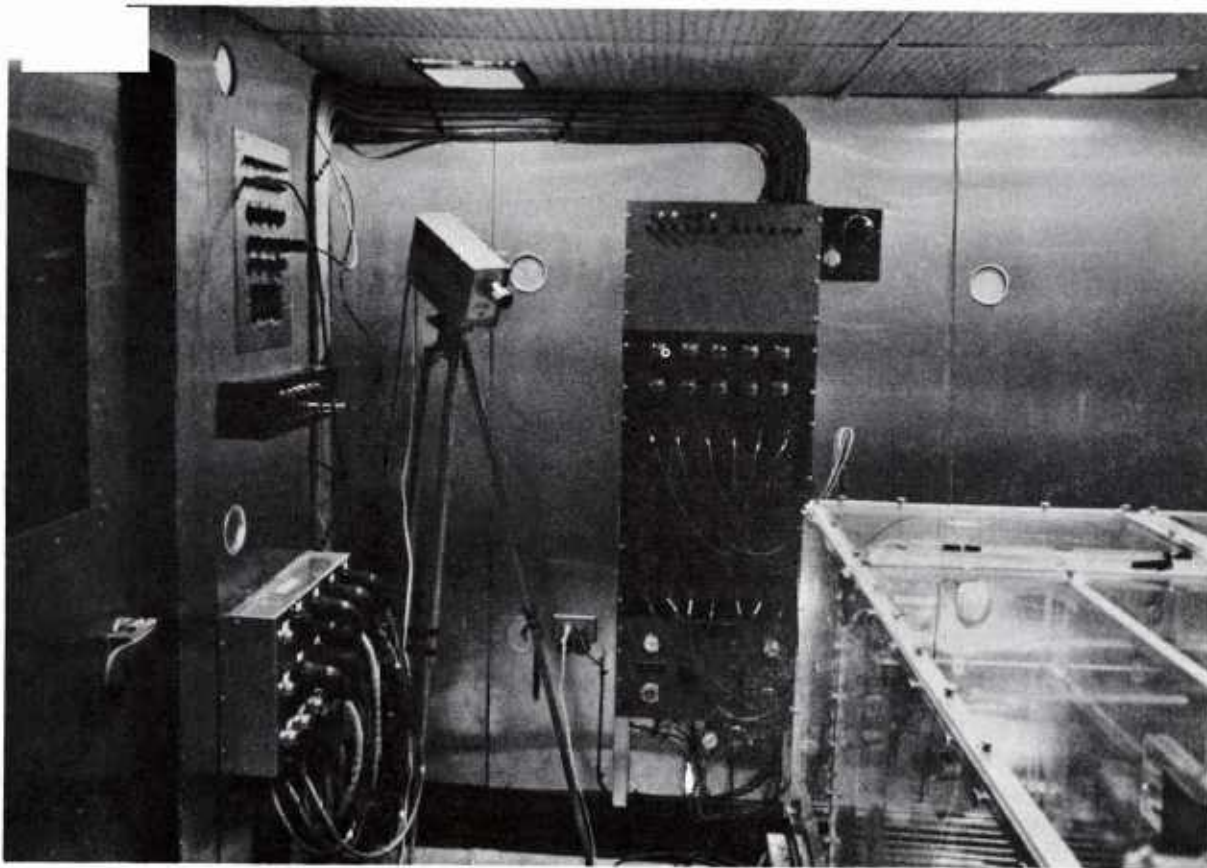


Figure 4. Interior of the environmental chamber with Kaplan-AFRRI Maze (KAM) and television monitor

The control room contains apparatus for recording physiological and psychological processes of the subject (Figures 5 and 6). Only relevant equipment for the KAM is presented here. The entire operational system is discussed in another report.\*

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\* Trageser, J. H. and Kavanaugh, J. W. Interface design, installation and checkout of A. F. R. E. I. physiological instrumentation and data recording systems for radiological research on primates. Technical Report, Technology Incorporated, Dayton, Ohio, Dec. 1966.

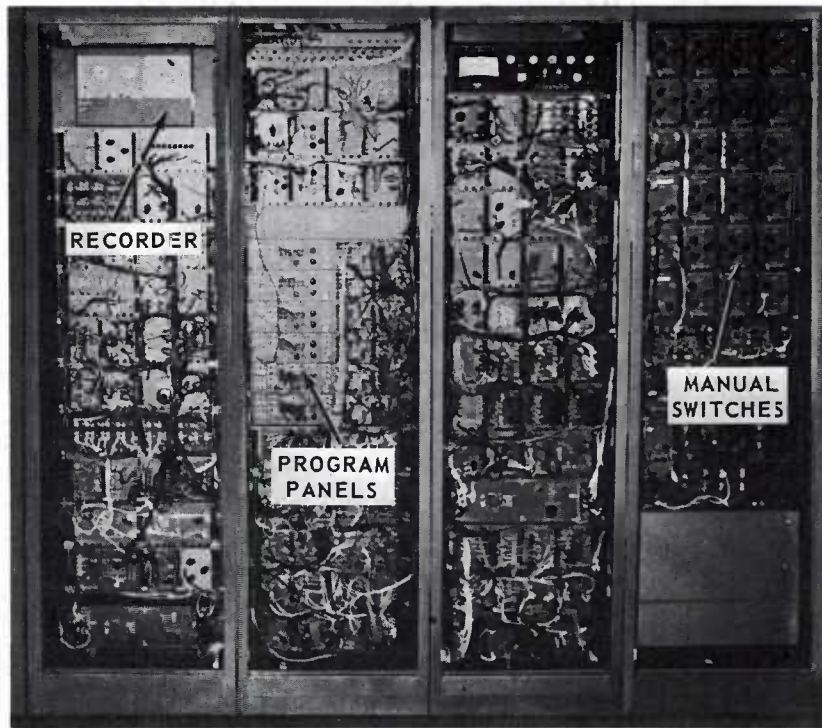


Figure 5. The Animal Trainer Electronic (ATE)

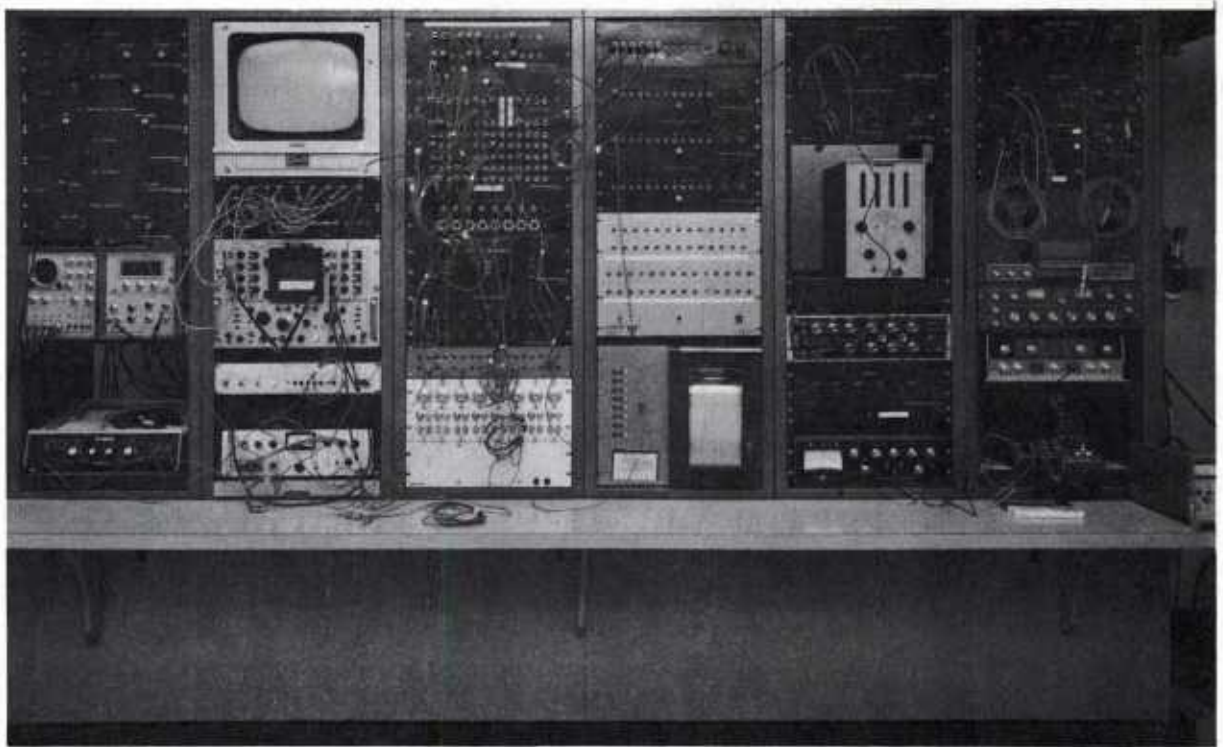


Figure 6. Physiological monitoring equipment

### III. THE ENVIRONMENTAL CHAMBER

The KAM is maintained in a special life support chamber designed to provide certain environmental controls. This chamber is prefabricated and self-contained including perforated ceiling, safety controls, heating, refrigeration, blowers, motors, humidifiers, dehumidifiers and auxiliary equipment and fixtures. The outside dimensions of the chamber are 10'8" x 10'8" x 7'7"; the inside dimensions are 10' x 10' x 6'7". The environmental chamber is equipped with a one-way observation window in the door permitting surveillance of the subject from the outside.

The sections of the chamber are constructed of 16 gauge aluminum, double walled, with 3-1/2 inches of compressed fiber glass insulation between the walls. The walls, ceiling and floor are constructed so that the room is almost soundproof but not anechoic. The floor and bottom 6 inches of the walls are covered with a smooth rubber mat making this area watertight. There is a recessed wash down trough, 2 inches wide and 1 inch deep located along the back wall, with a 1 inch diameter drain leading to the outside. This drain is positioned in the back left corner.

The chamber has a selective temperature range from 0 to 50°C with a variation of  $\pm .75^{\circ}\text{C}$  uniformity throughout the entire inside area. The temperature is checked by both wet and dry bulb thermistors located on an inside wall of the chamber and recorded on a circular strip chart recorder.

Radiofrequency electrostatic shielding encompasses the chamber and includes continuous metal contact around the periphery of the door, copper mesh screening over ventilation openings, continuous metal contact of all floor and wall panels,

and a radiofrequency filter for lighting fixtures and all other electrical penetrations.

There is recessed incandescent lighting installed in the ceiling, providing a minimum of 540 lumens per square meter throughout the chamber (standard 110-volt and 100-watt bulbs are used) during maximum illumination. The lighting circuit is controlled from outside by a rheostat mounted on the front wall to provide variable lighting intensity with a range between 0 and 540 lumens per square meter.

Air is circulated continuously by means of a blower. The controller for this system is located on the outside front wall of the chamber. The air is dehumidified, heated or cooled by circulation through a heat exchanger located against the back wall of the chamber above a false ceiling. Moisture is added to the air, if needed, by a humidifier located next to the heat exchanger.

The entire chamber is equipped with vapor proof electrical fixtures. Humidity is controlled between 20 to 95 percent in the temperature range of 20 to 40°C.

The room contains one duplex electric outlet on each wall placed 2 feet above the floor. Each outlet has its separate on-off control located on the outside front wall.

Bulkhead penetrations into the chamber have been made to accommodate the following wiring: 22 coaxial cables (single conductor and shield); 350 maze control and (return) response wires; wires for 1 television channel (including pan and tilt remote control); and wires for 12 physiological channels (two leads plus guard for each).

#### IV. OPERATION OF KAM

Manual Operation. The KAM may be operated by manual control with devices especially designed for this purpose. Manual operation is generally confined to the initial training of the subject, and is an available option in the event of equipment failure. Manual controls are located in the environmental chamber to the right of the television camera (Figure 4).

Momentary contact push switches are provided so that the operator may transmit signals and stimulate the subject via auditory and visual devices, as well as by shocking it through the grid floor. Pilot lamps are provided, so that the operator may know when the subject has pressed a device sufficiently to make contact. These are mounted on the chamber adjacent to the KAM.

Automatic Operation. The KAM may be automatically controlled by a device called the Animal Trainer Electronic (ATE). This instrument (Figure 5) is a special purpose computer designed to operate various behavioral programs involving the doors, shock grids, and aforementioned manipulanda and discriminanda.

The ATE is able to program operation of manipulanda for any of the functions in any or all of the compartments of the maze. Manipulanda may be operated for: (a) single momentary response to a cue (auditory or visual); (b) multiple responses to simultaneously presented light cues; (c) sequential pattern of responses to a sequential presentation of cues; and (d) single holding response to light or aural cue.

The ATE is equipped with a scrambler whose function is to insure that there is no fixed relationship in the voltage pattern of adjacent bars. The scrambler thus permits the ATE to direct the delivery of a scrambled shock of from zero to 800

volts to the maze grid. The ATE is also used to direct the administration of food reinforcements, and to control the doors and locking devices during the traffic pattern sequence.

Programming for Automatic Control. Programming the ATE for automatic operation is accomplished principally from a set of six program panels activated in sequence to present different programs in different compartments. These panels activate the needed programs and consist of a set of manual switches, plugs, and dials (Figure 5). A program consists of operations required of the subject and reinforcements given to the subject as a result of its response. More than one program may be activated on a single panel and all problems are presented in the test environment simultaneously. All active programs must be completed for the subject to obtain reinforcement. A maximum of eight operations may be required for reinforcement on each program panel and several completions of these operations may be required in each chamber. Upon correct completion of the required number of programs, the ATE activates the exit functions on the maze. The functions include the stimuli, the manipulanda (checkback switches), and the doors. Timing of the program and the exit functions are controlled by the adjustment of the manual switches (Figure 5). These timers determine the duration of the stimulus interval maximums, shock interval maximums and interstimulus intervals.

## V. DATA ACQUISITION SYSTEM

The Data Acquisition System of the ATE consists mainly of a binary encoder, a set of registers, a clock, and an eight-channel digital tape recorder. The data

are originally expressed as a voltage level change. A change from zero volts to -23 volts on a data line is considered an event. This event is encoded by the binary encoder into a specific code depending upon its respective data line.

A clock, which may be varied in resolution from 10 milliseconds to 1 second, feeds into a binary register. To keep the clock and the register running continuously and have no loss of time during the readout cycle, the register is immediately dumped into a parallel memory bank upon the occurrence of an event. The second memory bank is then fed into the tape unit with the event code. When the time register overflows this indication is fed to the tape unit as a time flag without any binary time information.

The recorder\* includes a rail mountable access panel for ease in use. Data may be entered at a rate up to 65 entries per second. These data may consist of either the above mentioned ATE generated characters or manually generated information. Manual information is generated by means of eight cumulatively lock push buttons on the access panel. The data to be written, either automatically or manually, are displayed on eight bit number indicators located on the access panel.

The information available is transferred in parallel to a shift register at the onset of the entry command, which also causes a pinch roller to engage the tape. The shift register then deposits the information serially on the tape in two tracks which are complements of each other. The normal track contains ones corresponding to data (logical 1) and zeros for logical 0. The complement track interchanges

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\* Kennedy Model trr-63

ones and zeros. The recorder then adds a 1 in each track to designate end of character and releases the pinch roller. The end of character is unique and the total number of magnetic ones on the tape must equal 8 for each two-track character. In the read mode, the shift register is used to assemble the serially stored tape information. When assembled it is presented to the outputs, in parallel, through reed relays whose coils are energized at the end of the assembly cycle. If the number of bits on the tape between end of character bits is not exactly 8, an indication is presented at the access panel.

## VI. AUTOMATIC DATA PROCESSING

The data are first recorded on digital magnetic tape (recorder) in the form of binary characters representing events (e.g., stimulus onset, correct response, etc.) or the time identification of the events. Subject number, day, time, etc., may also be recorded for ease in identifying data files at a later time in processing. This raw data must be scored in terms of latencies and responses in order to be analyzed.

The reduction and analyses of the behavioral data are accomplished in three phases which are diagrammed in Figure 7. Phase I is performed using the AFRR I Data Acquisition System SDS 920. Phases II and III are carried out on an IBM 7090.

Phase I. The first step accomplishes a conversion from two-track binary tape to paper tape. This process is accomplished using data and control lines connecting the data acquisition system to the recorder mounted in the experimental control room. The magnetic tape is read under program control using the SDS

interrupt system in addition to analog equipment interfaced with the SDS 920. Edited paper tape records are punched with records identified as containing either behavioral or subject identification data.

The paper tape records are input to a scoring program written in FORTRAN II. The output of this program is in terms of trial by trial responses, shocks, response latencies, shock latencies, and accumulated time from beginning of the session. The latencies are computed to within .01 second. The scored data may be typed out and/or filed on magnetic tape in binary coded decimal form. Subject identification and error messages are typed out during processing.

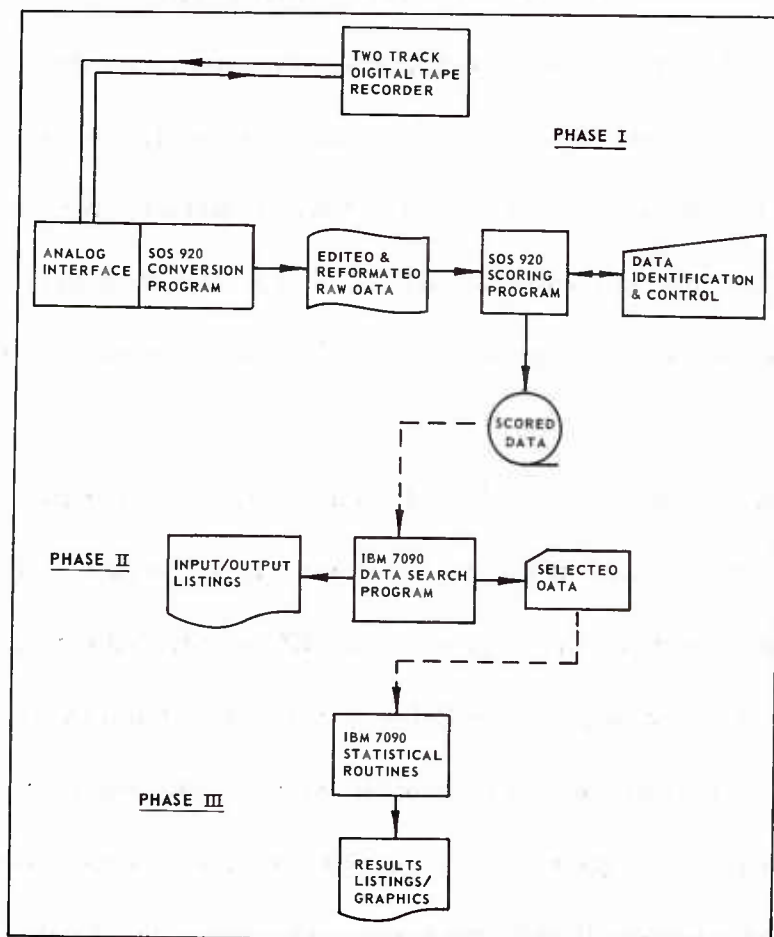


Figure 7. Data processing procedure

Phase II. Data output tapes from the above scoring program are listed on an IBM 7090. These tapes may then be searched, and selected data punched out in the correct format on cards for input into statistical routines. The data may be selected by trial and type of score.

Phase III. This phase consists of selection of the appropriate program or programs for the statistical analysis of the data. The biomedical computer programs<sup>1</sup> are available on the IBM 7090. Both data description and hypotheses testing programs are used.

## VII. CONCLUSIONS

The Kaplan-AFRRI Maze has been developed to measure the psychophysiology of the monkey as the animal performs in an unfettered environment. This apparatus has the capability for reflecting the sensory, motor, and cognitive faculties of an irradiated subject and will be used in experiments designed to study radiation effects upon behavior.

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