NASA SP-39

N64 12915

CODE-1

RESULTS OF THE PROJECT MERCURY BALLISTIC AND ORBITAL CHIMPANZEE FLIGHTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*

(NASA SP-39)

GPO: [redacted] $0.45

RESULTS OF THE PROJECT MERCURY BALLISTIC AND ORBITAL CHIMPANZEE FLIGHTS

Edited by

James P. Henry~~, M.D., Ph.D.~~ and John D. Mosely~~, D.V.M.~~, eds.

Corp. Auth.: NASA. ~~Prepared by~~ Manned Spacecraft Center, Houston, Texas

Imprint: Washington, NASA, 1963

77p refs

Office of Scientific and Technical Information 1963
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.

ACKNOWLEDGMENTS

The results presented in this report comprise a team effort requiring, in addition to the authors of the various sections, the collaboration of a large number of people in various disciplines. Too many contributed to mention everyone. However, the following must be cited: From the National Aeronautics and Space Administration, Manned Spacecraft Center, Dr. Stanley C. White, Mr. Richard S. Johnston, and Mr. Charles D. Wheelwright; from the 6571st Aerospace Medical Research Laboratory, Lt. Col. Rufus Hessberg, Lt. Col. H. Blackshear and, especially, Master Sgt. E. C. Dittmar; from Walter Reed Army Institute of Research, Maj. Joseph V. Brady and 2d Lt. Bernard Migler; from Indiana University Medical Center, Dr. Charles B. Ferster; from the Wenner-Gren Aeronautical Research Laboratory, University of Kentucky, Dr. F. C. Clark and Dr. K. O. Lange; and from the McDonnell Aircraft Company, Mr. Earl Younger, Mr. Dale Bennett, Mr. G. Stephens, and Mr. James McAllister. The many airmen and technicians of the National Aeronautics and Space Administration, the U.S. Air Force, and the McDonnell Aircraft Company whose unstinting cooperation was necessary for the completion of this task will be remembered with appreciation.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price 45 cents

FOREWORD

This publication presents a full account of the flights of the Project Mercury chimpanzees, from program planning through launch and recovery operations. A detailed account of training techniques, in-flight measurements, and postflight evaluation procedures is given. The suborbital ballistic flight of "Ham" on January 31, 1961, was the prelude to Alan B. Shepard's suborbital space flight, while the orbital flight of "Enos" on November 29, 1961, preceded the flight of Astronaut John H. Glenn.

The fact that we now categorize these events as belonging to the rather distant past, although they occurred only about two years ago, serves to emphasize the pace of development in the exploration of space. While the chimpanzee program may pale in the light of subsequent successes, its scientific and technological contribution should not be overlooked.

The significance of this project can be fully appreciated, and its contribution judged, only within the context of knowledge existing at the time of its conception. In addition to its essential training function, it verified the feasibility of manned space flight through operational tests of the Mercury life-support system. It demonstrated that complex behavioral processes and basic physiological functions remained essentially unperturbed during brief exposures to space flight. The Mercury Chimpanzee Program marked the first time that physiological and behavioral assessment techniques were combined for evaluating the functional efficiency of the total organism in space.

Perhaps the ultimate contribution of this program, however, was in providing the technological framework of knowledge upon which future scientific experiments on biological organisms, exposed to flights of extended durations, must be based. Biosatellite experiments designed to seek more subtle and elusive effects of prolonged space flight on biological functioning will require even more refined and difficult techniques, but will depend heavily on the technological groundwork laid in these early steps of Project Mercury.

RICHARD E. BELLEVILLE
Chief, Behavioral Biology
Bioscience Programs
Office of Space Sciences

CONTENTS

PREFACE

This document presents a compilation of papers reporting the results of the ballistic, or Mercury-Redstone 2 (MR–2), flight and of the orbital, or Mercury-Atlas 5 (MA–5), flight conducted with chimpanzees as subjects by the Manned Spacecraft Center of the National Aeronautics and Space Administration. The MR–2 flight with the chimpanzee "Ham," as a subject was conducted on January 31, 1961; and the MA–5 flight with the chimpanzee "Enos," as a subject was conducted on November 29, 1961. In both of these flights, the animals were handled in accordance with the "Principles of Laboratory Animal Care" established by the National Society for Medical Research.

1. SYNOPSIS OF THE RESULTS *of the* MR–2 AND MA–5 FLIGHTS

By James P. Henry, M.D., Ph. D.*

In April 1959, an animal test program with the following objectives was established for Project Mercury:

(1) Provision of animal verification of a successful space flight prior to manned flight.

(2) Provision of data on the physical and psychological demands which were to be encountered by the astronauts during space flight.

(3) Provision of a dynamic test of operational procedures and training of support personnel in handling the biomedical program for manned flight.

(4) Evaluation of the spacecraft environmental control system and bioinstrumentation under flight conditions.

The three sensory modalities most concerned with the weightless state are: vision, proprioception, and the labyrinth. Of these, it is primarily the otoliths in the labyrinth that lose their normal input during the weightless state. The tests were performed during the Mercury animal flights to ascertain whether the restrained animal, retaining visual and kinesthetic references, could respond normally during weightlessness to a series of problems graded in difficulty and in motivation. The animal was trained to respond on a schedule that involved mild punishment for error. In addition, a reward system, in the form of food pellets and drinks of water, was provided. The purpose of the schedule was both to determine whether there was a loss of appetite for food or water and, also, to establish that eating and drinking could be carried out normally in the weightless state. The bioinstrumentation resembled, as closely as possible, that used in the human Mercury flights for which these animal flights were to be introductions. One important addition for the MA–5 flight was the use of a special instrumentation package by which onboard recordings would be made from both the low (venous) and high-pressure (arterial) systems of the circulation before and during flight.

The comprehensive series of operant tasks involving both reward and avoidance was based primarily on the principles and techniques established by Skinner, Ferster (refs. 1 and 2), and Sidman (refs. 3 and 4). Originally, the feasibility of applying such techniques—which had already been worked out for the pigeon, rat and monkey—to the chimpanzee was problematical since previous operant studies of these animals had not used avoidance conditioning. It is one of the accomplishments of the animal program that solutions to the various problems in comparative psychology were so rapidly found and that a highly effective and complex series of in-flight tasks was developed and successfully used in space.

Methods

The techniques employed to adapt the chimpanzee to the Mercury spacecraft, the methods by which the operations of preparing the animal and delivering him in the ready state to the gantry at launch time were carried out, and a medical account of prelaunch preparations and recovery and postrecovery care are presented in this report.

Results

Results are also presented in the body of the report. They show that:

(1). Pulse and respiration rates, during both the ballistic (MR–2) and the orbital (MA–5) flights, remained within normal limits throughout the weightless state. Effectiveness of heart action, as evaluated from the electrocardiograms and pressure records, was also unaffected by the flights.

(2) Blood pressures, in both the systemic arterial tree and the low-pressure system, were not signifi-

---

*Colonel, Aerospace Medicine Division, Brooks Air Force Base, Tex., with permanent duty station at Department of Physiolgy, University of Southern California, Los Angeles, Calif. (formerly at NASA Manned Spacecraft Center).

cantly changed from preflight values during 3 hours of the weightless state.

(3) Performance of a series of tasks involving continuous and discrete avoidance, fixed ratio responses for food reward, delayed response for a fluid reward, and solution of a simple oddity problem, was unaffected by the weightless state.

(4) Animals trained in the laboratory to perform during the simulated acceleration, noise, and vibration of launch and reentry were able to maintain performance throughout an actual flight.

Conclusions

From the results of the MR-2 and MA-5 flights, the following conclusions were drawn:

(1) The numerous objectives of the Mercury animal test program were met. The MR-2 and MA-5 tests preceded the first ballistic and orbital manned flights, respectively, and provided valuable training in countdown procedures and range monitoring and recovery techniques. The bioinstrumentation was effectively tested and the adequacy of the environmental control system was demonstrated.

(2) A 7-minute (MR-2) and a 3-hour (MA-5) exposure to the weightless state were experienced by the subjects in the context of an experimental design which left visual and tactile references unimpaired. There was no significant change in the animal's physiological state or performance as measured during a series of tasks of graded motivation and difficulty.

(3) The results met program objectives by answering questions concerning the physical and mental demands that the astronauts would encounter during space flight and by showing that these demands would not be excessive.

(4) An incidental gain from the program was the demonstration that the young chimpanzee can be trained to be a highly reliable subject for space-flight studies.

References

1. Skinner, B. F.: The Behavior of Organisms. Appleton-Century-Croft (New York), 1938.
2. Ferster, C. B., and Skinner, B. F.: Schedules of Reinforcement. Appleton-Century-Croft (New York), 1957.
3. Sidman, Murry: Avoidance Conditioning with Brief Shocks and No Exteroceptive Warning Signal. Science, vol. 118, no. 3057, 1953, pp. 157-158.
4. Sidman, Murry: Time Discrimination and Behavioral Interaction in a Free Operant Situation. Journal of Comparative and Physiological Psychology, vol. 49, 1956, pp. 469-473.

2. ANTECEDENTS AND PLANNING ASPECTS *of the* MR–2 FLIGHT

By James P. Henry, M.D., Ph. D.,* and
John D. Mosely, D.V.M.**

Experimental bioastronautics began with the use of animals in the late 1940's and evolved in an atmosphere of sharp distinction from aviation medicine in which animals have been used mainly for on-the-ground support research. A number of ballistic flights with animals were accomplished with encouraging results during the period from 1948 to 1958. In 1959, with the initiation of the Mercury man-in-space program it was decided by the National Aeronautics and Space Administration that animals should be employed to test the adequacy of the various systems used to support life. The intention was not to make extensive physiological studies of the effects of the weightless state, but rather to use animals to ensure the adequacy of the life-support systems.

Little Joe Flight

The first step in the attempt at animal verification of the adequacy of the Mercury flight program was the development of two tests in collaboration with the U.S. Air Force School of Aviation Medicine in which there would be a biomedical evaluation of the accelerations expected during the abort of a Mercury flight at lift-off and shortly after lift-off. These flights were to be launched at the NASA Wallops Station with a "Little Joe" solid-fuel launch vehicle.

Two Little Joe firings were made with activation of the escape rockets during the boost phase to secure maximum acceleration, and only a brief period of weightlessness was attained. The first firing was on December 4, 1959, and the other on January 21, 1960. A 36- by 18-inch sealed, 125-pound, cylindrical capsule containing the subject, an 8-pound *Macaca mulatta* (monkey), the necessary life support system and associated instrumentation was flown in a "boiler plate" model of the Mercury spacecraft. A detailed report was prepared by the U.S. Air Force School of Aerospace Medicine. (See ref. 1.)

Chimpanzee Flight Program Planning

Immediately following initiation of the Little Joe biopack program, a meeting was held at NASA Manned Spacecraft Center on April 13 and 14, 1959, to plan a further series of flight tests of full-scale spacecraft containing animals in which observations could be made of the effects of long-range ballistic and orbital flights. The purposes of these studies were:

(1) To provide animal verification of the feasibility of a manned flight.

(2) To provide data on the level of mental and physical activity which could be expected during the flight.

(3) To provide a dynamic test of countdown procedures and training of support personnel in handling the biological aspects of manned flight.

The above mentioned planning group was composed of representatives of the McDonnell Aircraft Company, NASA Manned Spacecraft Center, and Navy, Army, and Air Force biomedical specialists. It was agreed that the existing Mercury spacecraft life support, environmental control, and instrumentation systems should be used without modification in all tests. The 6571st Aeromedical Research Laboratory at Holloman Air Force Base was assigned the responsibility for the training of the animals, their preparation for the flight, and their handling after recovery. A Manned Spacecraft Center representative was assigned as coordinator to insure integration of animal flights into the overall flight program and to insure cooperation of all organizations required to support the program. In order to provide the highest level of performance short of a human, it was decided that

---

*Colonel, Aerospace Medicine Division, Brooks Air Force Base, Tex., with permanent duty station at Department of Physiology, University of Southern California, Los Angeles, Calif. (formerly at Manned Spacecraft Center).

**Major, U.S. Air Force, School of Veterinary Medicine, Ohio State University, Columbus, Ohio.

chimpanzees should be used because of their size and physical similarity to man. Restraint would be minimal to permit performance of psychomotor tests. The electrocardiogram, body temperature, and respiratory movements would be recorded by the same techniques as those used for the man. If possible, arterial pressure would be recorded. Urine would be saved for a study of steroid output and there would be photography of the subject. At that time, it was decided that various types of performance would be required of the subjects to simulate the tasks of the human operator. They would involve simple motor movements of the arms and hands, discriminations of visual signals, and acts requiring judgment. In the longer orbital flight, the difficulty of the task would be raised to a level that would approximate the man's task as closely as possible within the animals' capability. The effect of the flights upon the animals' performance would be measured during flight and would be determined by preflight and postflight studies.

The three military services of the Department of Defense accepted the Manned Spacecraft Center's position and further agreed that all services would support the Aeromedical Research Laboratory insofar as practical.

Although the Aeromedical Research Laboratory (AMRL) had animals, veterinarians, and space physiologists, it had, at that time, no facilities to obtain behavioral measurements of these animals; therefore, several chimpanzees were trained under a contract with the Wenner-Gren Aeronautical Research Laboratory, University of Kentucky. In addition, the Air Force transferred, to the AMRL in whole, the animal performance facility and personnel of the Unusual Environments Section, Aerospace Medical Laboratory, Aerospace Systems Division, Dayton, Ohio. Before this group arrived in August 1959, arrangements were made with the Walter Reed Army Institute of Research to aid the preliminary establishment of the Comparative Psychology Branch at AMRL. As soon as possible after the establishment of the Comparative Psychology Branch, the training of eight chimpanzees began with the use of standard operant conditioning equipment and special restraint chairs.

Development Phases

Soon after assignment of the animal program to the Aeromedical Research Laboratory, the Laboratory began a series of meetings with representatives of the Manned Spacecraft Center and the McDonnell Aircraft Corporation. The first hurdle was to provide environmental support for the chimpanzee subject in the Project Mercury spacecraft. There are two loops in the environmental control system, one for the spacecraft cabin, and one for the astronaut pressure suit. The NASA decision was to use the chimpanzee to evaluate the suit environmental control loop. With this decision, it was feasible to design a couch to fit the chimpanzee and put a cover on this couch which then could be sealed. This simulated the astronaut pressure suit with the faceplate closed. (See figs. 2–1 and 2–2.) The details of the psychomotor apparatus are discussed in section 4 of this series of papers. Of great importance is the fact that, in keeping with the policy of noninterference with the Mercury spacecraft, in the final design the programing apparatus was to be completely within the chimpanzee couch and to require from the spacecraft system only the power for its operation.

In order to condition the animal realistically to his surroundings, McDonnell Aircraft Corporation fabricated six training couches identical to the flight couch with the exception that they were to be used at ambient atmospheric pressure and that the psychomotor apparatus would be programed with standard laboratory equipment. In addition, the McDonnell Aircraft Corporation furnished four plywood mockups of the Mercury spacecraft in order to simulate the physical surroundings of the couch. The mockups included replicas of the astronaut panel and panel lights.

At the same time that training was progressing, the Veterinary Services Branch of the Aeromedical Research Laboratory began collecting normal baseline data on the entire colony of immature chimpanzees. These data consisted of complete physical examinations, including X-rays at specified intervals; and in addition, examinations were made immediately before and after any work session or aircraft flight of the animal. Data were gathered on normal blood and urine values; X-rays were taken; and blood pressure, respiration, and heart rate were measured at regular intervals. At this time, because postlanding temperatures were in the critical zone, the Ecology Section of the Bio-Astronautics Branch began thermal-humidity experiments to determine the temperature and humidity tolerance of the chimpanzees. Details of the method of restraint were worked out by the Aeromedical Research Laboratory and the restraint suits were designed and fabricated by the Aerospace Medical Laboratory, Aeronautical Systems Division, Dayton, Ohio. A series of simulated flights were then conducted on the centrifuge at the Aerospace Medical Laboratory to determine the effects of accel-

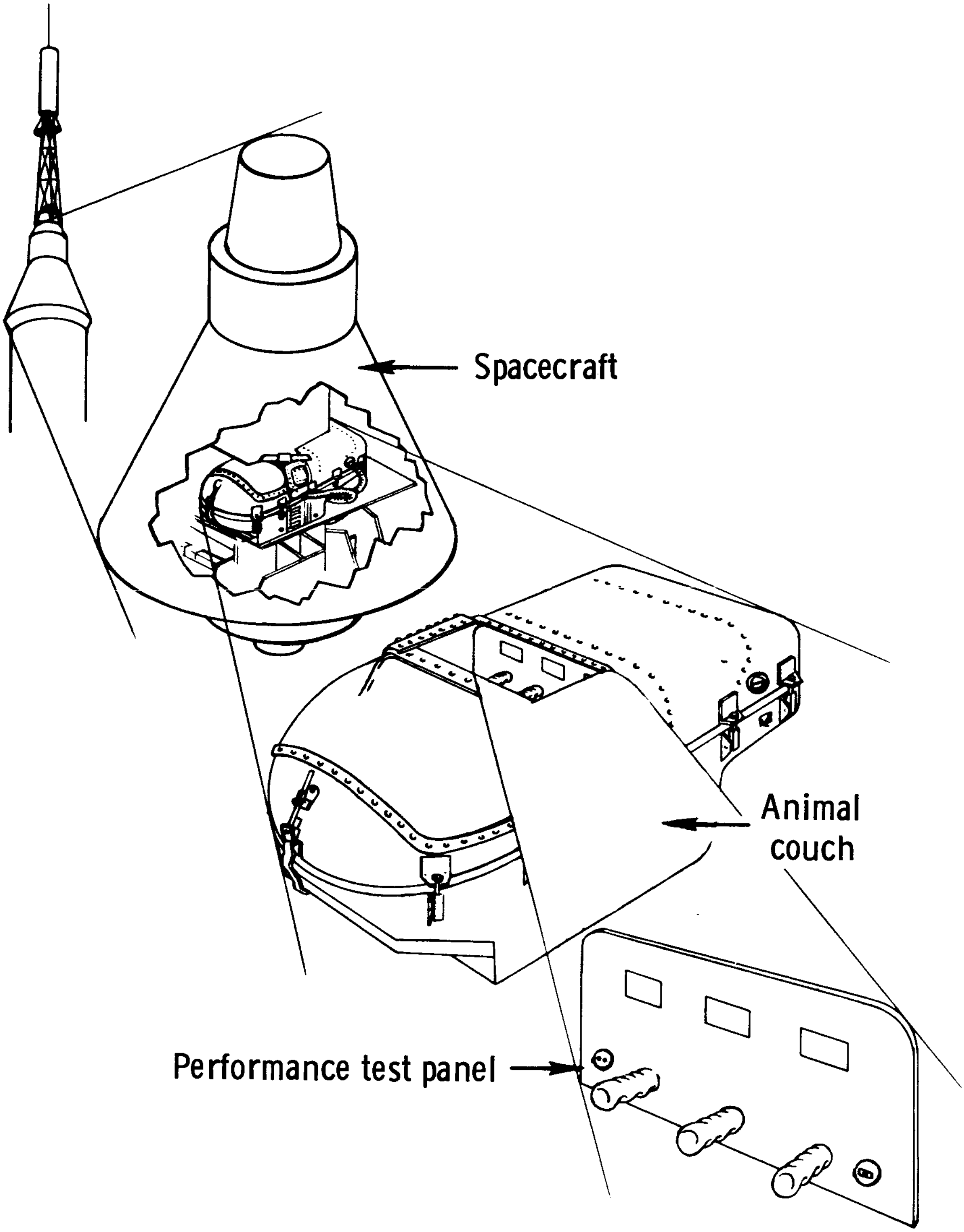


FIGURE 2-1.—Diagram of the location of the animal pressurized couch within the Mercury spacecraft and the placement of the performance test panel within the couch. Immediately to the right of the three levers are the spring loaded fingers that present the special banana-flavored reward pellets. In the rectangles above the levers, the colored lights and symbols are displayed. The water dispenser is not depicted but lies to the right of the animal's head in the top portion of the couch.

eration and vibration on the chimpanzee, to acclimate the animals to the flight conditions, and also to evaluate the complete chimpanzee-couch system.

The medical recovery plans were formulated by Manned Spacecraft Center, the Office of the Staff Surgeon, Patrick Air Force Base, and the Aeromedical Research Laboratory. Veterinary officers and veterinary technicians of the U.S. Army and the U.S. Air Force were selected and sent in small groups to the Aeromedical Research Laboratory for 2 weeks training in the care and handling of chimpanzees. A total of 35 veterinary technicians and 10 veterinary officers were so trained.

The prelaunch operation began on January 2, 1961, when 20 officers and airmen of the Aeromedical Research Laboratory flew from Holloman Air Force Base to Cape Canaveral with 6 chimpanzees and the necessary support equipment. The animals were moved immediately upon arrival into an aeromedical van complex which had in the meantime been prepared for them and placed within the fence of Hangar S on the Atlantic Missile Range.

Reference

1. Green, Cloid D., Welch, B. E., et al.: Studies of Escape from Ballistic Space Vehicles—I. Biomedical Evaluation. School of Aviation Medicine, Brooks Air Force Base Rep. 61–29, Apr. 1961.

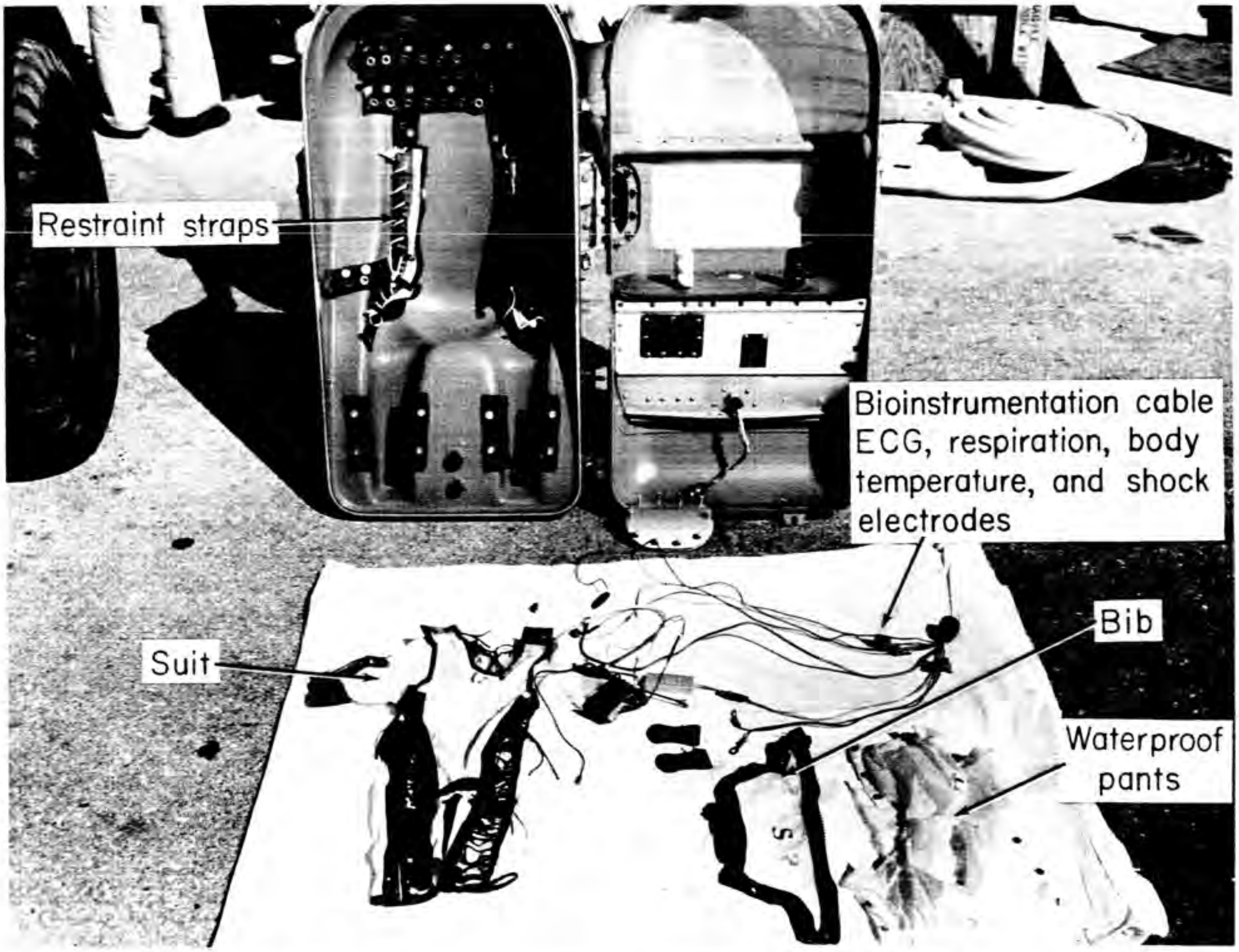


FIGURE 2–2.—Display of the ballistic flight couch showing on the left of the picture the couch proper with the tabs and adjustments for attaching the subject's restraint suit. The suit is shown immediately below the couch. The nylon lacing adjustment can be seen. On the right is the couch lid containing the ballistic psychomotor apparatus and two levers. The hand access cover can be seen at the base of the lid. It fits over a hole seen above and to the left of the white lever. On the right and below are the diaper and nylon waist panel used for separating the animal from his rectal probe. Above on the sheet are the two psychomotor stimulus plates contoured to fit the soles of the feet; the respiratory sensor, rectal probe, and the ECG sensors all connected to a plug which in turn fits into a receptacle on the base of the couch on the left of the photograph.

3. MR-2 OPERATIONS

By Norman E. Stingely,*
John D. Mosely, D.V.M.,** and
Charles D. Wheelwright***

Prelaunch Activities

The animal operations at Cape Canaveral, Florida, for the MR-2 flight began January 2, 1961, with the arrival of 6 chimpanzee subjects and 20 scientific and technical personnel. The early arrival, 29 days prior to the launch date, was required to stabilize the animal subjects, to enable the preparation team to practice with the animal and its flight apparatus, and to perform spacecraft systems checkouts with chimpanzee subjects. A minimum of 21 days for subject acclimatization was deemed necessary to give the chimpanzees time to adapt to the change in environment. (The altitude at Holloman Air Force Base, N. Mex., is approximately 4,000 feet above sea level as opposed to the sea-level altitude at Cape Canaveral, Fla.)

The facilities for quartering, training, and preparing the subjects for flight consisted of seven trailers (two caging, two training, one medical, one transfer, and a house trailer) located in a fenced enclosure adjacent to Hangar S at Cape Canaveral, Florida. (See fig. 3-1.) The basic requirements and the designs of the interior for these vans were formulated by the Manned Spacecraft Center with the cooperation of the Aeromedical Research Laboratory. The vans were designed, engineered, and supplied by NASA Manned Spacecraft Center (ref. 1). One caging and one training van were connected front to front in train couple fashion which provided two identical caging-training units. In order to avoid a possible spread of disease, the chimpanzees were separated, three animals to each caging-training unit, with separate provision for food storage and food preparation.

Each training van had two training cubicles and one Mercury spacecraft mockup to simulate isolation conditions of the Mercury flight while the chimpanzee subjects maintained their proficiency on the psychomotor performance tasks. (See section 4.) During the preflight period 29 training sessions were conducted.

The medical van was equipped as a combined clinical and surgical facility for physical examination, clinical laboratory analysis, minor surgery, and treatment of illness or injury. It was also used for the installation of the various biosensors, the restraint garment, and placement of the animal in the couch.

The transfer van was designed to accommodate either a man or a chimpanzee subject in the couch while enroute from the Hangar S complex to the launch pad. In addition, it was used for checkout of the physiological sensors and psychomotor apparatus and for testing the pressurized couch to determine if it was in a flight-ready condition. An eight-channel Sanborn 350 recorder was used for the physiological and psychological performance checks and to record preliminary flight data. A Firewell pressure-suit test console with air supply was used for the pressure check of the chimpanzee couch and to sustain the subject while in the transfer van. A portable liquid-oxygen supply was used for sustaining the subject while moving from the transfer van up to the gantry and into the spacecraft.

The animal complex was manned at all times to maintain continuous observation of the animal colony, to detect any illness, and to preclude any emergency condition, such as faulty temperature regulation in the caging vans. The house trailer served to house personnel on duty at night and was used as an office for the operation.

Five practice countdowns were conducted by the medical preparation team for the MR-2 flight. They consisted of preparing the subject and couch, and proceeding up the gantry. The couch was placed outside or inserted into the spacecraft and connected to the spacecraft environmental control system (ECS) and electrical system. One countdown was performed for a telemetry check, one for a spacecraft-pressure check,

---

*Captain, U.S. Air Force.

**Major, U.S. Air Force, School of Veterinary Medicine, Ohio State University, Columbus, Ohio.

***NASA Manned Spacecraft Center.

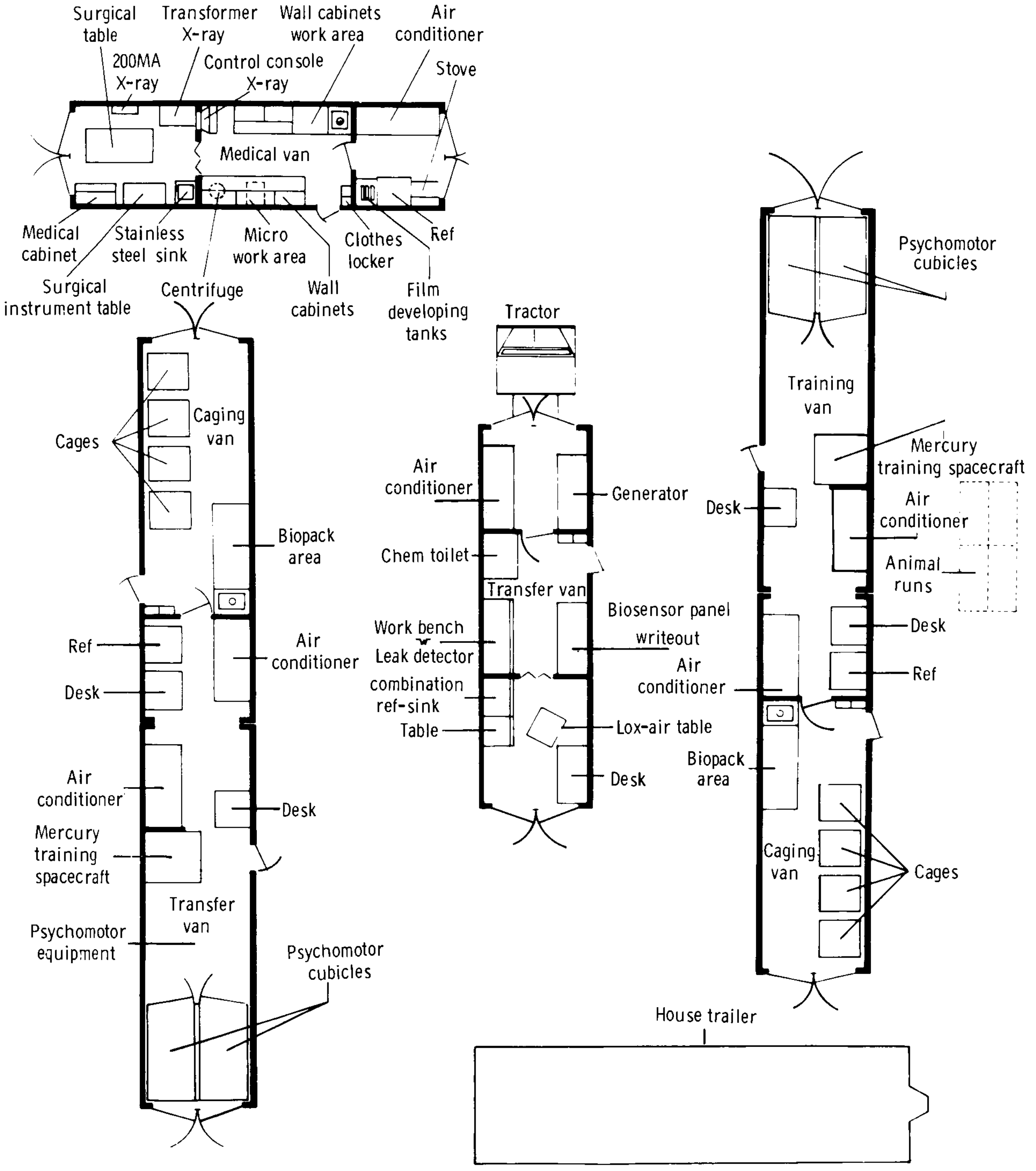


FIGURE 3-1.—Animal van complex for the MR-2 and MA-5 flights. Each van measured 28 by 8 feet.

one for a radio-frequency compatibility test, and two were simulated flights.

Flight Preparation and Insertion

The flight preparation and insertion of the couch into the spacecraft was performed in a two-part countdown. The time-consuming operations, such as the physical examination of all potential flight subjects and a complete checkout of all animal preparation equipment were performed on T—1 day; the actual animal preparation took place on T day. The sequence of events as they occurred, with times expressed as Eastern Standard, are presented in the following paragraphs.

T—1 Day (January 30, 1961)

The activities of the day prior to the flight were as follows:

Ground support equipment.—The following checks of ground support equipment were made at 8:00 a.m. (T—26 hr 54 min):

1. All vans were checked to see if the necessary equipment and supplies were available and in their proper place.
2. A check of all test equipment was initiated.
3. The pressure-suit console and air supply were checked for proper operation.

Flight equipment.—At 8:00 a.m. (T—26 hr 54 min) the three available flight couches and sensor cables were checked to see that the ECG leads, respiration sensors, rectal temperature thermistors, and psychomotor programers functioned within specifications.

At 2:00 p.m. (T—20 hr 54 min), restraint suits and couch attachments were selected and fitted to the flight and backup subjects. They were then placed in their respective flight couches and fitted to them.

Diet and feeding schedule (all animals).—All subjects were placed on a diet and feeding schedule at T—26 hr 54 min. At that time, each subject received 15 commercial food pellets and one-fourth of an orange. All subjects received 12 ounces of a low bulk diet at 2:00 p.m. (T—20 hr 54 min) and again at 8:00 p.m. (T—14 hr 54 min).

Clinical studies.—The following clinical studies were conducted at 8:00 a.m. (T—26 hr 54 min):

1. Blood and urine samples for analysis and Metabolic Profile Studies were collected and processed.
2. A comprehensive clinical ECG and overall body X-rays were conducted.

Water intake.—Water intake was limited to a total of 800 cc from T—24 hours through recovery.

Physical examination.—A complete physical examination was given to each of the four primary subjects at 8:00 a.m. (T—26 hr 54 min). The physical examination included a check of body weight, rectal temperature, blood pressure, pulse, respiration, skin, eyes, ears, nose, mouth and throat, chest, abdomen, and extremities.

At the completion of the physical examination, the flight and backup animals were chosen. This decision was based on the veterinarian's judgment, the physical condition of the animals, and the psychologist's evaluation of the animal's psychomotor performance ability.

T Day (January 31, 1961)

The chronological events of the launch day are as follows:

1:15 a.m. (T—9 hr 36 min).—A physical examination of the flight subjects was again conducted, and physiological sensors, disposable diapers, and plastic waterproof pants were placed on the subject.

1:45 a.m. (T—9 hr 6 min).—An operational test of the attached sensors was made in the medical van. The electrical resistance of the ECG leads was checked to insure compatability with the spacecraft ECG amplifiers. A telethermometer was used to test the operation of the rectal temperature thermistor.

2:03 a.m. (T—8 hr 51 min).—The subject was placed in the prefitted suit and zipped and laced in the couch (figs. 2-2 and 3-2). The restraint suit consisted of nylon webbing reinforced by nylon tape at the cuffs and other points of stress. The suit which was developed by the Aeromedical Research Laboratory personnel and fabricated by the Aeronautical Systems Division represented a modification of suits previously used in chimpanzee research. (See ref. 2.) Provisions were made for expansion of the suit to compensate for growth of the subject by zipping the suit to preattached leg and torso tabs. Loose restraint of the legs with nylon cord completed the couch restraint. Psychomotor stimulus plates were attached to the sole of each foot and were electrically checked for continuity. The panel, designed to prevent the subject from reaching the sensor leads, was plugged into the couch base.

2:31 a.m. (T—8 hr 20 min).—The flight subjects and couch base were moved to the transfer van. Immediately thereafter, the backup subject was moved to the medical van and prepared to the same point as the flight subject. The flight subject and complete couch were weighed and ballasted to a prearranged total of 95.45 pounds. The instrumentation within the couch was then attached to the Sanborn recording equipment and a check made for normal ECG and respiration waveforms and for rectal temperature. Respiration

FIGURE 3-2.—Animal in couch (compare with fig. 2-2). The lacing on the arms to fit the adjustable nylon restraint suit is visible. The waist panel with its zipper which is attached to the couch lid can also be seen.

rate, heart rate, and rectal temperature were recorded every 5 minutes, both to monitor the subject and to plot trend data to aid the flight control surgeons in determining the subject's flight readiness.

The digital counters on the psychomotor programer were read and recorded, and the couch lid was electrically connected to the couch base and loosely placed upon it without tightening the pressure seat. Power was applied to the psychomotor programer, and the programer was checked to ascertain that the right- and left-hand levers produced a signal each time they were depressed and that a pulse appeared with every presentation of shock and blue light.

3:02 a.m. (T—7 hr 52 min).—The flight and backup subjects received 8 ounces of the prescribed diet. The lid tiedown bolts were all torqued to 15 inch-pounds. The inlet and outlet air hoses were attached to the couch and a flow of air was initiated. The couch porthole covers were attached and torqued to 10 inch-pounds. Leakage was checked by pressurizing the couch to 5 psi and recording any pressure drop. The leak rate was below 50 cc per minute, the lowest that could be read on the pressure-suit test console. Fifteen minutes of psychomotor performance data were collected during this procedure. The couch pressure was then returned to ambient and the subject was ventilated with an air flow of 75 to 100 liters per minute until he was moved up the gantry. The subject remained on standby in the transfer van at the animal complex until directed by the blockhouse surgeon to move to the launch pad.

5:04 a.m. (T—5 hr 50 min).—The transfer van was directed to move to the launch pad and arrived at 5:29 a.m.

6:05 a.m. (T—4 hr 49 min).—The subject and couch were switched from the transfer van air supply to the portable liquid-oxygen supply, moved up the gantry, inserted into the spacecraft, and connected to the ECS and electrical system. The physiological monitoring of the flight subject was then switched to the blockhouse.

Immediately after the departure of the flight subject, the backup subject was placed in the transfer van. The subject and couch were checked by the same procedure as that for the primary subject and placed on standby.

ECS monitoring.—The ECS was monitored by a direct line to the blockhouse while a final bubble-leak check was performed in the spacecraft at the junction of the inlet and outlet ECS hoses. Three recordings were made of the psychomotor responses at the blockhouse before the spacecraft hatch closure was completed. The durations of these checks were 1 minute 57 seconds, 3 minutes 40 seconds, and 1 minute.

Before the gantry was removed, the transfer van was moved to an adjacent blockhouse. Monitoring of the backup subject in the transfer van continued until T—30 minutes when all personnel and the backup subject and couch with portable air supply were moved into this blockhouse.

Hatch closure was completed at 7:10 a.m. and the gantry was removed at 8:05 a.m. At 9:08 a.m. the count was recycled, the gantry returned, and the hatch opened to cool an inverter.

The count was resumed at T—2 hr (10:15 a.m.) and performed at an accelerated pace. Portions of the count were not repeated. Again three psychomotor recordings were made in the recycled count. The duration of these checks were of 2 minutes 4 seconds, 1 minute 38 seconds, and 1 minute 50 seconds. The last check began just prior to lift-off and continued in flight.

Lift-off.—Lift-off occurred at 11:54:51 a.m.

Flight Characteristics

The spacecraft reached an apogee of 136.2 nautical miles and a range of 363 nautical miles in a flight lasting approximately 16 minutes 29 seconds.

Upon separation from the launch vehicle, the spacecraft rotated slowly about all three axes. The motion in pitch and yaw became attitude stabilized at 3:54 minutes with a steady roll rate of 9.5° per second which continued until main parachute deployment. At T+8 minutes 55 seconds, the spacecraft began to turn around and to reenter the atmosphere with the heat shield pointed in the direction of flight.

The longitudinal acceleration loads imparted to the subject in the transverse plane are presented in figure 3-3. The acceleration increased from 1.2g at lift-off to 6.5g at T+2 minutes 17 seconds. At T+2 minutes 18 seconds the escape rocket fired, due to a failure in precise timing of launch-vehicle cutoff, and the acceleration peaked at 17.0g. It then returned to 0g for a 6½-minute period. Reentry deceleration started at T+9 minutes 20 seconds, reached a maximum of 14.6g at 9 minutes 36 seconds, and then decayed to 1.3g. The drogue-parachute deployment caused a pulse of less than 0.5g at T+10 minutes 54 seconds, and the main-parachute deployment caused a brief 3g deceleration at T+11 minutes 28 seconds. Lateral and head-to-foot accelerations during flight were negligible. Abrupt landing decelerations in the longitudinal plane of the spacecraft ranged from the tolerable values of 20g to −7g, the lateral deceleration varied from 3.5g to −4.7g, and the head-to-foot deceleration with respect to the subject ranged between 3.4g to −16.8g.

The ECS was designed so that the subject breathed 100-percent oxygen from lift-off until descent when the snorkel valve opened at 18,000 feet. As the craft went to altitude, the pressure reduced to and leveled off at 5.5 psi and then on descent, just prior to landing, returned to ambient pressure.

The couch inlet temperature did not change significantly during the flight. It was 58° F at lift-off and varied ±0.5° F until the craft reached an altitude of 18,000 feet on descent when the ECS opened to ambient air. The couch temperature at landing was 66° F.

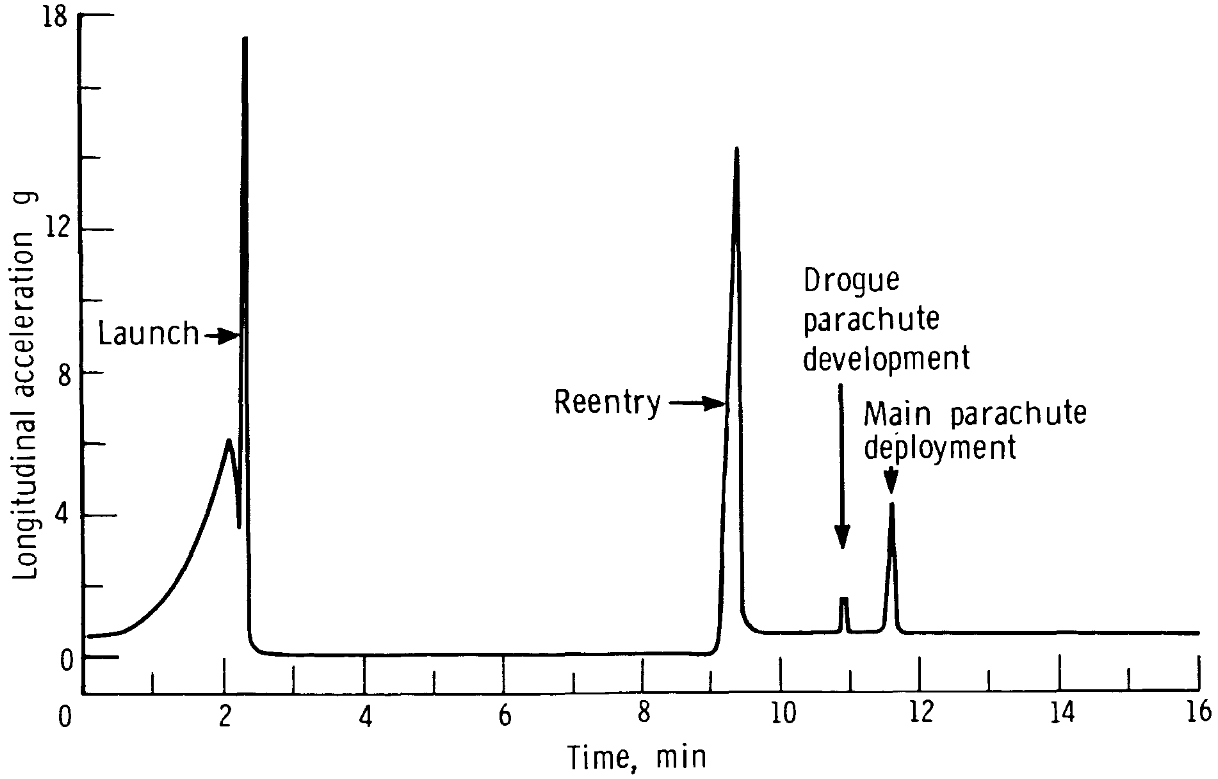


FIGURE 3-3.—The longitudinal acceleration profile of the Mercury-Redstone 2 flight. The extra peak to 17g during launch was caused by escape rocket firing.

Monitoring

Real-time monitoring of the subject occurred at three Cape Canaveral locations. It began in the transfer van and was then transferred to the blockhouse after the subject was placed in the spacecraft. The blockhouse was monitored by hardline transmission (spacecraft umbilical) until T—30 minutes when telemetry commenced; then both blockhouse and Mercury Control Center (MCC) monitored until lift-off. After lift-off MCC was the sole monitor. The three monitoring stations were connected by Missile Operations Intercom System (MOPS), a closed-loop voice link. In addition, the Hangar S medical facility, the point recovery team, emergency spacecraft recovery team, Patrick Air Force Base hospital, and Grand Bahama medical facility were informed of countdown events via MOPS.

The blockhouse monitoring phase used two consoles which displayed physiological, psychological, and environmental control system variables. In addition, two channels of ECG (leads 1 and 3), respiration waveform, rectal temperature, and three psychomotor variables were recorded on a strip chart. Range time was substituted as a readout in lieu of the fourth psychomotor channel. Indication of mild shock to the subject during the blockhouse period was obtained through a disturbance of the ECG waveform. The console also provided for the display of either lead of ECG on an oscilloscope. Adjacent to the physiological and psychological display was the environmental control system monitoring console. The environmental data which had direct bearing on the condition of the subject included couch and spacecraft pressure and temperature, amount of oxygen in the ECS, and available coolant.

At the Mercury Control Center, the data readout was the same as that at the blockhouse except that the transmission of an electrical shock was recorded.

Since this was a suborbital flight, the range stations of the Worldwide Mercury Network did not participate. Two Atlantic Missile Range stations (San Salvador and Grand Turk) participated for purposes of checking telemetry signal quality.

In addition to monitoring records, both the Cape Canaveral Telemeter II and an airborne station collected data. Other data sources for determining the status of the subject during flight were an onboard tape recording and photography of the subject.

Recovery and Postflight Periods

Three major animal recovery areas were used. They were the emergency spacecraft recovery area, the point recovery area, and the downrange normal recovery area. All of these areas permitted the exercise of the manned procedures. Emergency spacecraft recovery effort was designed to provide care for the subject in the event of a canceled mission (abort of the mission prior to launch). The point recovery effort, a highly coordinated land, sea, and air effort, was designed to provide the retrieval of the occupant in the event of a pad or launch abort; it extended for a 12-mile radius from the launch site. The normal recovery effort consisted of an airborne surveillance supported by eight ships distributed along the line of probable landing. A land-based medical facility on the Grand Bahama Island for postflight examination and animal care was provided. The movement of the animal after recovery was to this land-based facility.

The significant events occurring during recovery included the retrieval of the Mercury spacecraft by helicopter and its delivery to the recovery vessel at 3:40 p.m. e.s.t., January 31, 1961. The spacecraft hatch was opened at 3:42 p.m. e.s.t.

Moisture on the interior of the plexiglass couch cover prevented observation of the chimpanzee; however, it was heard vocalizing normally. The environmental control system (ECS) inlet hose was disconnected at 3:44 p.m. e.s.t. and fresh air (ship's air) under pressure was introduced into the couch. The right-hand couch cover porthole was removed and the air source was then placed in the port. The fresh air cleared away the condensate on the interior of the couch cover and the animal's condition appeared to be normal. Upon removal of the couch from the spacecraft, the cover was removed and the subject and lower half of the couch were transported to the ship's sick bay where the chimpanzee was given a physical examination.

He was retained overnight on the recovery ship until the morning of February 1, 1961. The subject and equipment were then transported by helicopter to the Grand Bahama forward medical facility and arrived at 8:10 a.m. e.s.t.

The subject, equipment, and personnel were then transferred by pressurized aircraft to Patrick Air Force Base, Florida, and returned to the Cape Canaveral animal complex. There, another physical examination was performed. A post-test calibration check was made of the psychomotor equipment and physiological sensor harness. The test indicated that all equipment was operating within preflight specifications. On February 2, 1961, two ½-hour psychomotor performance sessions were conducted and the physiological variables were recorded. Finally, on February

3, 1961, a similar test was conducted, and on the next day the subject was returned to Holloman Air Force Base, New Mexico.

References

1. Stingely, Norman E.: Countdown and Procedures for Project Mercury Flight MR-2 (Chimpanzee Subject). Air Force Missile Development Center TR-61-20, June 1961.
2. Archibald, Erwin R., and Ward, William E.: Chimpanzee Temperature-Humidity Tolerance Tests—Control Tests at 80° F, 50 Percent Relative Humidity. Air Force Missile Development Center TR-61-11, Apr. 1961.

4. BEHAVIORAL APPARATUS
for the
MR–2 AND MA–5 FLIGHTS

By E. J. Brown* and R. D. Iwan*

As the preceding sections have indicated, the Mercury animal program generated a requirement for the development of lightweight, miniature, highly reliable equipment with which a series of tasks could be presented to the animal. This "psychomotor apparatus" had to fit into the confines of the animal's pressurized couch and its development within the imposed limits of time, space, and weight presented considerable difficulties. This section describes the solution of the McDonnell Aircraft Corporation to the problem of producing an instrumentation package which met the specifications given by the NASA and the 6571st Aeromedical Research Laboratory.

Apparatus

Two versions of the apparatus were developed; one for use in the ballistic flight (fig. 4–1) and the other

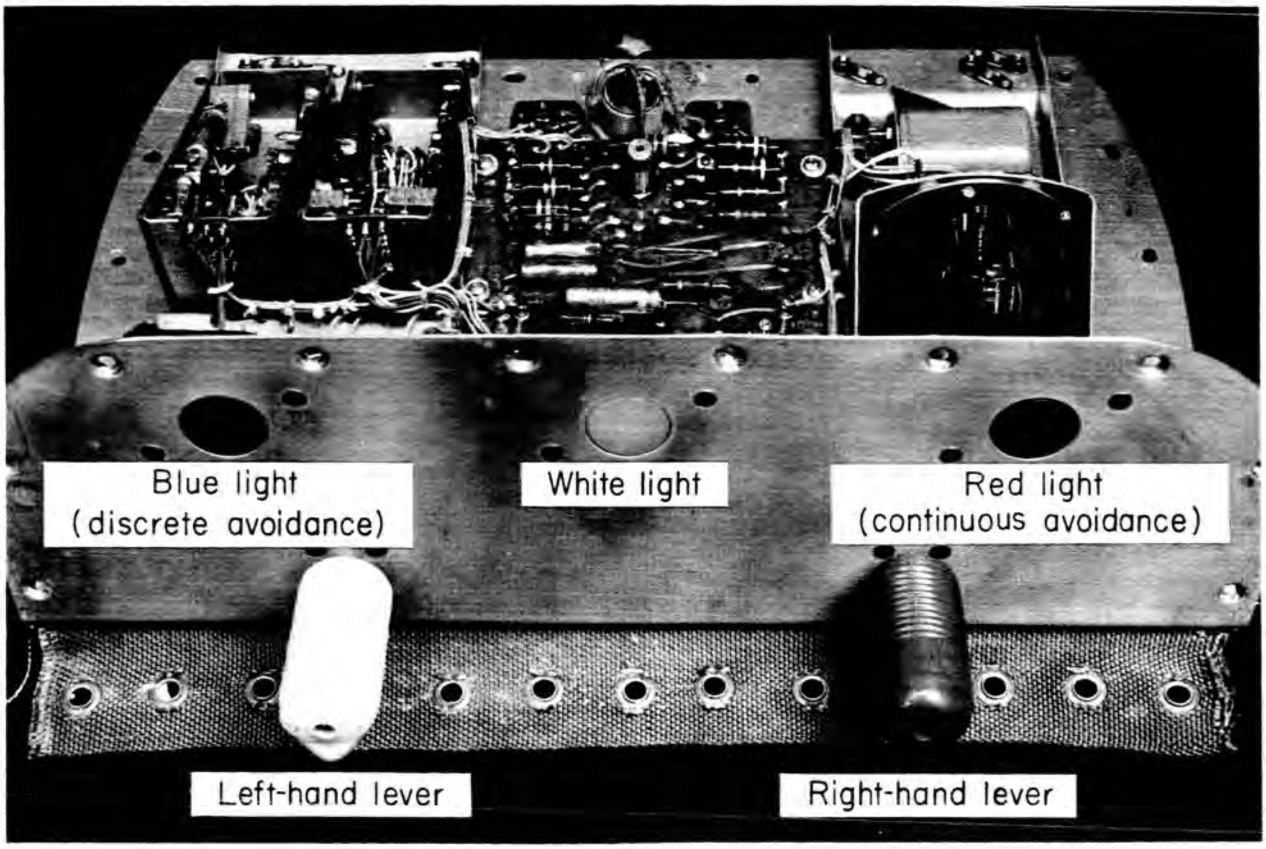


FIGURE 4–1.—The MR–2 ballistic flight psychomotor panel with its attached CA–DA programer. (Also see fig. 5–1.) The white light indicates that the right lever has been satisfactorily depressed. The blue light must be extinguished by pressing the lever within 5 seconds or a shock will be received.

---

*McDonnell Aircraft Corp.

for use in orbital flight (fig. 4-2). The ballistic unit presented two shock-avoidance programs. The primate had to depress levers in response to colored light stimuli within a certain time period to avoid a mild shock. The orbital unit had three additional programs during various phases of which the primate obtained drink and banana-flavored food-pellet rewards or shock punishment for error or failure to respond. The stimuli for a particular program consisted of colored lights and symbols presented in display units. The performance tasks are described in sections 5 and 9.

System Operation

The system is composed of two types of basic parts, a stepper switch and a timer.

Of the stepper switches, one utilizes 9 positions on 7 wafers and the other 20 positions on 9 wafers. Since space was at a premium, commercial switches were modified; and a container was designed to eliminate as much waste space as possible and yet to provide a hermetic seal on the coil and contacts.

The time circuit is a radical departure from conventional types. One of small size, low power drain, high reliability, large dynamic range, and low weight was required. Extreme variations in the supply voltage and excessive transients further complicated the problem.

Figure 4-3 is a schematic diagram of the basic timing circuit which is used to give time periods from 0.125 second to 900 seconds. Basically, it is constant-current generator formed by resistors R_1, R_2, transistor Q_1, and a Zener diode D_6 feeding capacitor C_1. This timing circuit causes the voltage across C_1 to rise linearly until Q_2, a unijunction transistor, fires and discharges C_1 to the valley voltage of the unijunction. Neglecting leakage currents, the time period $T=\frac{KC}{I}$ where I is constant current, C is capacitance, and K is a proportionality constant. As the circuit is shown, it is highly susceptible to voltage variations and negative-going transients on the power supply bus. Figure 4-4 shows the major modifications incorporated in this circuit to eliminate power prob-

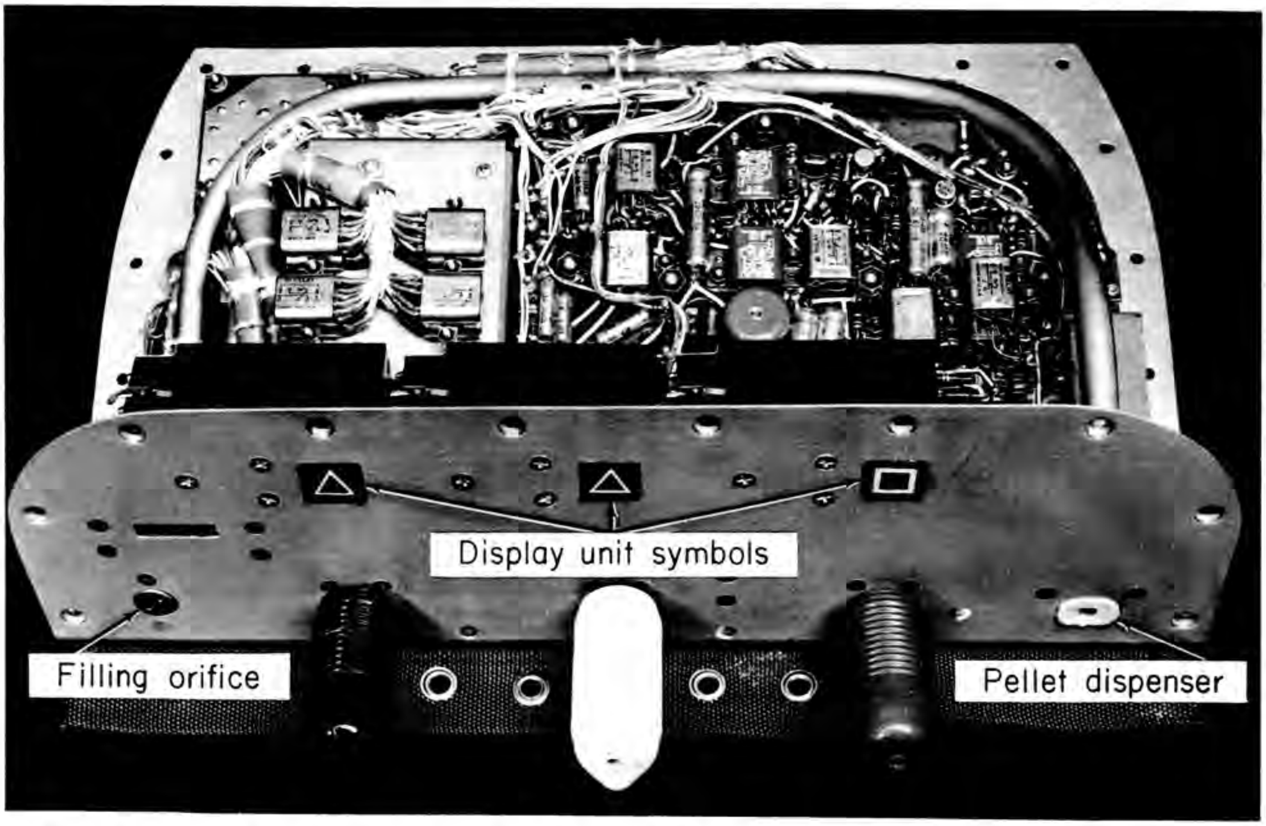


FIGURE 4-2.—Advanced orbital MA-5 psychomotor flight programer with the accompanying panel (compare with figs. 2-1 and 9-1). A digital counter records lever presses. Illustrative model symbols are pasted to the display unit windows above each lever. The reservoir tube of the pellet dispenser curves back around the programer to the circular filling orifice. The waist restraint panel is laced to the tab appearing below the panel.

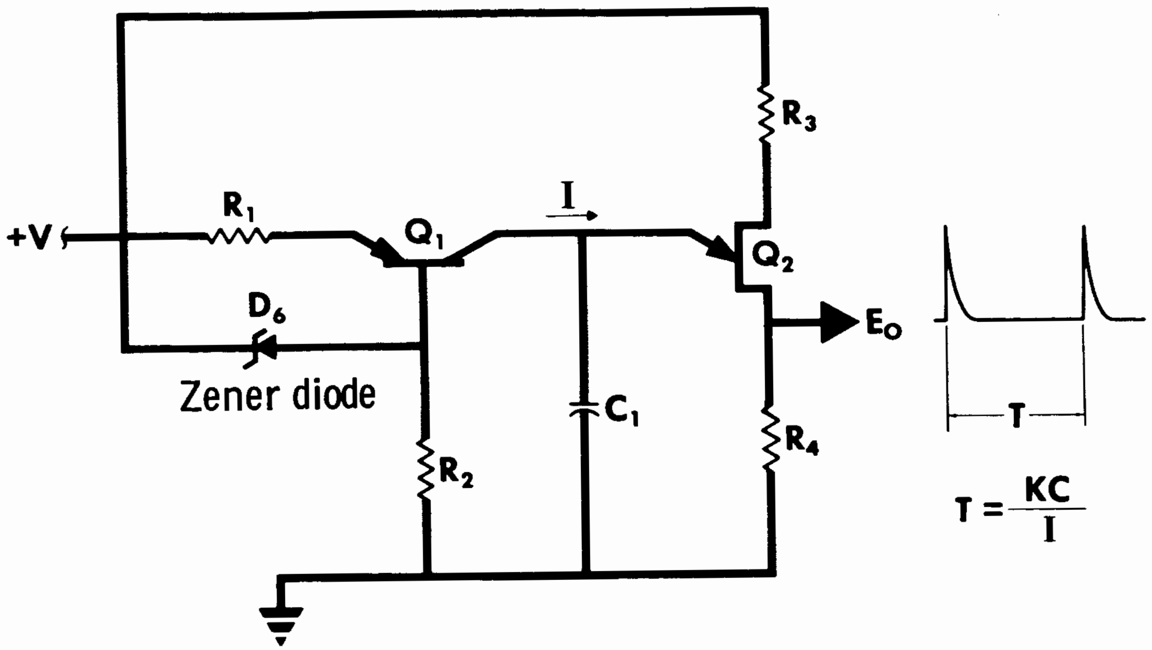


Figure 4-3.—Basic timing schematic diagram.

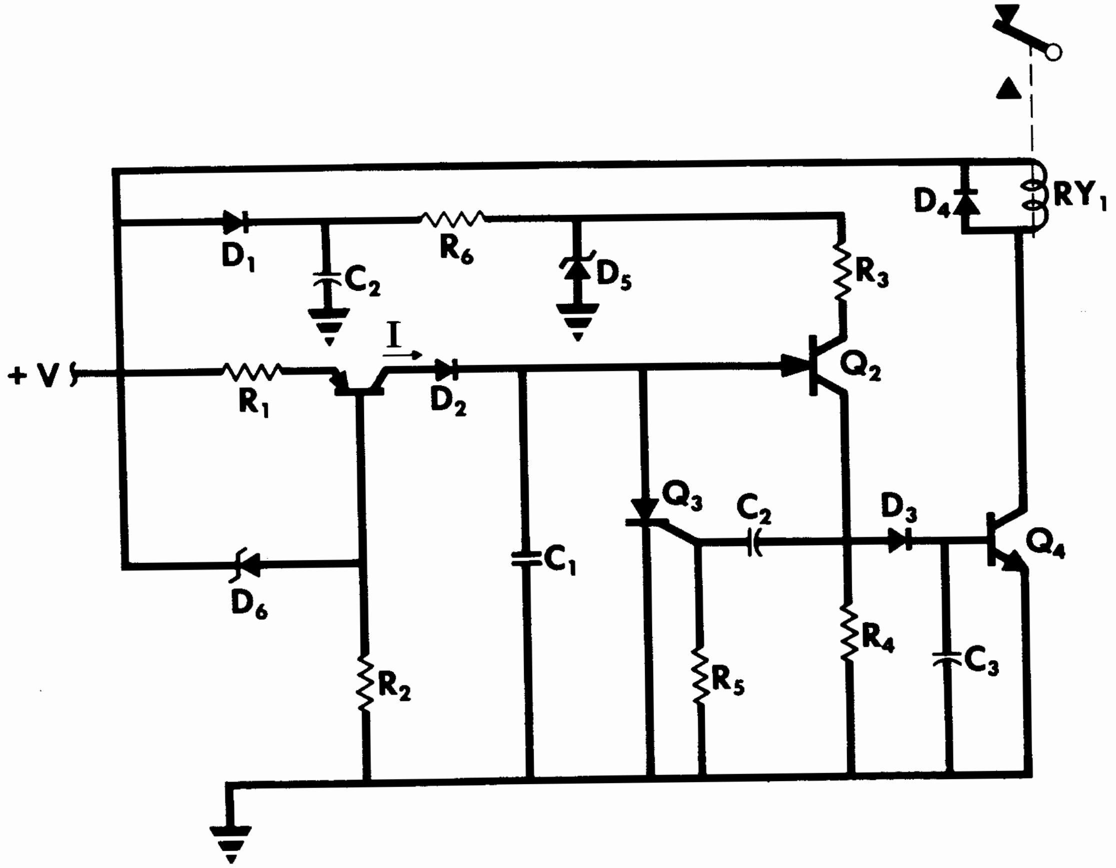


Figure 4-4.—Timing circuit with switching and transient protection.

lems and to improve the overall characteristics. A regulated voltage to Base 2 of the unijunction transistor is provided by D_1, D_5, R_6, and C_2, to prevent input voltage variations from varying the firing voltage. The diode D_2 prevents C_1 from discharging through a transistor during a severe negative-going transient. The capacitor C_1 is discharged by Q_3, R_5, and C_2 to approximately 1 volt above ground, which is lower than the valley voltage of Q_2. It is also possible to reset C_1 to zero with an inhibit pulse prior to the firing of Q_2 by coupling a trigger signal to the gate of Q_3.

The diode D_3 enables C_3 to obtain a charge when Q_2 fires and yet to hold or stretch the pulse so that Q_4 will reliably pull in RY_1.

The diode D_4 is used to suppress the transient produced by the interruption of current through the inductance of RY_1 when Q_4 stops conduction.

By varying the value of R_1, the period of the timer can be varied greatly. For excessive changes in the period, C_1 must be charted too. For periods up to 2 minutes, 50 microfarads were used for C_1; for 2 to 6 minutes, 300 microfarads were used; and for 5 to 15 minutes, 800 microfarads were used.

Figure 4-5 aids in explaining the operation of the system. When power is applied, the master timer begins a countdown and the program selector channels provide power through the display selector to turn on the red light in the right-hand display unit and route power to start the discrete avoidance and continuous avoidance programs. While in this mode of operation, right-hand lever depressions inhibit a shock for 15 seconds; meanwhile, the blue light comes on every 2 minutes and requires a depression of the left-hand lever within 5 seconds or the light is terminated and a shock is delivered.

After 15 minutes the master timer delivers an output to the program selector which turns the power off for all but the cumulative response circuits and allows a 6-minute time-out or rest period.

At the end of 6 minutes, the master timer delivers another output to the program selector, which, in turn, powers the circuits required for the differential reinforcement of low rates (DRL) program. A green light in the right-hand display window alerts the primate to the program identity. A 20-second timer begins to count down and permits the "drink" dispenser to be armed at the end of 20 seconds if the right-hand lever is depressed. If it is depressed prior to the passage of 20 seconds, the timer is reset; and the "drink" dispenser cannot be armed for an additional 20 seconds. Once armed, it will remain so for 5 seconds or until the primate has received his allotted amount of liquid, whichever comes first. This program lasts for 10 minutes, at which time the master timer advances the program selector to the second timeout period.

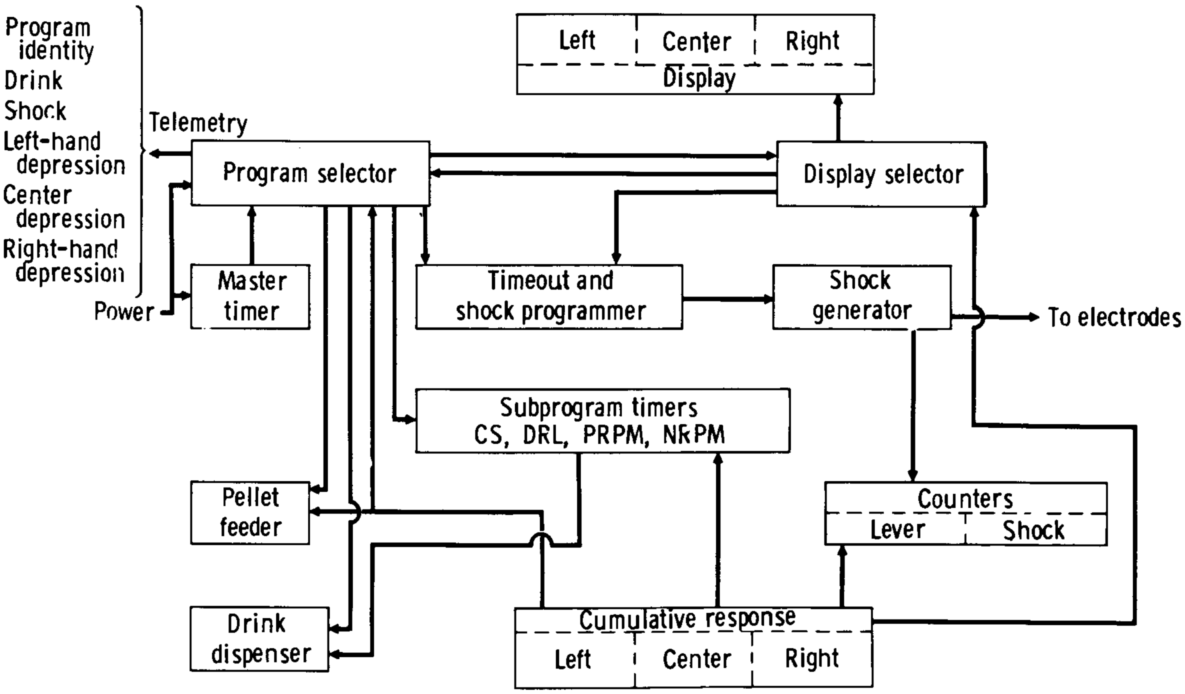


FIGURE 4-5.—Orbital psychomotor block diagram.

After 6 minutes the master timer advances the program selector to fixed ratio (FR) reinforcement program for food rewards. The stimulus for this program is the illumination of a yellow light on the center display window. When this light is on, the subject has to press the center lever 50 times for one pellet of food. After 10 minutes the animal has another rest period.

At the end of 6 minutes the master timer advances the program selector to the positive reinforcement perceptual monitoring (PRPM) or negative reinforcement perceptual monitoring (NRPM) oddity problem mode. The choice of modes is determined prior to launch. A latching relay is preset electrically to program the desired mode of operation. In the PRPM mode, symbols are displayed in each of the three display windows. Displays in two of the windows are always alike, and one is always different. If the primate depresses the lever under the odd symbol, he is rewarded with a banana pellet and a new display. If a wrong lever is depressed, the primate is punished by not receiving a pellet and a 15-second blackout of the displays. After 15 seconds, the same display is shown again.

The oddity problems last until 36 combinations of displays have been shown or until 5 minutes have elapsed, at which time the master timer will return the program selector to the discrete-avoidance-continuous-avoidance mode and the entire program is repeated.

The oddity problem which was employed in the MA-5 flight uses negative reinforcement (NRPN) in order to conserve food pellets. A wrong answer results in a ½-second shock, followed by a 15-second blackout of the displays and a representation of the same set of symbols. A right answer results in no shock, a 15-second timeout, and a new set of symbols. If no response is given in 35 seconds, a shock is delivered every 5 seconds until either a right or a wrong answer is given. This program lasts until 18 combinations have been shown twice or until 10 minutes have elapsed.

The following information was telemetered over four channels:

For the discrete-avoidance-continuous-avoidance task,
(1) Shock indication
(2) Number of left-hand-lever switch closures
(3) Blue light "on" time
(4) Number of right-hand-lever switch closures

For timeout,
(1) Program identification
(2) Number of left-hand-lever switch closures
(3) Number of center-lever switch closures
(4) Number of right-hand-lever switch closures

For the differential reinforcement of low rates task,
(1) Program identification
(2) Number of left-hand-lever and number of center-lever switch closures
(3) Drink indication
(4) Number of right-hand-lever switch closures

For the fixed-ratio (food reward) task,
(1) Program identification
(2) Number of left-hand-lever switch closures
(3) Number of center-lever switch closures
(4) Number of right-hand-lever switch closures

For the oddity problem,
(1) Program and display number indication
(2) Number of left-hand-lever switch closures
(3) Number of center-lever switch closures
(4) Number of right-hand-lever switch closures

In addition to the telemetered data, an electromechanical counter on the front panel records the total cumulative number of lever switch closures. (See fig. 4-2.)

5. PERFORMANCE ASPECTS

of the

MR–2 FLIGHT

By Frederick H. Rohles, Jr.,*
Marvin E. Grunzke,** and
Richard E. Belleville, Ph. D.***

In April of 1959 when the National Aeronautics and Space Administration defined the animal program of Project Mercury, it was specified that both behavioral and physiological measurements would be made on the subject. The behavioral aspects of this program were assigned to the Comparative Psychology Branch of the Aeromedical Research Laboratory, Holloman Air Force Base, N. Mex. (ref. 1). The purpose of this section is to describe the performance aspect of the first of the chimpanzee flights of Project Mercury, which was the ballistic flight of the Mercury-Redstone 2 spacecraft on January 31, 1961.

Methods

Subject

The subject, Ham (Aeromedical Research Laboratory subject No. 65), was a male chimpanzee weighing 37 pounds. On the basis of dental eruptions, his age was estimated to be 44 months. He had received 219 hours of training in the behavioral task over a 15-month period, and prior to the flight he had been subjected to simulated Redstone launch profiles on the centrifuge at the U.S. Air Force Aerospace Medical Laboratory, Dayton, Ohio.

Performance Apparatus and Task

Figure 4–1 shows the performance test panel, containing three lights and two levers, which was mounted perpendicular to the subject at waist level. The levers are approximately 1 inch in diameter and protrude 2¼ inches from the face of the panel. A force of 2 pounds was required to activate each lever so that it could not be depressed by the force of inertia accompanying launch.

The task, which is described in detail in reference 2, was one in which an intermittent or discrete avoidance procedure on the left lever was superimposed on a right-hand lever schedule which required continuous avoidance behavior. Each response by the subject on the right-hand lever postponed the occurrence of the next scheduled shock for 15 seconds and, as a consequence, a consistent and stable rate of responding was developed by which the animal could avoid shocks indefinitely.

In contrast to the continuous task, discrete avoidance employed a signal as a warning of impending shock if the correct response was not made. In the MR–2 flight, the warning signal was the illumination of the blue light. This light came on once every 2 minutes. However, a fixed time interval was not employed during training in order to eliminate the possibility of temporal conditioning. The time between the appearance of the blue light and the pressing of the left lever was the subject's reaction time.

During the flight the subject had to press the right lever at least once every 15 seconds and at the same time press the left lever within 5 seconds after each presentation of the blue light. A detailed description of the psychomotor programer operation is presented in section 4. Since redundancy in data collection was desired, five digital counters were included in the programing unit of the couch. These counted the responses on the right-hand lever, the blue-light presentations, responses on the left-hand lever, the number of shocks for failure to perform continuous-avoidance task, and the number of shocks for failure to make discrete-avoidance responses. Readings from these counters after flight verified the information obtained via telemetry and the onboard tape recorders.

---

*Lieutenant Colonel, U.S. Air Force.

**Major, U.S. Air Force.

***NASA Headquarters, Office of Space Sciences.

Results and Discussion

From a behavioral viewpoint, this flight can be described as an experimental investigation to determine the effects upon learned behavior of exposure to the environmental distractions imposed by space flight. Following the flight, an investigation was made of those variables which could be studied in the laboratory without risk of injury to the subject. This investigation was made in an attempt to rule out certain extraneous factors that could possibly have affected the performance.

The first variables studied were the minor stresses on the subject that occurred immediately prior to the flight. These variables included the awakening after only 5 hours of sleep, installation of the physiological sensors including the suture ECG electrodes, and the nearly 9 hours of restraint prior to launch. The introduction of these variables raised questions as to the physical condition of the subject at the time of launch. It was suggested that the chimpanzee may have been fatigued. If this were true, then a reduced response rate on the continuous-avoidance behavior and an increased reaction time on the discrete task might be expected. However, because neither of these were observed and because the novelty and uniqueness of the flight itself could possibly compensate for subject fatigue, these stresses were again imposed upon the subject 2 weeks after the flight. The subject was kept awake on the 13th day after launch, was allowed to go to sleep at the usual time and was then awakened at 1:00 a.m. on the 14th day and subjected to the same activities as those during the countdown. It was then given a 17-minute trial in which both tasks were performed. The results of this test showed performance to be stable and unaffected. Thus, it was concluded that the physical condition of the subject resulting from preflight activities did not affect its in-flight performance.

With the exception of the noise and vibration accompanying the launch, the environmental factors associated with the remainder of the flight can be summarized in terms of the physical forces acting upon the subject during the launch, flight, and reentry into the earth's atmosphere. The magnitude, duration, and time of occurrence of these forces during the flight are shown in figure 5–1. The figure also shows the level of performance of the discrete-and-continuous-avoidance task during the flight. During the launch the animal was subjected to a maximum acceleration of 17g. This acceleration was followed by 6½ minutes of weightlessness. When the spacecraft started on its downward course into the denser atmosphere, its flight attitude was reversed so that during reentry the deceleration again imposed a transverse force of inertia which acted from back to front of the subject. Although the magnitude of the force was not so great as it was during launch, its duration was much longer; that is, there were accelerations of more than 14g for 5 seconds and more than 10g for 10 seconds.

The flight can be divided into three periods: launch accelerations, weightlessness, and reentry. In terms of performance of the continuous-avoidance task, the sharp reduction in response rate following launch was expected on the basis of the results obtained from previously exposing the subject to accelerations of 6g on the centrifuge at the U.S. Air Force Aerospace Medical Laboratory. Immediately following launch, the subject received his first shock. However, it is believed that this shock was due to a malfunction in the timing apparatus since analysis of the telemetry recording shows that the time between responses at this period of the flight was less than 15 seconds. Performance was not directly affected by weightlessness; however, exposure to the reentry decelerations was critical from the performance standpoint. A gradual decrement in the response rate for the continuous-avoidance task was observed, but reaction time was unaffected. (See table 5–I and fig. 5–1.)

It might appear that the high deceleration that accompanied reentry was responsible for the persistent decrement in performance of the continuous avoidance task; however, the launch accelerations and the weightless state (either individually or in combination) could also have accounted for the decrement. Moreover, since there was no information concerning performance following reentry, there was no way of determining whether the subject returned to normal response rates soon after the reentry portion of the flight was over or whether recovery was delayed. (See table 5–I and fig. 5–1.)

Reaction time, as measured by the discrete task, was unaffected. For the nine presentations of the blue light during the flight, the mean reaction time was 0.82 second which was slightly above the 0.80-second mean of his preflight performance. (See table 5–I and fig. 5–1.)

These flights represent a beginning in the measurement of animal behavior in space and as such, it is believed they can provide valuable data for the planning of further animal flight studies.

Concluding Remarks

Performance of a two component avoidance task was measured on a chimpanzee that was flown on the

Mercury-Redstone 2 ballistic flight. As a result of this flight and the laboratory investigations which followed, it was concluded that the minor stresses imposed immediately prior to the flight, that is, prolonged wakefulness, physiological examination, and restraint, did not affect inflight performance. The accelerations accompanying launch and reentry were associated with a brief decrease in the response rates for the continuous avoidance task; however, the rate rapidly returned to normal and the immediate postlaunch rate showed no change from preflight control. This finding duplicated that following exposure to radial acceleration on the centrifuge at the Aerospace Medical Laboratory. Performance during weightlessness was steady and unimpaired. However, a sharp decrement in the response rate of the continuous task was noted following the acceleration that accompanied reentry. Performance of the discrete avoidance task was consistent and near the preflight mean throughout the flight.

References

1. Rohles, Frederick H., Jr.: Behavioral Measurements on Animals Participating in Space Flight. Air Force Missile Development Center TN–60–5, Mar. 1960.
2. Belleville, Richard E., Rohles, Frederick H., Jr., Grunzke, Marvin E., and Clark, Fogle C.: Complex Avoidance Behavior in the Chimpanzee and its Applicability to the Study of Space Environments. Air Force Missile Development Center TR–60–27, Sept. 1960.

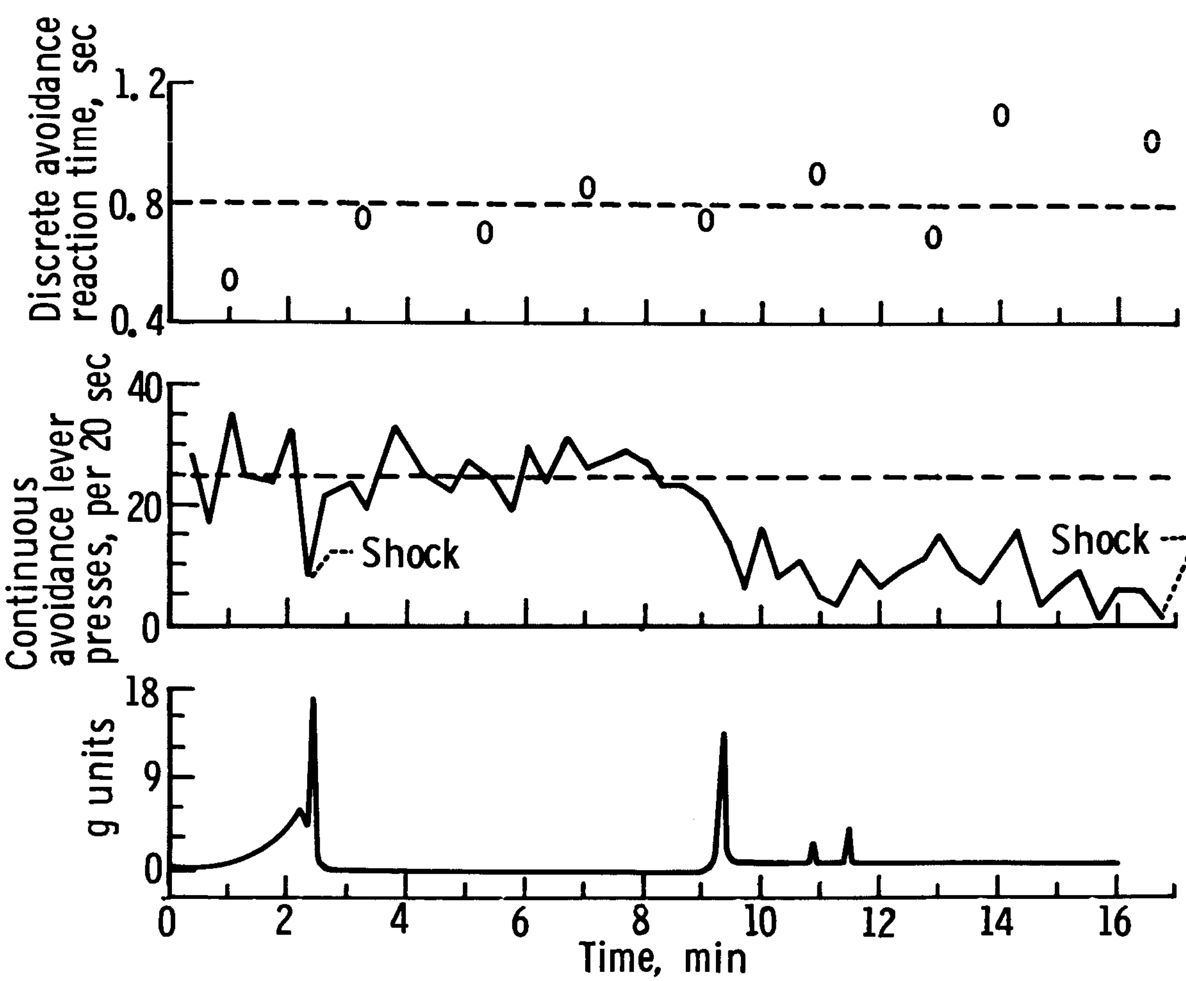


FIGURE 5–1.—Responses of the MR–2 flight animal to the blue light (classical avoidance giving reaction time) and the red light (Sidman test; a continuous monitoring task in which the lever must be pressed once every 20 seconds). The transverse dotted lines represent the average preflight responses of this subject. Discrete avoidance responses stay well within preflight means. The rate of pressing the continuous avoidance lever is normal during weightlessness and only falls significantly after exposure to the reentry acceleration.

TABLE 5-I.—*Raw performance data for continuous- and discrete-avoidance task in MR-2 flight*

Time from launch, sec	Number of responses		Number of shocks		Discrete avoidance presentations	Duration of discrete avoidance reaction, sec
	Continuous avoidance lever	Discrete avoidance lever	Continuous avoidance	Discrete avoidance		
0 to 20	28					
21 to 40	17					
41 to 60	25					
61 to 80	34	1	....	....	1	0.55
81 to 100	24					
101 to 120	32					
121 to 140	7	....	1			
141 to 160	23					
161 to 180	24					
181 to 200	19	1	....	....	1	.75
201 to 220	33					
221 to 240	28					
241 to 260	25					
261 to 280	23					
281 to 300	27					
301 to 320	25	1	....	....	1	.70
321 to 340	19					
341 to 360	30					
361 to 380	24					
381 to 400	31					
401 to 420	26	1	....	....	1	.85
421 to 440	27					
441 to 460	29					
461 to 480	27					
481 to 500	24					
501 to 520	24					
521 to 540	21	1	....	....	1	.75
541 to 560	15					
561 to 580	6					
581 to 600	16					
601 to 620	7					
621 to 640	10					
641 to 660	4	1	....	....	1	.90
661 to 680	2					
681 to 700	11					
701 to 720	6					
721 to 740	9					
741 to 760	11	1	....	....	1	.65
761 to 780	14					
781 to 800	9					
801 to 820	6					
821 to 840	10					
841 to 860	16	1	....	....	1	1.10
861 to 880	2					
881 to 900	5					
901 to 920	8					
921 to 940	0					
941 to 960	5					
961 to 980	5	1	....	....	1	1.00
981 to 1000	0	....	1			

6. MEDICAL AND PHYSIOLOGICAL ASPECTS *of the* MR–2 FLIGHT

By William E. Ward,* and
William E. Britz, Jr.**

The chimpanzee subject was procured by the U.S. Air Force on July 9, 1959. It originated in the Cameroons, West Africa.

The animal was repeatedly given tuberculin tests with negative results and has remained in excellent health.

During the 18-month period from July 11, 1959, until January 31, 1961 (MR–2 flight), the subject received six complete, quarterly physical examinations. All of the findings were within normal ranges for the immature chimpanzee (ref. 1).

Prelaunch Preparation of Primary, Secondary, and "Backup" Subjects

Physical Examination and Diet

At T—26 hours 54 minutes (8:00 a.m. e.s.t.) following the prelaunch physical examination (see ref. 2 and table 6–I) the subject was placed on a low bulk, low gas-forming liquid diet (section 3).

At T—9 hours 36 minutes (1:15 a.m. e.s.t.) the subject was removed from its cage and taken to the medical van for flight preparation. It was given a physical examination and found to be in excellent condition for the flight.

Data Collecting Methods

The following physiological parameters were measured: ECG (leads 1 and 3), respiration waveform, and rectal temperature. Prelaunch physiological data were recorded on Sanborn direct writing recorders; flight data were recorded on onboard tape and telemetered to ground stations and to recorders located on inflight aircraft.

TABLE 6–I.—*Results of preflight and postflight physical examination conducted on MR–2 subject*

[Subject: Immature male chimpanzee named "Ham"
Age: 3 years 8 months (approximately)
Clinical history: Subject has had no serious illness within 6 months prior the launch date]

Date	Time	Location	Weight, lb	Rectal temperature, °F	Blood pressure, mm/Hg	Pulse, beats/min	Respiration breaths/min	ECG	X-ray
Jan 30, 1961	8:00 a.m. e.s.t.	Animal complex, Cape Canaveral.	37	99.8	122/98	104	28	Normal	Normal
Jan 31, 1961	1:15 a.m. e.s.t.	Animal complex, Cape Canaveral.	37.25	96.4	138/110	140	32	Normal	Normal
Jan 31, 1961	4:30 p.m. e.s.t.	Recovery ship	....	ª 99	130/90	120	32	....	
Feb 1, 1961	8:10 a.m. e.s.t.	Grand Bahama Island	....	98.8	130/85	100	30	Normal	
Feb 2, 1961	8:00 a.m. e.s.t.	Animal complex, Cape Canaveral.	35.25	98.8	110/84	92	24	Normal	Normal
Feb 7, 1961	10:00 a.m. m.s.t.	Holloman Air Force Base, N. Mex.	38.75	99.4	128/98	104	32	Normal	Normal
Feb 14, 1961	1:00 p.m. m.s.t.	Holloman Air Force Base, N. Mex.	38.0	100.0	148/120	124	30	Normal	Normal

ª Axillary

---

*Captain, U.S. Air Force.

**Captain, Veterinary Corps, U.S. Air Force.

Electrocardiogram.—The ECG was detected by three electrodes (fig. 6–1). Two electrodes were made of male and female snap fasteners grasping steel sutures 0.28 inch in diameter, which were implanted under the skin of the chest as described in reference 3. (See figs. 6–1 and 6–2). A stainless-steel-mesh fluid

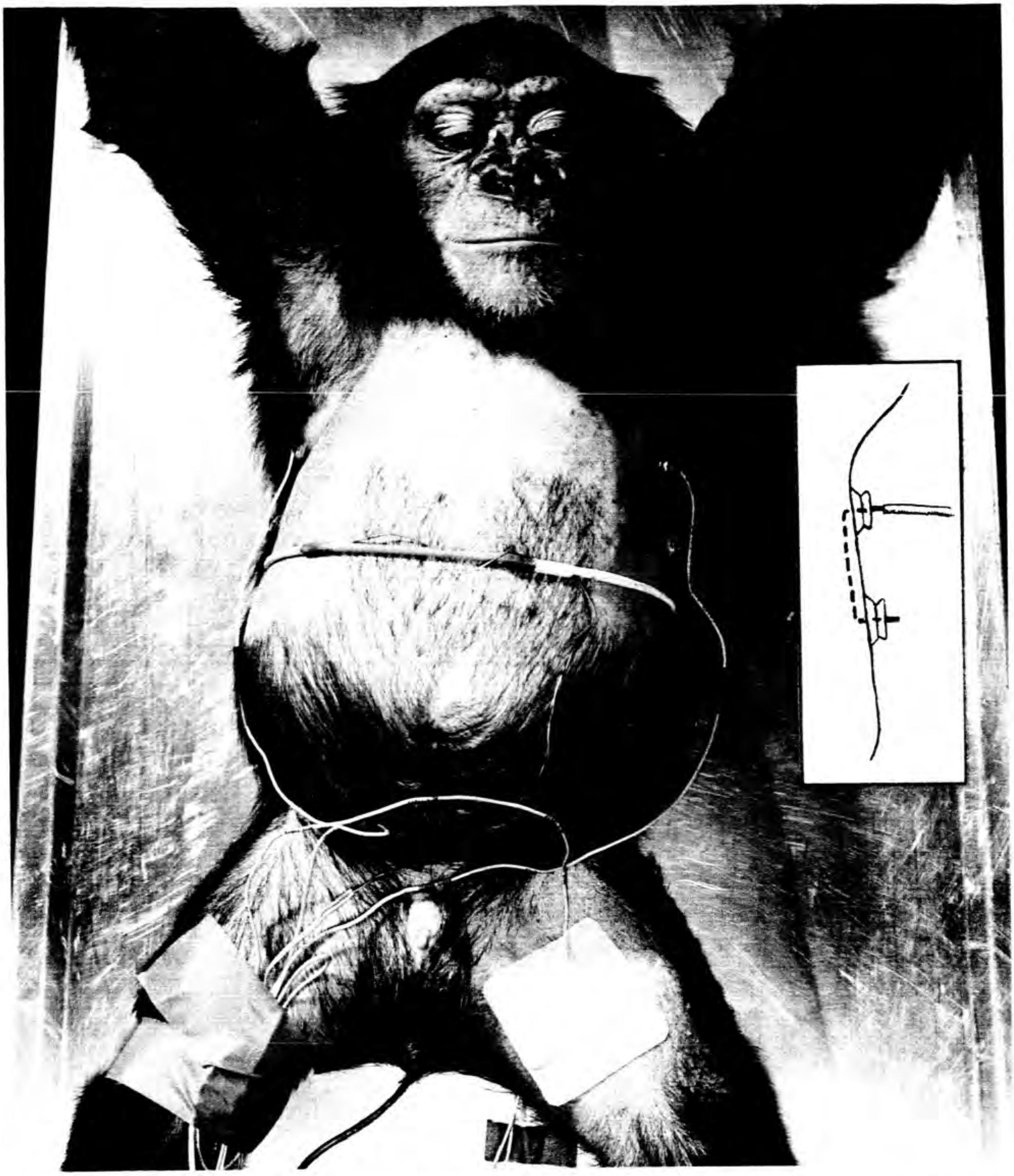
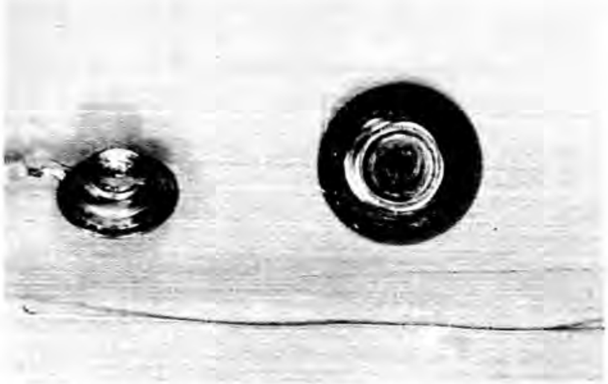
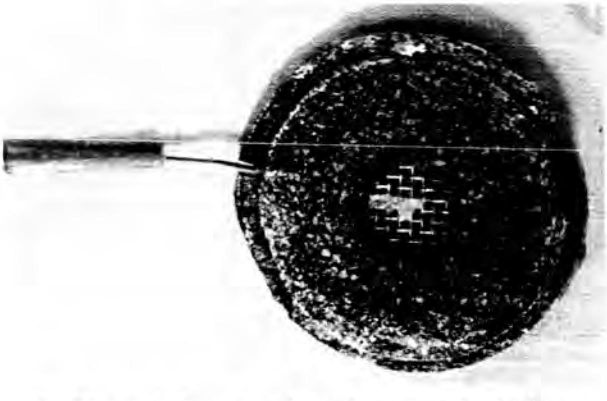


FIGURE 6-1.—Subject following installation of the rectal thermistor, ECG electrodes, and copper sulfate pheumograph. The insert to the right depicts how the wire suture used for the ECG pickup is clipped between one pair of snap fasteners (see fig. 6–2) and passes under the skin to be brought out at the other.

electrode (bentonite paste as a conductor) of the type to be used in the manned flights was applied to the left medial thigh (fig. 6-2).



(a) Enlargement showing male and female snap fasteners and wire used for the suture electrodes.



(b) Wire mesh electrode with a cork surround that holds the mesh away from the skin and provides a space for electrode jelly.

FIGURE 6-2.—Steel suture electrodes.

The areas of attachment were first clipped and cleaned with alcohol. Then tincture of Merthiolate was applied. The suture electrodes were attached to each side of the subject transverse to the fifth and sixth ribs and parallel to the anterior axillary plane. The wires were inserted through the female snap fasteners and then under the skin of the subject. The wires extended, subcutaneously and parallel to the surface of the skin for $1\frac{1}{2}$ inches. The ends of the sutures were then brought out of the skin through female snap fasteners and secured with male fasteners to which electrical leads had been attached. The fluid electrode was applied to the medial aspect of the left thigh with bentonite paste. The electrode was secured with adhesive tape.

Respiration.—The respiration sensor (fig. 6-3) was a flexible plastic and rubber tube of $\frac{1}{8}$-inch inside diameter, $\frac{3}{16}$ inch outside diameter, and length of approximately 1 inch less than the chest circumference of the subject.

A 3-inch rubber section of the tube was filled with a 15 percent solution of copper sulfate. Electrical connections from each end of this section led to a resistor-capacitance coupled transistorized amplifier with limited band pass and was connected to a subcarrier oscillator of the spacecraft telemetry system. The transducer was placed on the subject so that the sensing element was over the sternum and midway between the xyphoid process and the manubrium (fig. 6-1). Resistance changes from respiratory movements provided an excellent signal response for data recording.

Body temperature.—Rectal temperature was measured with an internal (esophageal-rectal) temperature probe as described in reference 3. The probe was inserted approximately 8 inches into the rectum and held in place by tape applied to the buttocks.

Heart rates prior to launch were checked by counting the QRS complexes of lead 3 for 1 minute in every 10 minutes. (Lead 3 was chosen because there was less electrical interference on this channel than on

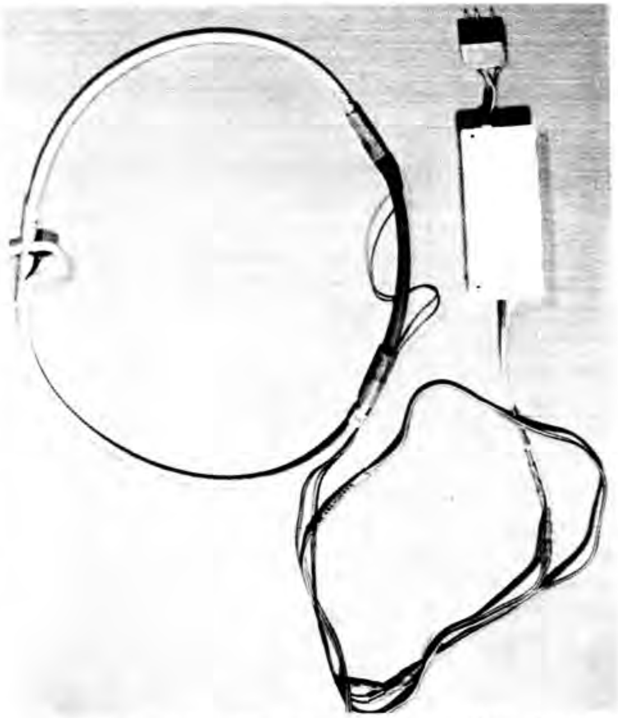


FIGURE 6-3.—Respiratory sensor (pneumograph) consisting of a rubber tube filled with saturated copper sulfate solution whose resistance will vary as the tube is stretched by breathing movements. A resistance-capacitor coupled transistorized amplifier (top right) eliminated drift by passing only the variations whose frequency is greater than $\frac{1}{2}$ cycle per second.

lead 1). Heart rate during the flight was determined by counting all QRS complexes per minute for each minute of the flight. Prelaunch respiration rates were determined by counting waveform peaks for 1 minute in every 10 minutes. Respiration rate during the flight was compiled by counting the number of waveform peaks per minute and recording totals at the end of each minute of flight. Body temperature values were recorded at 10-minute intervals during the prelaunch period and at the end of each minute during the flight.

Results

Physiology

The physiological data from the MR-2 flight are presented in figure 6-4. Time on the abscissa scale is in minutes from launch. Total flight time was 16 minutes 39 seconds.

Prelaunch heart rate.—For the period 8 hours prior to launch, the mean heart rate was 94 beats per minute, a rate slightly lower than the mean established for the subject in a previous test (see table 6-II). However, during the early morning period the subject was lying quietly in the couch. At approximately T—8 hours and again at T—7 hours the subject was engaged in a 15-minute psychomotor work performance.

Launch and flight heart rate.—From lift-off to T+1 minute, the heart rate was 126 beats per minute. During the third minute of flight, there was an increase in heart rate to 147 beats per minute (ECG

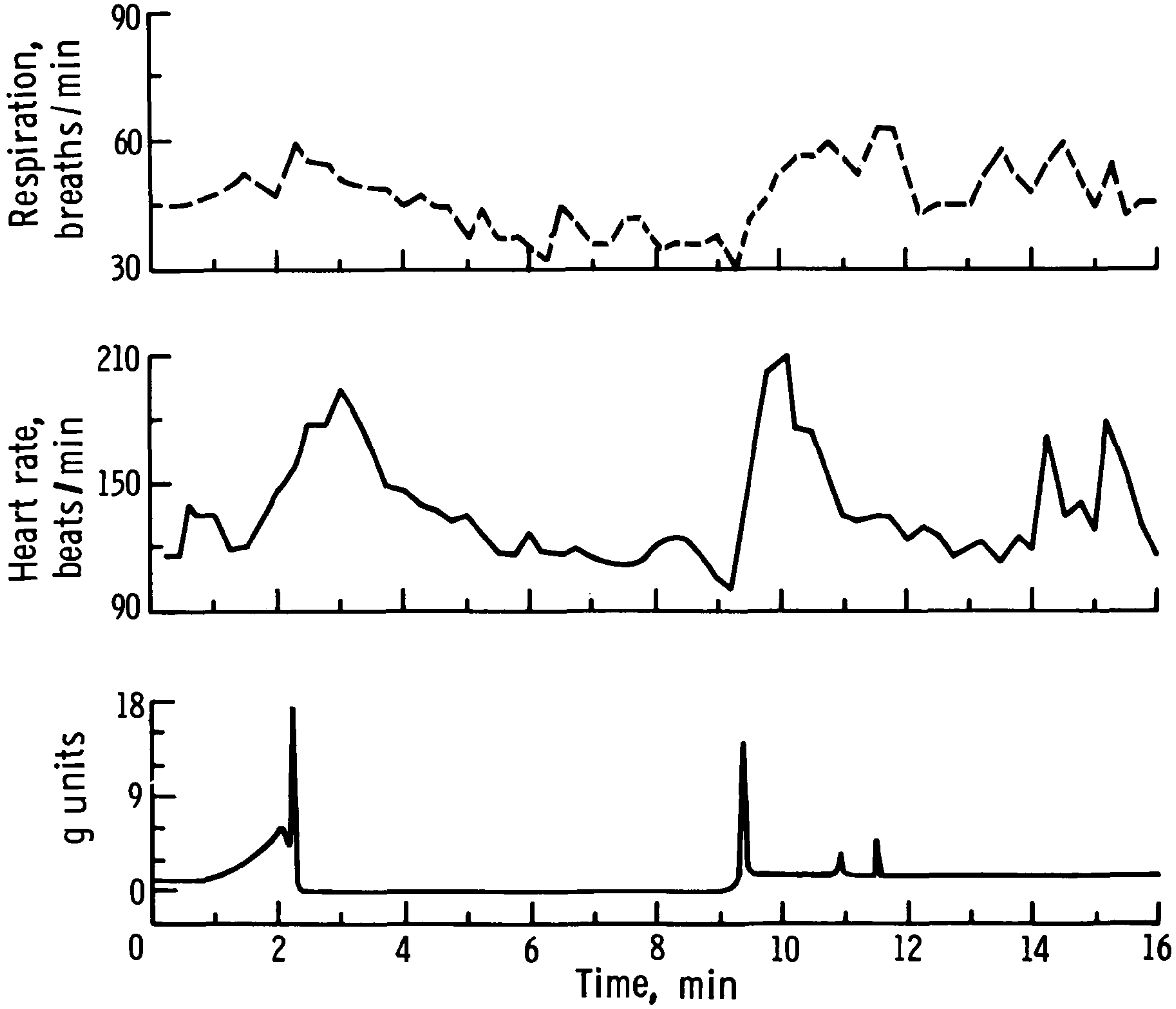


FIGURE 6-4.—Heart and respiratory rates (based on 10-sec intervals) throughout the MR-2 flight. Rates fall to preflight values during the weightless state. (For preflight control data, see table 6-II.)

telemetry was lost during this period for 10 seconds). Peak acceleration was experienced at T+2.3 minutes; then acceleration traces returned to zero. From T+3 to T+4 minutes there was a rise in the mean heart rate to 158 and then a gradual decline during the weightless period. Figure 6–5 is an example of the in-flight data taken during the weightless state. This period lasted approximately 7 minutes. Reentry peak acceleration occurred at T+9 minutes 35 seconds. From T+10 to T+11 minutes there was a dramatic rise in the heart rate to 173 beats per minute; the heart rate then fell slowly to 119 beats per minute at T+14 minutes. In one 10-second period from T+10 to T+11 during the peak reentry acceleration, 34 beats were recorded. If this rate had been sustained it would have constituted a rate of 204 beats per minute from T+10 to T+11. Heart rate was approximately 130 beats per minute at landing (muscle noise artifact prevented a full count).

Recovery and Postflight Observations

The MR–2 flight lasted approximately 17 minutes, and landing occurred approximately 130 nautical miles beyond the planned point. After the arrival of spacecraft onboard the recovery ship, the LSD Donner, the animal couch was taken out, its top removed, and the subject was examined by an Air Force veterinarian. According to his report, the animal was in good condition, even though the inside of the couch was hot and humid.

The veterinarian removed the subject from the couch and performed the postflight physical examination. A 30-cc blood sample was taken for postflight blood count and chemistry studies.

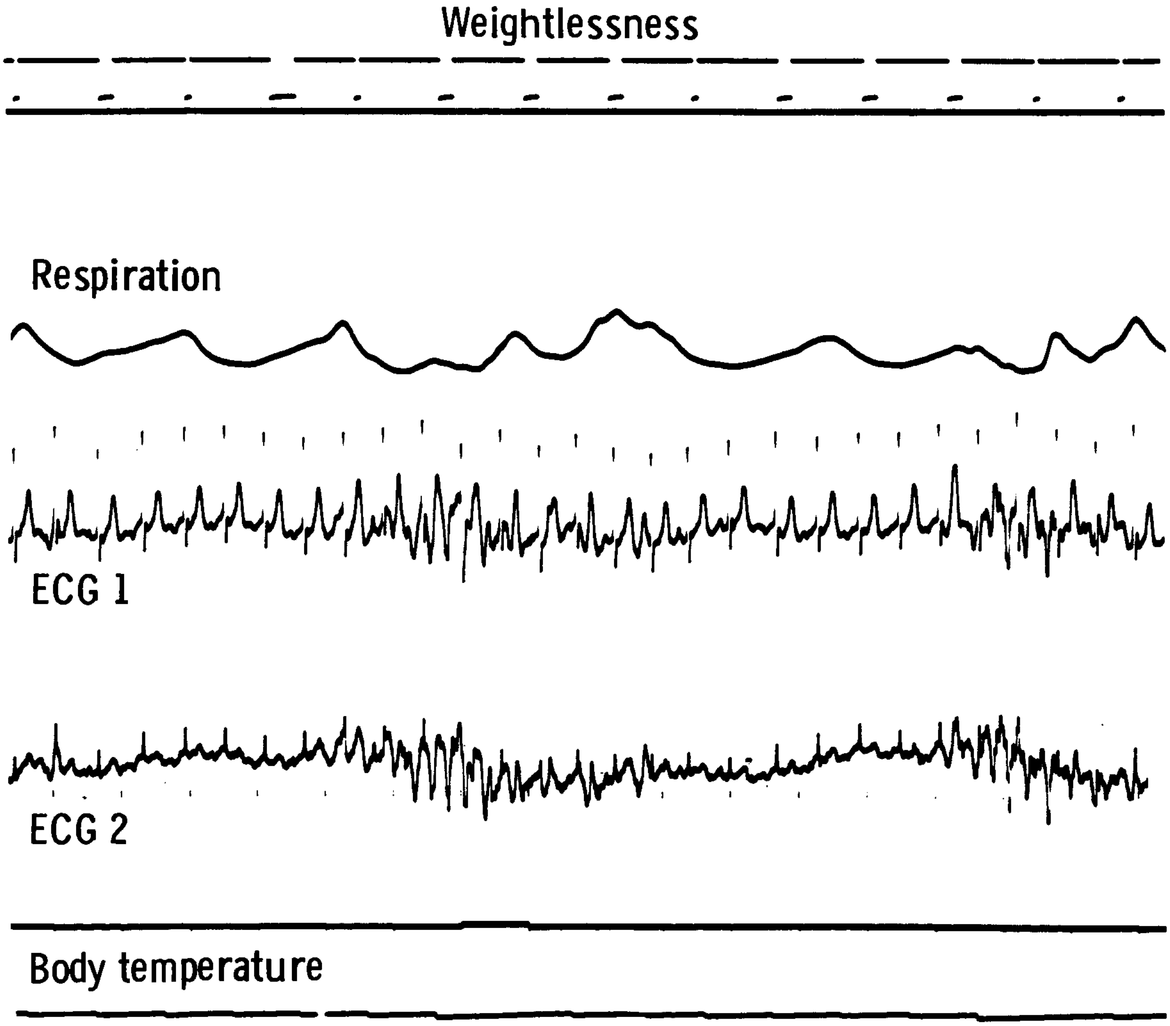


FIGURE 6–5.—Portion of the inflight telemetered MR–2 data showing the records obtained from the electrocardiogram and respiratory sensors at an altitude of approximately 100 nautical miles during the weightless state.

TABLE 6–II *Heart and respiration rates*

[Control data established 4 days before launch]

Heart rate:	
Mean, beats/min	121
Standard deviation, beats/min	3.2
Range, beats/min	100 to 154
Respiration rate:	
Mean, breaths/min	44
Standard deviation, breaths/min	4.8
Range, breaths/min	22 to 72

The subject appeared slightly dehydrated and somewhat exhausted immediately after the flight. Despite the dehydration no change in the hematocrit was observed. However, there was a 5.37-percent loss in the total body weight. This loss was to be expected in view of the fact that the subject had received no food or water for approximately 16 hours. The same change has been observed in controlled temperature-humidity studies conducted at the Aeromedical Research Laboratory. The subject responded to sounds; he was alert; and no incoordination of limb, head, or body movements was detected. All reflexes were normal. Ophthalmoscopic examination showed no changes from the observations made during the preflight examination. A small abrasion was present on the bridge of the nose, but it was insignificant and appeared to be self-inflicted. A small amount of dried vomitus (5 to 10 cc), containing what was thought to be traces of blood, was noted in the couch. No abnormalities were noted during the auscultation of heart and lungs.

After completion of the physical examination, the subject was placed in a small cage provided on the ship. He was then fed fruit, given water when he wanted it, and allowed to rest for the remainder of the night.

The following morning the subject was transported to the forward medical facility at the Grand Bahama Islands. There, he was given a complete physical examination. (See table 6–III.) The only abnormality noted at this time was a slightly dehydrated appearance, and the animal appeared physically exhausted.

The subject was then transported from the forward medical station back to Cape Canaveral and was allowed to rest for the remainder of the day.

On the second day after the flight (February 2) the subject was given another complete physical examination and found to be in good condition. (See table 6–III.) Following this physical examination, he was fully instrumented and placed in the flight couch for a postflight psychomotor evaluation test.

On February 4 the subject was returned to the Aeromedical Research Laboratory at Holloman Air Force Base. He was given a complete physical examination

TABLE 6–III.—*Clinical and laboratory results before and after the MR–2 flight*

[MR–2 launched at 11:54 a.m. e.s.t. on Jan. 31, 1961]

	Jan. 30	Jan. 31[a]	Feb. 2	Feb. 7	Feb. 14
Cardiac auscultation	Normal	Normal	Normal	Normal	Normal
Pulmonary auscultation	Normal	Normal	Normal	Normal	Normal
Condition of subject	Normal	Fatigued	Normal	Normal	Normal
Laboratory results:					
Urinalysis	Normal	Normal	Normal	Normal	Normal
Fecal analysis	Normal	Negative for blood—normal.	Normal	Normal	Normal
Complete blood count:					
Red blood cells, millions per mm³	7.35	5.23 to 5.21	[b] 5.75	4.29	5.04
Hemoglobin, grams	13.0	13	[b] 12.0	13.32	12.95
Hematocrit, percent	46	41	[b] 45	45	44
White blood cells, per mm³	13,700	16,000	[b] 12,500	16,350	12,800
Neutrophiles, percent	31	94	[b] 14	35	28
Lymphocytes, percent	69	4	[b] 84	60	69
Monocytes, percent		1		1	1
Eosinophiles, percent			[b] 2	3	2
Basophiles, percent				1	

[a] Immediately after recovery.

[b] Blood sample taken on Feb. 3.

on February 7 (1 week after the flight), and again on February 14 (2 weeks after the flight). The results were completely within normal ranges, and the subject was in excellent condition.

Discussion

During launch acceleration, there was a rise in both heart and respiratory rates followed by a gradual decline during the weightless state. At 1½ minutes after peak reentry acceleration there was a marked rise in respiration rate, far exceeding the rise during initial launch. Respiration rate declined during the next 2 minutes, then rose slightly, and finally exhibited a downward trend prior to landing. Following the rise during and immediately after launch acceleration, the heart rate declined rather slowly for the first 3 minutes of the weightless state. It then stabilized, rising during reentry and falling again with the return to 1g (fig. 6–4). During the physical examination conducted approximately 4½ hours after impact, the heart rate was 120 beats per minute, and respiration was 32 breaths per minute. No significant change in body temperature was noted.

The subject was without water for 16 hours from the time of placement in the couch until the postflight examination. Upon observation 16 hours after this examination, it appeared to be slightly dehydrated. It had access to food and water when it wished, from the time of recovery; nevertheless, when weighed 44 hours after the flight there was a 5.3-percent loss from his initial body weight. Reference 4 states that a 5-percent body weight loss in man represents significant dehydration. Young chimpanzees who are deprived of water and food and restrained in a chair for 20-hour periods show the significant loss of 4-percent of body weight. Hence, the data on the flight subject suggest that it was significantly dehydrated.

Heart and respiration rates, and the body temperature of the subject during the MR–2 flight were well within the normal range established for chimpanzees during the control temperature-humidity tests.

Probably the most dramatic and significant change seen in the MR–2 subject was in the postflight hematology. The differential white blood cell count showed an extreme reversal of the neutrophile-lymphocyte ratio. (See table 6–III.) The blood sample taken during the 24-hour preflight physical examination showed a ratio of 31-percent neutrophiles to 69-percent lymphocytes (4,247 total neutrophiles to 9,453 total lymphocytes). These values are essentially normal for immature chimpanzees. The sample taken on board the recovery ship immediately following recovery (2 hours, 44 minutes after the flight) showed a ratio of 94-percent neutrophiles to 4-percent lymphocytes (15,040 total neutrophiles to 800 total lymphocytes). All other hematological findings, except the eosinophile count, which is discussed subsequently, were within normal ranges. Similar, though less severe, changes have been observed following 20-hour controlled temperature-humidity studies at the Aeromedical Research Laboratory. Three days after the flight, the ratio was slightly higher than normal: 14-percent neutrophiles to 84-percent lymphocytes (1,750 total neutrophiles to 10,500 total lymphocytes). One week after the flight, the ratio was again within normal ranges: 35-percent neutrophiles to 60-percent lymphocytes (5,273 total neutrophiles to 9,810 total lymphocytes).

After the flight, there was a significant change in the total circulating eosinophile count. Normally, the count of this subject was more than 100 per mm. Immediately after the flight, there was a complete absence of eosinophiles in the circulating blood.

Biochemical analyses of plasma and urine samples obtained before and after the flight indicate a level of 17 hydroxycorticosteroid activity of 50 micrograms per 100 cc of plasma. These results represent an increase of approximately 36 micrograms per 100 cc of plasma during the MR–2 flight. Thus, a marked pituitary-adrenal response is indicated.

Fecal samples immediately after recovery and 2 days after the flight were negative for blood by the guaiac test. These results eliminate the possibility of gastrointestinal hemorrhage of any magnitude. It is presumed that the 5 to 10 cc of dried vomitus noted on opening the couch was a result of either eructation or retching during the postlanding period while the spacecraft was subjected to wave action pending recovery. The postflight urine samples contained traces of albumin which persisted for 2 days following recovery. These traces indicate that there may have been severe oliguria.

Concluding Remarks

The MR–2 flight, conducted on January 31, 1961, was characterized by good telemetry which permitted a thorough study of the physiological reactions of the chimpanzee subjected to this unusual environment.

Heart- and respiration-rate recovery from acceleration following a weightless period of almost 7 minutes was slower than recovery following launch acceleration.

The subject's heart and respiration rates and body temperature did not exceed ranges established for young chimpanzees in a thermally neutral environment.

Body weight loss, hematological findings, and biochemical analyses of plasma and urine samples taken after recovery indicate that the total prelaunch, flight, and recovery experience had exposed the animal to significant stress.

References

1. Cook, James E., Fineg, Jerry, and Miksch, Eldon D.: Physiological Base-Line Studies of Zoological Specimens. Phase I: Hematological Values of Immature Chimpanzees. Air Force Missile Development Center TN–60–9, July 1960.
2. Stingely, Norman E.: Countdown and Procedures for Project Mercury Flight MR–2 (Chimpanzee Subject). Air Force Missile Development Center TR–61–20, June 1961.
3. Wheelwright, Charles D.: Physiological Sensors for Use in Project Mercury. NASA TN D–1082, 1962.
4. Adolph, E. R.: Physiology of Man in the Desert. Interscience Publishers, Inc. (New York), 1947.

7. SUMMARY OF RESULTS *of the* MR–2 FLIGHT

By John D. Mosely, D.V.M.,* and James P. Henry, M.D., Ph. D.**

The original questions posed by the results of the MR-2 flight have been answered by manned flights prior to the publication of these papers. Nevertheless, the flight has some real significance. In it, a high-order primate was subjected to the stresses of the prelaunch operations, launch, flight, reentry, landing, and recovery from the ocean. Despite these various stresses, few measurable physiological and behavioral changes were noted. When compared with a photograph (fig. 7–1) taken before the flight, figure 7-2 indicates the animal's good condition onboard ship only a few hours after recovery. As previously described in references 1 to 3 there was a significant lag after launch in the recovery of heart rate to normal values. The heart rate rose to 158 beats per minute between T+3 to T+4. It required approximately 4 minutes of weightlessness for it to return to the preflight values. After the tachycardia accompanying the reentry acceleration following the period of weightlessness, the heart rate returned slowly to normal values. However, during this period, drogue parachute opening, main parachute opening, and impact were interspersed in the low acceleration field and these events may have deferred the return of the rate to normal. The respiration rate was not greatly disturbed by the launch accelerations and returned to preflight values during weightlessness, varying from a low of 22 to a high of 72 breaths per minute with a mean throughout the flight of 44 breaths per minute. The environmental control system of the Mercury spacecraft performed so well that the subject's temperature was essentially unchanged throughout the flight.

Of interest is the neutrophile-lymphocyte ratio shift, which is believed to be a result of the exposure to the stresses of launch preparation, flight, and postlanding period in the ocean awaiting recovery. Upon recovery and release from the spacecraft, the white-blood-cell count showed a ratio of 94-percent neutrophiles to 4-percent lymphocytes with a total count of 16,000 white blood cells. Seventy-two hours later, there were 14 neutrophiles to 84 lymphocytes. By February 7, nine days after flight, the neutrophile-

FIGURE 7-1.—Chimpanzee subject before MR-2 flight.

---

*Major, U.S. Air Force, School of Veterinary Medicine, Ohio State University, Columbus, Ohio.

**Colonel, Aerospace Medicine Division, Brooks Air Force Base, Tex., with permanent duty station at Department of Physiology, University of Southern California, Los Angeles, Calif. (formerly at NASA Manned Spacecraft Center).

FIGURE 7-2.—Chimpanzee subject after MR-2 flight.

lymphocyte ratio had returned to the normal 35-percent of neutrophiles (see table 6-III). This shift in the ratio which is found during stress has previously been described in reference 4 in the analysis of blood samples obtained from chimpanzee subjects in studies exposing them to high temperature and humidity.

The excellent performance of the chimpanzee on the two required tasks was gratifying. Of the two shocks received during the flight, only one was deserved. The reliability of the subject on the continuous avoidance task shows that this type of work can be monitored by a higher primate under these space-flight conditions. In controlled laboratory experiments on a centrifuge, chimpanzee subjects have been exposed to accelerations of 6 g in simulating the launch of the Redstone vehicle. At that time, a decrement in performance on a continuous avoidance task was noted; therefore, the decrement observed following launch and reentry was to be expected. However, the decrement after launch was followed by recovery to prelaunch values within approximately 1 minute. There was also a decrement following reentry. Although determination of its significance must await the results of further flights, it is possible that it was related to oscillation of the spacecraft prior to stabilization by the deployment of the drogue parachute.

References

1. Von Beckh, Harold J.: Human Reactions During Flight to Acceleration Preceded or Followed by Weightlessness. Aerospace Medicine, vol. 30, June 1959, pp. 391–409.
2. Koustnetzov, A. G.: Some Results of Biological Experiments in Rocket and Sputnik II. Journal of Aviation Medicine, vol. 29, 1958, p. 781.
3. Gazenko, O. G., and Yazdovsky, V. J.: Some Results of Physiological Reactions to Space Flight Conditions. 12th IAF Congress (Washington, D.C.), Oct. 1961.
4. Archibald, Erwin R., and Ward, William E.: Chimpanzee Temperature-Humidity Tolerance Tests—Control Tests at 80° F, 50 Percent Relative Humidity. Air Force Missile Development Center TR-61-11, Apr. 1961.

8. MA–5 OPERATIONS

By Norman E. Stingely,* and
John D. Mosely, D.M.V.**

Prelaunch Activities

For the Mercury-Atlas 5 (MA–5) orbital mission, the animal launch operations at Cape Canaveral, Florida, began October 29, 1961, with the arrival of 3 chimpanzees and 12 scientific and technical personnel. Two chimpanzees and eight personnel were already at Cape Canaveral as of October 29, 1961, having been employed in previous Project Mercury system tests.

One practice countdown was conducted by the medical preparation team. It consisted of preparing the subject and couch, but it did not include inserting them into the spacecraft or connecting them with the spacecraft environmental control system (ECS) or electrical system. Seven additional preliminary countdowns were accomplished. In these countdowns, the couch and subject were either connected to the spacecraft internal ECS and electrical system from the outside or inserted into the spacecraft and attached to the systems. Four of the countdowns were systems tests, one was a flight acceptance composite test, one was a launch simulation and radio frequency compatibility test, and one was a simulated flight.

In addition to these practice countdowns, 53 training sessions served to maintain animal performance proficiency.

Flight Preparation and Insertion

T—2 Days (November 27, 1961)

7:30 a.m.—Complete physical examinations were given to the three primary subjects. The physical examination was the same as for the MR–2 flight. (See section 3.)

1:30 p.m.—All three primary subjects underwent 270 minutes of behavioral training. The duration and the test simulated that of the programed flight, and control data were collected during this time.

At the completion of the physical examination and behavioral training, the flight and backup animals were chosen (section 3). It is of interest to note that the MR–2 flight animal was one of the three final flight candidates.

T—1 Day (November 28, 1961)

7:30 a.m.—All vans were checked to see that the necessary animal preparation equipment and supplies were available and in their proper place. Blood and urine samples for metabolic studies were collected and processed. These samples were later analyzed for use in the study of the physiological responses of chimpanzees to the stresses imposed by space flight.

All subjects were placed on a diet and feeding schedule. At approximately T—26 hours (7:30 a.m.), each received a few commercial food pellets, one banana, and 500 cc of water. No more food or water was given to the flight animal until recovery when it was given food and water when it wanted them.

A check of all test equipment was initiated (section 3).

1:00 p.m.—Restraint suits and couch attachment tabs were selected and fitted to the flight and backup subjects. They were then placed in their respective flight couches and fitted to them. The urine collection and drinking water systems were serviced.

11:00 p.m.—Physiological sensors were applied by the same procedure as is described in section 6.

11:24 p.m.—A urinary catheter was inserted and the retention bladder was inflated. The subject was then diapered, placed in his prefitted suit (see fig. 8–1), and readied for arterial and venous catheterization. The arterial catheter was inserted into the anterior tibial artery and the venous catheter into the right saphenous vein. The blood-pressure sensor was attached to the catheter immediately upon insertion, and a slow flow of physiological normal saline solution containing heparin was initiated. The subject was then zipped and laced into the couch. A psychomotor stimulus plate was attached to the sole of each foot. Finally, the blood-pressure sensor and the respiration-sensor amplifier were attached (fig. 8–1). The urine

---

*Captain, U.S. Air Force.

**Major, U.S. Air Force, School of Veterinary Medicine, Ohio State University, Columbus, Ohio.

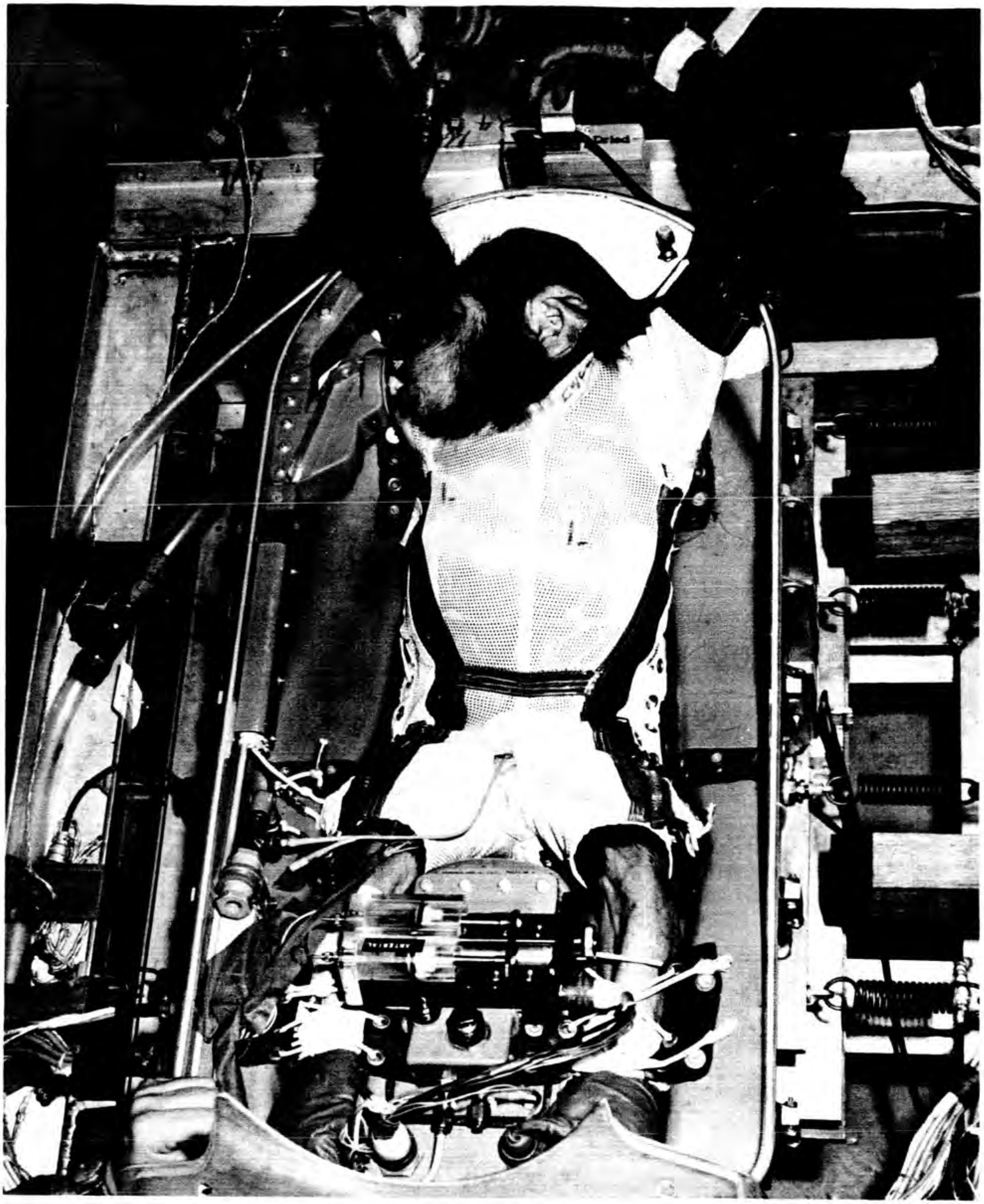


FIGURE 8-1.—Subject in flight couch in the act of taking a fluid reward. Animal diapered with urinary catheter inserted. Pressure transducers appear between the legs mounted transversely to the pressurized water bottles.

flow was directed into a container (100-cc capacity) to be saved for postflight analysis.

Launch Day (November 29, 1961)

2:28 a.m.—The flight subject and couch base were moved from the medical to the transfer van where the same procedures were carried out as are described for the MR-2 flight in section 3.

3:10 a.m.—Couch leak was carried out the same as MR-2 (section 3).

3:21 a.m.—The transfer van was directed to move to the launch pad and arrived at 3:41 a.m.

4:00 a.m.—The subject and couch were moved up the gantry and inserted into the spacecraft. Hatch closure was completed at 7:25 a.m. and the gantry was taken away. At 8:00 a.m., an 85-minute hold occurred, while the gantry was returned and the hatch was opened to set a telemetry switch. The count was resumed at 9:25 a.m. The psychomotor performance apparatus was turned on at T—2 minutes.

10:07:57 a.m.—Lift-off occurred.

Monitoring

The monitoring procedures at Cape Canaveral are described in section 3. Since this was an orbital flight, worldwide monitoring of the subject occurred at Mercury Control Center (MCC) and its 17 subsidiary stations distributed on a belt around the earth. The stations stretch across the Atlantic Ocean and are situated on Grand Bahama Island, Grand Turk Island, Bermuda, Grand Canary Island, and in a ship in mid-Atlantic. The network includes African sites at Kano, Nigeria, and Zanzibar; a ship in the Indian Ocean; Australian stations at Muchea and Woomera; Canton Island in mid-Pacific; and Kauai Island, Hawaii. The system also has stations at Point Arguello, California; Guaymas, Mexico; White Sands, New Mexico; Corpus Christi, Texas; and Eglin Air Force Base, Florida.

Data from the subject as well as from the numerous spacecraft systems were transmitted back to earth in real-time. The MCC received continuous readouts from Bermuda and Grand Turk Island; whereas all other stations, after making their observations of data from the spacecraft systems and subject, immediately reported their opinions back to MCC where decisions were made as to the conduct of the flight. There was real-time surveillance of the subject for 77.4 percent of the total flight time.

Data collection in addition to the monitoring of records was conducted at the Cape Telemetry II station. Other data sources for postflight evaluation of the flight subject were onboard recorders and onboard photography of the subject.

Flight Characteristics

The acceleration in the longitudinal axis of the launch vehicle which was imparted to the subject in a transverse plane is presented in figure 8-2. From lift-off, the accelerations increased to 6.8g at T+2 minutes 11 seconds. The booster engines were then jettisoned and the acceleration dipped to 1.6g. The sustainer engine continued until T+5 minutes and reached a peak of 7.6g. At burnout, the acceleration returned to zero gravity.

Spacecraft separation from the launch vehicle was uneventful with no large oscillation occurring, and the turn-around of the spacecraft was satisfactory. The spacecraft entered an orbit inclined 32.5° to the equator, with a perigee of 99.5 statute miles, an apogee of 147.4 statute miles, and an orbit period of 88 minutes and 26 seconds.

The couch inlet temperature was 63.5° F at lift-off and gradually increased throughout the flight. Soon after the beginning of the second orbital pass, the couch inlet air and cabin temperatures started to rise rapidly making continued flight questionable. However, towards the end of this orbit the inlet air temperature leveled off; and since the rectal temperature remained within normal limits, a three-orbit flight could have been accomplished. The couch inlet air temperature with the snorkel valve open was 87.5° F at landing, and 9 minutes after landing reached its maximum of 92.0° F.

The couch-pressure controls worked satisfactorily. The environmental control system was designed so that the subject breathed 100-percent oxygen from lift-off until descent when the snorkel opened at 14,300 feet. As the craft went to altitude, the pressure was reduced to 6 psig at 3 minutes 20 seconds after launch, and pressure reduction continued as a linear function until it reached its minimum of 5.05 psig at 3 hours after launch. The pressure then returned to ambient just prior to landing.

Mechanical trouble precluded completion of the scheduled three orbits. Mercury Control Center requested that the California Mercury Network station initiate retrofire at 3 hours and 15 seconds after launch. Initial reentry deceleration began at T+3 hours 10 minutes, reached a maximum of 7.8g at T+3 hours 13 minutes 12 seconds, and declined to 1.2g at T+3 hours 15 minutes 36 seconds (fig. 8-2). The drogue parachute deployment caused a pulse of 0.4g and the main parachute deployment caused a

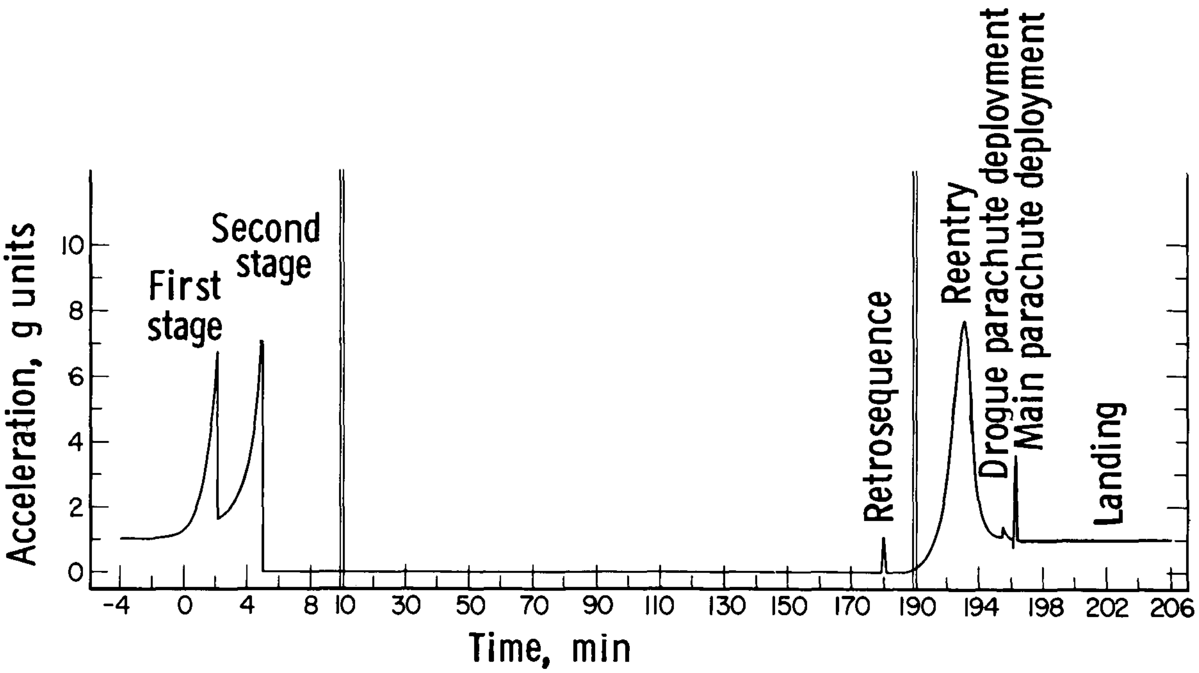


FIGURE 8-2.—Relation between accelerations transverse to the subject and time during the MA-2 flight.

3.6g deceleration. Lateral and normal accelerations during flight were negligible.

Recovery and Postflight Periods

Recovery support was available from Cape Canaveral across the Atlantic to the Canary Islands. If the unexpected had happened and an abort had occurred on the launch pad, point recovery, a highly coordinated land, sea and air effort, would have been called upon to retrieve the spacecraft and subject. This recovery unit extends for a radius of 12 miles from the launch site.

The normal recovery force consisted of airborne surveillance and 18 ships distributed along four probable impact areas. These four areas were designed to meet spacecraft recovery needs in the following four possible contingencies: First, if the spacecraft did not go into orbit, and second, third, and fourth, in the event of normal termination with reentry after the first, second, or third orbits, respectively.

Landing occurred 3 hours and 21 minutes (1:29 p.m. e.s.t.) after lift-off. The spacecraft landed 200 miles south of Bermuda at a point 28°57′ N. latitude by 66°04′W. longitude. The scout aircraft pilots sighted the spacecraft as it descended and maintained observation until the recovery ship, U.S.S. *Stormes*, arrived at 4 hours 37 minutes after launch and retrieved it. The spacecraft was immediately opened and the couch with the subject in it was removed at 7 hours 45 minutes after launch.

During the delay in getting the subject and couch out of the spacecraft, the subject damaged several sensor items and inflicted minor injury to himself by breaking through his nylon restraint panel and removing an inflated urine catheter. The broken sensors such as ECG leads and the conductor to the respiration sensor, did not affect the results of the flight since flight data accumulation had ceased before the subject damaged the sensors.

The subject was removed from the recovery ship at approximately 7:00 a.m., November 30, 1961, and taken directly to the Kindley Air Force Base hospital at Bermuda, where a complete physical examination was made. The animal remained in Bermuda for 24 hours and was returned to Cape Canaveral on December 1, 1961, at which time another complete physical examination was given. It was returned to Holloman Air Force Base, New Mexico, on December 7, 1961.

9. PERFORMANCE ASPECTS *of the* MA–5 FLIGHT

Frederick H. Rohles, Jr.,*
Marvin E. Grunzke,** and
Herbert H. Reynolds**

In the first of the two flights described in sections 2 to 7, a chimpanzee was placed through a ballistic flight trajectory. During the flight, the animal had to perform a continuous and discrete motor task that had been learned on the ground. Details of this flight relative to the performance have been reported in section 5. In the second flight, a chimpanzee performed a complex multiple operant task while orbiting the earth twice. The details of the performance aspects of that flight are presented in this section.

Subject

The subject was a 42-pound male chimpanzee, Enos, whose age was estimated to be 63 months. Prior to flight, he had been exposed to simulated launch accelerations on the centrifuge at the University of Southern California (see ref. 1). As discussed in reference 2, he also had served as a subject for a laboratory model of a 14-day flight in which he performed the same tasks as he did during the orbital flight. He had received a total of approximately 1,263 hours of training over a 16-month period; 343 hours of this training was accomplished under restraint conditions in a laboratory model of the actual couch used during the flight.

Performance Test Panel

As shown in the photograph in figure 4–2, the performance test panel consisted of three miniature inline digital displays (IDD) and three levers. The IDD's were centered on a line 4 inches above the bottom of the panel; the center display was mounted on the midpoint of this line and the two additional displays were mounted on center lines which were 3.8 inches to the left and right of this point. Centered and mounted 2.8 inches below each display was a 1-inch-diameter aluminum lever. Each lever protruded 2.25 inches beyond the face of the panel and required a 2-pound force for activation.

A pellet feeder was also incorporated into the panel. This consisted of a tube or magazine which served as a "hopper" for 106 specially designed food pellets, weighing 0.5 gram each. A spring maintained pressure on the single "column" of pellets in the tube, and one pellet at a time was delivered by means of a solenoid which pushed the pellets from the tube into two small plastic fingers which were located on the face of the panel below and to the right of lever 3. The pellets were loaded into the tube on the left side of the panel. The tube curved behind the panel and terminated at the plastic fingers. (See fig. 4–2.)

For water reinforcement, a lip-lever drinking tube, described in reference 3, was mounted in the couch to the right of the subject's head. A small green lamp was mounted either above or below this tube and when illuminated served to cue the subject that water was available when he bit the lever (figs. 9–1 and 9–2). Water for this device was kept under pressure against a valve on the lip-lever by a bottle of compressed air. Details relevant to the operation and design of both the liquid and pellet feeders have been reported in reference 4.

The method for programing the tasks, the procedure for delivering the electrical shock, and the shock level were the same as in the MR–2 flight. The task programer units were transistorized and housed behind the performance test panel. Their design is summarized in section 4. Three techniques were used, simultaneously, to collect the performance data. In

---

*Lieutenant Colonel, U.S. Air Force.

**Major, U.S. Air Force.

FIGURE 9-1.—Orbital flight couch showing the triangular upper section of the pressurized drinking reservoir. On the side of the couch close to the animal's head is a nipple connected by a hidden tube to the reservoir. The animal squeezes the nipple to obtain a water reward. The green signal light is seen close to the nipple. (See also figure 11-1.)

FIGURE 9-2.—An early training assembly showing the animal turning its head to obtain a drink. The green signal light appears just above the nipple.

one, data were routed through four points on a multiplex unit and the commutated data were transmitted to ground receiving stations. These data were also retained on magnetic tape on the onboard recorder. In the second, the performance information was coded by voltage controlled oscillators and continuously recorded on two subchannels of the onboard recorder tape. Since space and weight were critical, a single digital counter was mounted behind the performance panel and served as a final method for collecting the performance data. The total of all responses was recorded on this counter.

Performance Task

The task required performance on a five-component, multiple-operant conditioning schedule; the details of the training procedures are presented in reference 5. A description of the apparatus is presented in section 4. The first two tasks, continuous avoidance (CA) and discrete avoidance (DA), were the same as in the MR-2 flight. Performance of the continuous avoidance task was measured in terms of the number of lever presses in a 30-second period; the discrete avoidance task was essentially a visual monitoring task and performance was measured in terms of reaction time. Figure 9-3 shows how the responses to this task were recorded and telemetered on the cumulative response channels.

The third task required the subject to perform on an operant conditioning schedule involving differential reinforcement of a low rate (DRL). Water was used as the reinforcer or reward. Performance of the DRL task was measured in terms of the time that the subject waited between reward lever presses. An example of the response pattern is shown in figure 9-4.

The fourth task was a fixed ratio (FR) reinforcement program for food reward. Performance on this

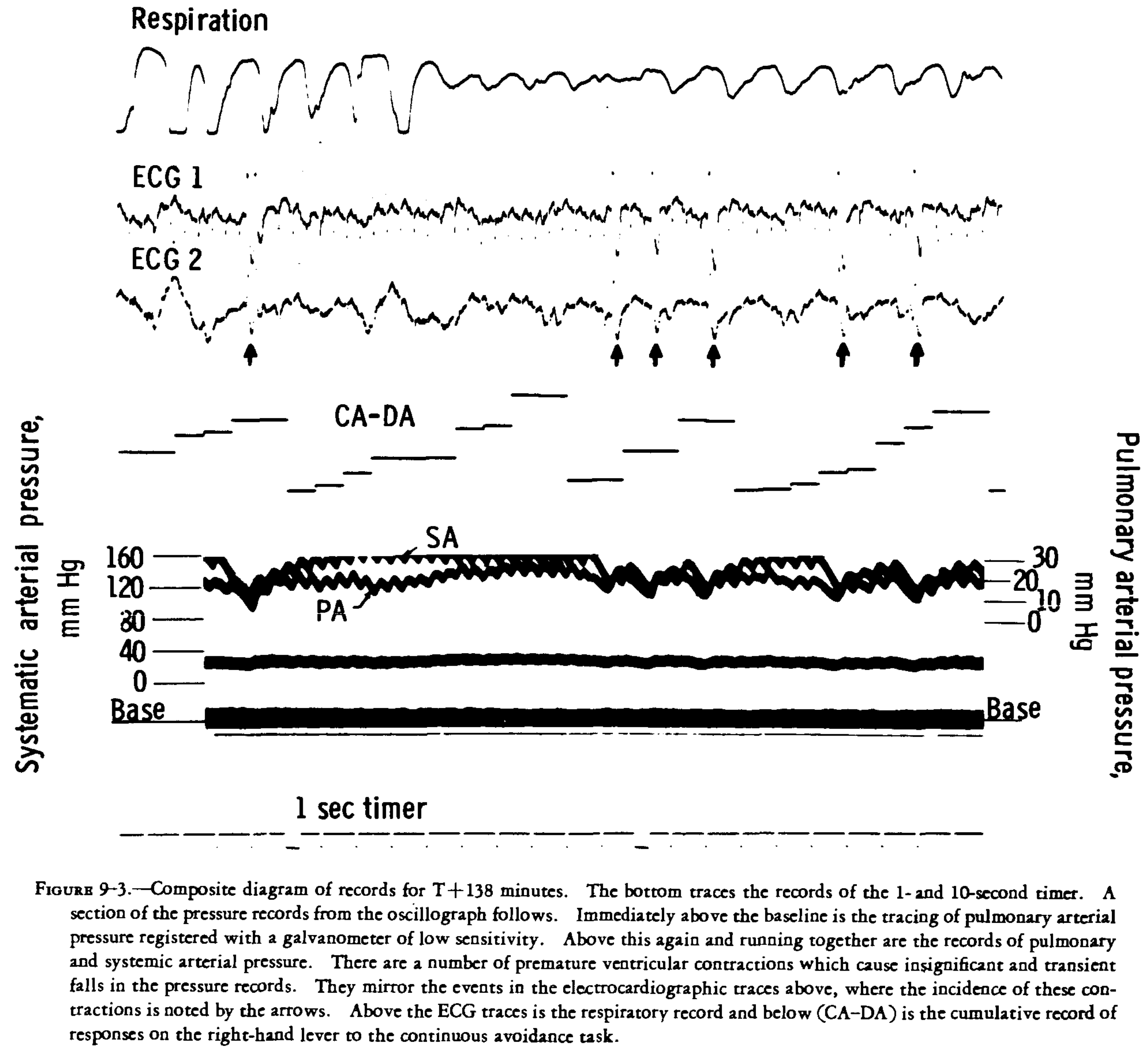


Figure 9-3.—Composite diagram of records for T+138 minutes. The bottom traces the records of the 1- and 10-second timer. A section of the pressure records from the oscillograph follows. Immediately above the baseline is the tracing of pulmonary arterial pressure registered with a galvanometer of low sensitivity. Above this again and running together are the records of pulmonary and systemic arterial pressure. There are a number of premature ventricular contractions which cause insignificant and transient falls in the pressure records. They mirror the events in the electrocardiographic traces above, where the incidence of these contractions is noted by the arrows. Above the ECG traces is the respiratory record and below (CA-DA) is the cumulative record of responses on the right-hand lever to the continuous avoidance task.

schedule was measured for each pellet reinforcement separately in terms of the time required for each set of 50 lever presses. An example of the response pattern is shown in figure 9-5.

The fifth task consisted of the 18 oddity problems shown in table 9-I.

One problem at a time was presented to the subject by means of the three IDD's. The level of performance of this task was measured in terms of discrimination accuracy by the following formula:

$$\text{Efficiency} = \frac{18}{\text{Total discriminations}}$$

Flight Results

The CA-DA task was turned on 2 minutes before launch and the subject performed on all components of the program from that time until 10 minutes after landing. The time during the flight in which each task was in effect is presented in table 9-II.

The chimpanzee's performance of the CA-DA task is presented in figure 9-6, which is a comprehensive chart presenting the tasks in their temporal relationship to each other and to the major acceleration events of the flight. As depicted in the graph, acceleration constitutes the bottom trace. The traces above show the performance during the first session in the course

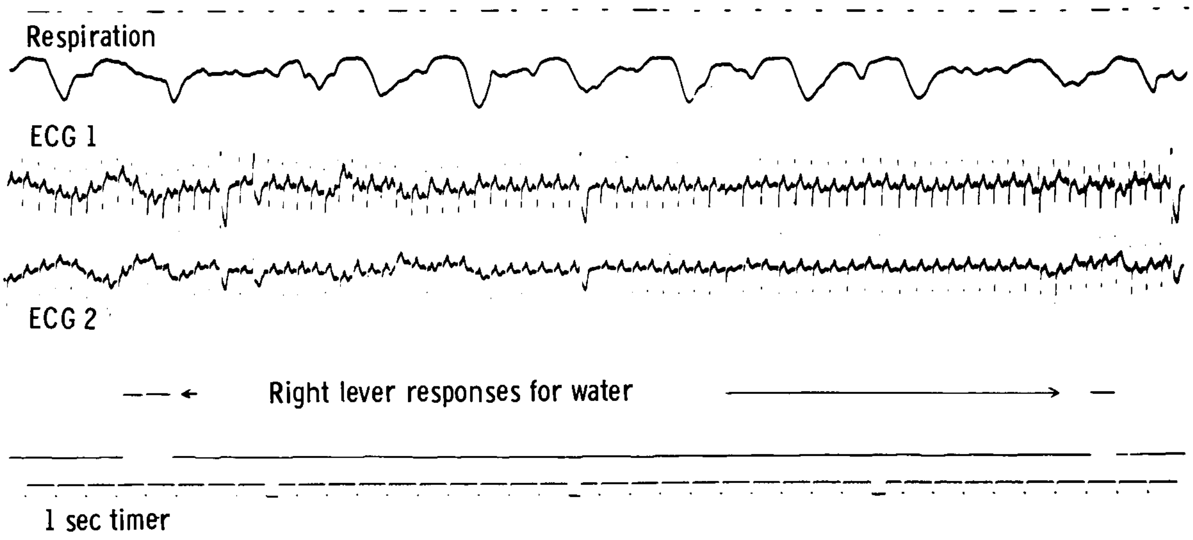


FIGURE 9-4.—A portion of the onboard record taken after approximately 1½ hours of weightlessness. The 1-second time is broken at 10-second intervals by a longer timing bar. . Two right lever responses for water are spaced 29 seconds apart. The two electrocardiogram leads show a number of premature ventricular contractions which have no effect on the performance, above these again is the respiratory record.

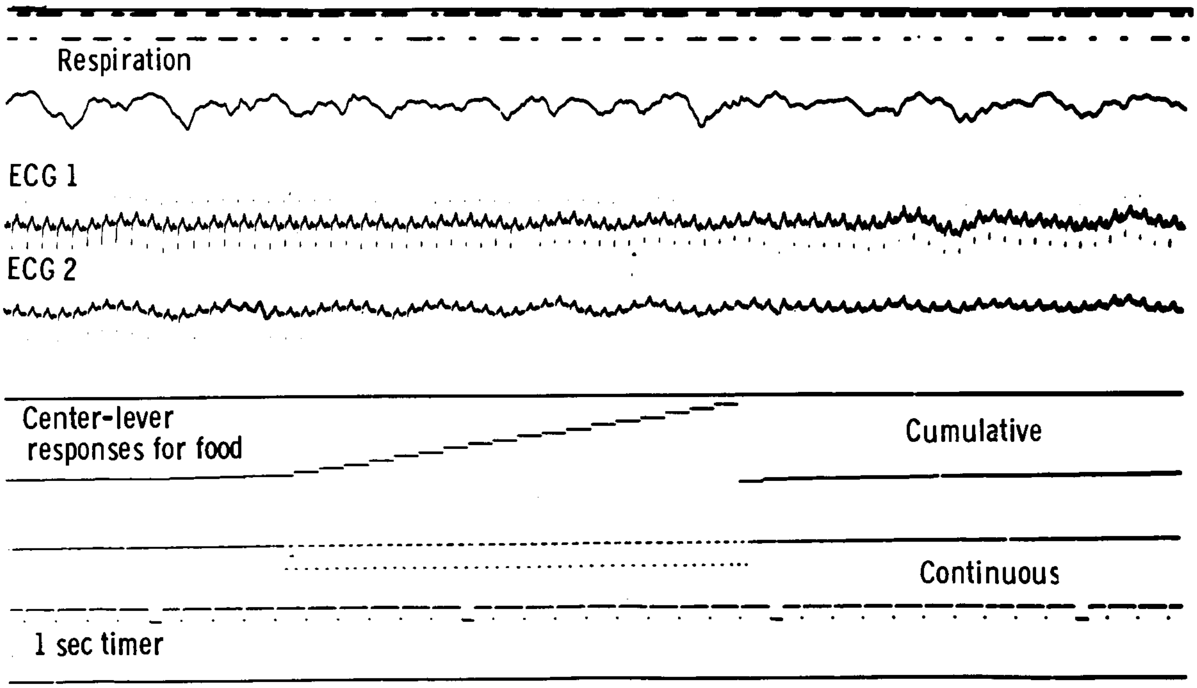


FIGURE 9-5.—Onboard record of responses for food pellets showing performance after approximately 30 minutes of weightlessness. After the 1- and 10-second timing line, reading from below upward, comes the response on the center lever as recorded onboard on the continuous data channel. On the record, the animal made 50 responses in order to obtain a banana-flavored pellet. Above this, a cumulative record of the responses on the center lever is shown by the upward stepping of a steady, uniform response performance, which is at the subject's normal rates. Above these responses come the two ECG records and the respiration trace. Above these again is the record of timing of events on the onboard tape.

of the launch accelerations, during sessions 2 and 3 when the subject was weightless, and finally during reentry. While performing the CA-DA tasks, the subject received only two shocks—one for the CA task during the first session and one for the DA task during the fourth session. While performance of the

TABLE 9-I.—*Series of 18 oddity problems presented during flight*

Problem No.	Symbol on display		
	1	2	3
1	○	△	○
2	△	△	○
3	○	○	□
4	△	○	○
5	△	○	△
6	□	□	△
7	○	□	□
8	△	□	□
9	△	△	□
10	□	○	□
11	□	△	△
12	○	□	○
13	○	○	△
14	○	△	△
15	△	□	△
16	□	○	○
17	□	△	□
18	□	□	○

TABLE 9-II.—*Temporal sequence of performance tasks*

Task	Time from launch, min	Duration of task, min	Total accumulated time, min
CA-DA	−2 to 17	20	20
Timeout	18 to 23	6	26
DRL-20	24 to 33	10	36
Timeout	34 to 39	6	42
FR-50	40 to 49	10	52
Timeout	50 to 55	6	58
Oddity	56 to 65	10	68
CA-DA	66 to 80	15	83
Timeout	81 to 86	6	89
DRL-20	[a] 87 to 96	10	99
Timeout	97 to 102	6	105
FR-50	103 to 112	10	115
Timeout	113 to 118	6	121
Oddity	119 to 128	10	131
CA-DA	129 to 143	15	146
Timeout	144 to 149	6	152
DRL-20	150 to 159	10	162
Timeout	160 to 165	6	168
FR-50	166 to 175	10	178
Timeout	[b] 176 to 181	6	184
Oddity	182 to 191	10	194
CA-DA	[c] 192 to 206	15	209

[a] Completed first orbit at Launch T+90 min

[b] Completed second orbit at Launch T+180 min; retrorockets fired at Launch T+181 min

[c] Impact at sea occurred at T+202 min

CA was variable during and immediately following launch (session 1), the subsequent sessions show a stable response rate within the range of the preflight mean plus or minus one standard deviation. The mean response time for 29 presentations of the blue light was 1.49 seconds which was somewhat slower than the preflight mean of 1.03 seconds. It should also be pointed out that eight presentations of the blue light were made during the first session, whereas only seven were made during each of the three following sessions. The raw performance data for the combined CA-DA tasks are shown in table 9-III.

An overall picture of the performance on the three sessions of the DRL task is presented in figure 9-6. For this task, the interresponse times were somewhat higher than those established under the preflight conditions. Table 9-IV, which presents the raw performance data for the three DRL sessions during flight, shows each DRL response during each of the three 10-minute periods that the task was in effect; for example, during session 1 the first response occurred after 23 seconds, and the second response, after 33 seconds. During session 1, the subject made 14 responses and earned 13 water reinforcements (7 cc's of water for each reinforcement); during session 2, sixteen responses were made and sixteen reinforcements received; and during session 3, twenty responses were made and eighteen of these were rewarded. Figure 9-4, taken from the record made onboard, shows a typical delayed response after 1½ hours of weightless flight.

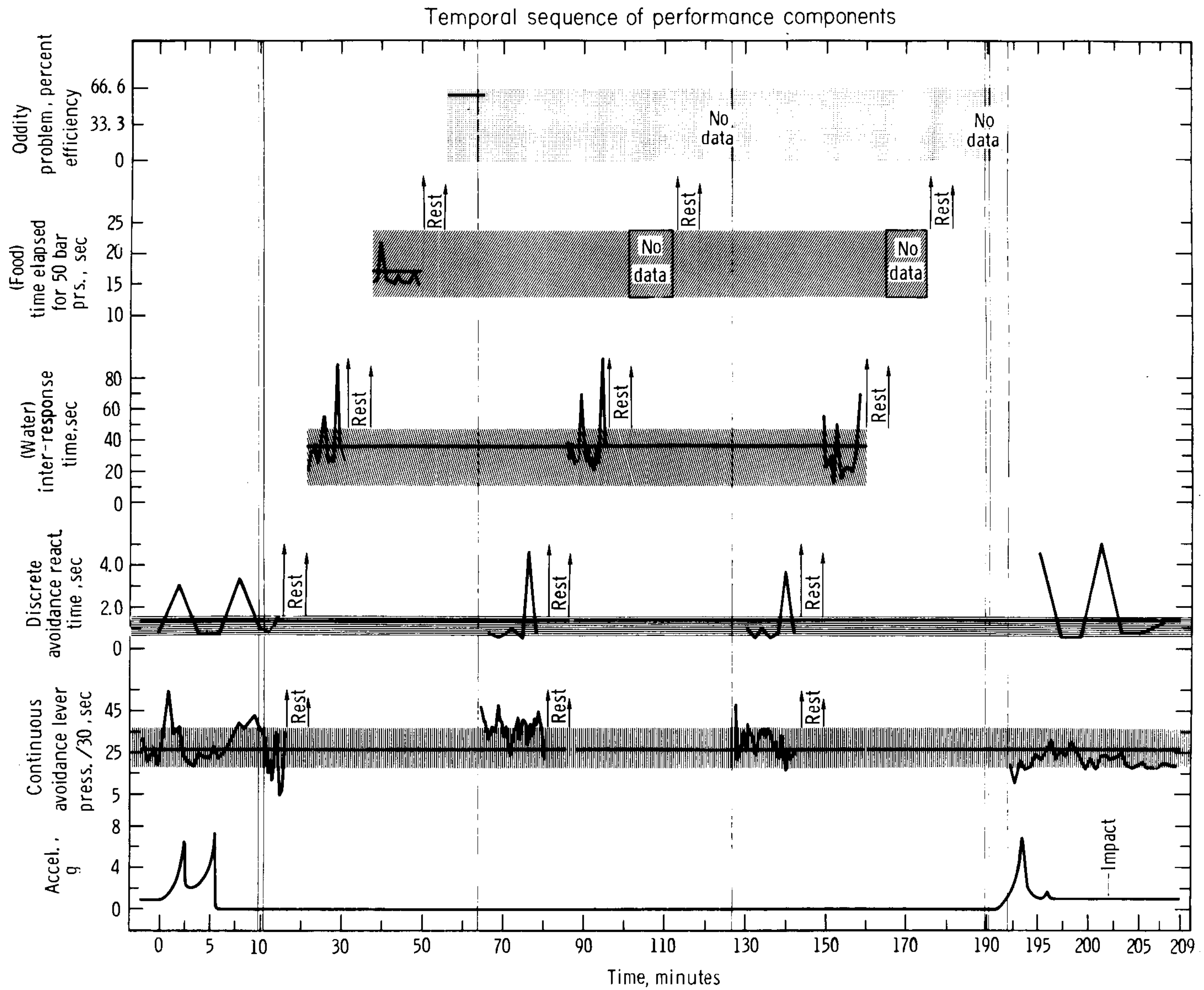


FIGURE 9–6.—Diagram summarizing the performance data obtained during the MA–5 flight and showing the sequence of events. Next to the abscissa is the record of acceleration transverse to the animal. The broad shaded bands indicate one sigma deviation in each direction from the subject's preflight performance norm for any particular task. The transverse heavy line represents the arithmetic mean of the animal's performance for the tasks during the flight.

TABLE 9-III.—*Raw performance data for continuous- and discrete-avoidance tasks in MA-5 flight*

Time from launch, min	Number of responses		Number of shocks		Discrete avoidance presentations	Duration of discrete avoidance reaction, sec
	Continuous avoidance lever	Discrete avoidance lever	Continuous avoidance	Discrete avoidance		
FIRST SESSION						
−2.0 to −1.5	32					
−1.5 to −1.0	21					
−1.0 to −0.5	27					
−0.5 to −0	19	1	...	...	1	0.75
0 to 0.5	34					
0.5 to 1.0	55					
1.0 to 1.5	34					
1.5 to 2.0	37	1	...	...	1	3.10
2.0 to 2.5	23					
2.5 to 3.0	20					
3.0 to 3.5	19					
3.5 to 4.0	25	1	...	...	1	.75
4.0 to 4.5	23					
4.5 to 5.0	23					
5.0 to 5.5	28					
5.5 to 6.0	23	1	...	...	1	.75
6.0 to 6.5	25					
6.5 to 7.0	31					
7.0 to 7.5	35					
7.5 to 8.0	39	1	...	...	1	3.40
8.0 to 8.5	37					
8.5 to 9.0	40					
9.0 to 9.5	43					
9.5 to 10.0	37	1	...	...	1	1.00
10.0 to 10.5	34					
10.5 to 11.0	29					
11.0 to 11.5	15					
11.5 to 12.0	21	1	...	...	1	.75
12.0 to 12.5	12					
12.5 to 13.0	30					
13.0 to 13.5	35					
13.5 to 14.0	21	1	...	...	1	1.50
14.0 to 14.5	5					
14.5 to 15.0	7					
15.0 to 15.5	38	...	1			
SECOND SESSION						
64.0 to 64.5	48					
64.5 to 65.0	40					
65.0 to 65.5	40					
65.5 to 66.0	32					
66.0 to 66.5	33	1	...	...	1	0.75
66.5 to 67.0	38					
67.0 to 67.5	35					
67.5 to 68.0	37					
68.0 to 68.5	48	1	...	...	1	.56
68.5 to 69.0	41					
69.0 to 69.5	40					
69.5 to 70.0	33					

Table 9-III.—*Raw performance data for continuous- and discrete-avoidance tasks in MA-5 flight*—Continued

Time from launch, min	Number of responses		Number of shocks		Discrete avoidance presentations	Duration of discrete avoidance reaction, sec
	Continuous avoidance lever	Discrete avoidance lever	Continuous avoidance	Discrete avoidance		
SECOND SESSION						
70.0 to 70.5	38	1	....	....	1	.75
70.5 to 71.0	30					
71.0 to 71.5	24					
71.5 to 72.0	36					
72.0 to 72.5	37	1	....	....	1	1.00
72.5 to 73.0	42					
73.0 to 73.5	32					
73.5 to 74.0	41					
74.0 to 74.5	41	1	....	....	1	.56
74.5 to 75.0	39					
75.0 to 75.5	29					
75.5 to 76.0	39					
76.0 to 76.5	34	1	....	....	1	4.70
76.5 to 77.0	42					
77.0 to 77.5	39					
77.5 to 78.0	45					
78.0 to 78.5	39	1	....	....	1	.75
78.5 to 79.0	36					
79.0 to 79.5	22					
THIRD SESSION						
128.0 to 128.5	49					
128.5 to 129.0	22					
129.0 to 129.5	23					
129.5 to 130.0	26					
130.0 to 130.5	36	1	....	....	1	1.00
130.5 to 131.0	27					
131.0 to 131.5	39					
131.5 to 132.0	34					
132.0 to 132.5	34	1	....	....	1	.56
132.5 to 133.0	30					
133.0 to 133.5	24					
133.5 to 134.0	30					
134.0 to 134.5	36	1	....	....	1	1.00
134.5 to 135.0	35					
135.0 to 135.5	37					
135.5 to 136.0	33					
136.0 to 136.5	37	1	....	....	1	.56
136.5 to 137.0	35					
137.0 to 137.5	33					
137.5 to 138.0	26					
138.0 to 138.5	31	1	....	....	1	.75
138.5 to 139.0	23					
139.0 to 139.5	23					
139.5 to 140.0	34	1	....	....	1	3.75
140.0 to 140.5	21					
140.5 to 141.0	17					
141.0 to 141.5	27					
141.5 to 142.0	23					
142.0 to 142.5	25	1	....	....	1	.75
142.5 to 143.0	25					

Table 9-III.—*Raw performance data for continuous-and discrete-avoidance tasks in MA-5 flight—Continued*

Time from launch, min	Number of responses		Number of shocks		Discrete avoidance presentations	Duration of discrete avoidance reaction, sec
	Continuous avoidance lever	Discrete avoidance lever	Continuous avoidance	Discrete avoidance		
FOURTH SESSION						
193.0 to 193.5	19					
193.5 to 194.0	11					
194.0 to 194.5	21					
194.5 to 195.0	17					
195.0 to 195.5	18	1	...	...	1	4.50
195.5 to 196.0	24					
196.0 to 196.5	22					
196.5 to 197.0	25					
197.0 to 197.5	31	1	...	...	1	.56
197.5 to 198.0	22					
198.0 to 198.5	26					
198.5 to 199.0	24					
199.0 to 199.5	30	1	...	...	1	.56
199.5 to 200.0	27					
200.0 to 200.5	22					
200.5 to 201.0	17					
201.0 to 201.5	24	0	...	1	1	5.00+
201.5 to 202.0	24					
202.0 to 202.5	22					
202.5 to 203.0	23					
203.0 to 203.5	25	1	...	...	1	.75
203.5 to 204.0	19					
204.0 to 204.5	18					
204.5 to 205.0	19					
205.0 to 205.5	20	1	...	...	1	.75
205.5 to 206.0	18					
206.0 to 206.5	18					
206.5 to 207.0	18					
207.0 to 207.5	20	1	...	...	1	1.20
207.5 to 208.0	20					
208.0 to 208.5	19					
208.5 to 209.0	19					

Table 9-IV.—*Raw performance data for differential reinforcement of low rates in MA-5 flight*

Interresponse time, sec	Number of reinforcements
First session, from T+21.5 min to T+31.5 min	
20.3	0
33.3	1
33.0	1
36.3	1
26.4	1
35.0	1
55.4	1
51.6	1
25.7	1
29.7	1
28.2	1
89.1	1
37.2	1
27.1	1
	—
	13 drinks
Second session, from T+85.5 min to T+95.5 min	
39.0	1
29.0	1
37.0	1
27.8	1
25.4	1
28.0	1
69.9	1
27.3	1
35.7	1
24.6	1
29.3	1
21.5	1
34.4	1
26.2	1
86.8	1
37.5	1
	—
	16 drinks
Third session, from T+149.5 min to T+159.5 min	
56.0	1
23.8	1
25.0	1
29.5	1
30.6	1
13.2	0
51.2	1
29.3	1
18.0	0
22.2	1
23.4	1
22.6	1
23.6	1
26.9	1
26.2	1
23.8	1
21.1	1
27.7	1
28.1	1
70.7	1
	—
	18 drinks

On the FR task, the subject received 13 pellets during the first FR session. He exhibited an extremely stable response rate which, as can be seen in figure 9-6, closely approximated his preflight average. A count of the number of food pellets remaining in the feeder following the flight verified that it was functioning and supported the data which indicated that the subject received 13 pellets in session 1, and 4 in the unrecorded session 2. The raw performance data for this session are presented in table 9-V. While the second session of the FR task was in effect a malfunction occurred in the switch of center lever; and although it presented no major problem during

Table 9–V.—*Raw performance data for fixed ratio task in MA–5 flight*

[First session, from T+37.5 min to T+48.25 min]

Number of responses on center lever	Number of pellets dispensed	Number of responses per second
16	1	3.2
23	1	3.0
47	1	3.0
22	1	4.6
47	1	3.1
46	1	3.0
48	1	2.8
47	1	3.5
48	1	3.1
51	1	3.0
35	1	3.0
48	1	3.3
46	1	3.0
	13	

the FR task, the malfunction prohibited an accurate measurement of performance on sessions 2 and 3 of the FR task as well as the performance on the two subsequent oddity components. Figure 9–5 shows the performance of the animal after 30 minutes of weightless flight while the center lever switch was still functioning. The chimpanzee's steady uninterrupted actuation rate is responsible for the consistency of the slope.

Figure 9–6 also shows the animal's performance of the oddity task in relation to the others. A detailed account of performance on the first session of the oddity problems is presented in table 9–VI. During this session the subject performed at 64.2-percent efficiency which was essentially the same as his preflight mean of 66 percent. He received 10 shocks due to errors in discrimination. As a result of the malfunctioning center lever, the efficiency of discrimination is virtually meaningless for sessions 2 and 3; however, certain inferences can be made concerning the behavior during these periods.

As shown in table 9–VII in which performance on the second session of the oddity problems is presented, the first problem required a response on the center lever. On the basis of previous performance, it can be inferred that the subject would make this discrimination correctly two out of three times (66 percent). Yet, because of the lever malfunction, a response on the center lever was not effective in turning off the displays. Consequently, the subject was still confronted with the problem; and with the time rapidly approaching in which a shock would be delivered for "nonresponse," the subject pressed the left lever which turned off the displays, but since the action was incorrect, it also resulted in a shock. As a result, the "insoluble" problem was presented again and if the probability of correct solution can be inferred as before, the subject made a correct response—the pressing of the center lever. However, the result was the same as for the first presentation of the problem; namely, the displays remained on. Since the subject had experienced an identical situation on the first presentation of the problem, and since he had received a shock for pressing the left lever, it may be inferred that he varied his behavior and responded on the right lever. Moreover, the alternation of responses between the left and right levers was

Table 9–VI.—*Performance of the oddity problem for session 1*

[Efficiency=18/28=64.2 percent]

Problem no.	Response by lever			Number of shocks
	Lever 1	Lever 2	Lever 3	
1	X	□		✓
1		☒		
2			☒	
3		X	□	✓
3			☒	
4	☒			
5		☒		
6	X		□	✓
6		X	□	✓
6	X		□	✓
6	X		□	✓
6			☒	
7	☒			
8	□	X		✓
8	□	X		✓
8	☒			
9			☒	
10		☒		
11	☒			
12		□	X	✓
12		☒		
13		X	□	✓
13			☒	
14	☒			
15		☒		
16	☒			
17		☒		
18			☒	
Total	10	11	7	10

X=Response. □=Required response. ☒=Correct response.

TABLE 9-VII.—*Performance of the oddity problem for session* 2

Problem No.	Response by lever			Number of shocks
	Lever 1	Lever 2	Lever 3	
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1		☐	X	✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1		☐	X	✓
1		☐	X	✓
1	X	☐		✓
1		☐	X	✓
1		☒		
2			☒	
3			☒	
4	☒			
5		☐	X	✓
5	X	☐		✓
Total	15	1	23	35

X = Response. ☐ = Required response. ☒ = Correct response.

apparent on subsequent presentations of the problem. Eventually, however, on the 34th presentation of the first problem, the switch functioned properly and the problem was solved, lending credence to the hypothesis that the subject was making the correct discrimination on two out of every three presentations of the problem before varying his behavior. The fact that more responses were made during this session on the right lever than on the left lever is also significant as is the finding that during the third session the subject, while also exhibiting the alternation behavior, made 10 responses on the left lever and 33 responses on the right lever in attempting to solve the first problem, the only one presented during the session. This behavior is explained on the basis of the number of possible reinforcements for the CA and DA tasks since for the CA task (right lever) at least one response is required every 20 seconds to avoid six shocks; whereas only one response every 2 minutes is required on the left lever to avoid shock for the DA task.

An indication of the subject's discriminatory ability can be derived from the fact that no lever presses were recorded during the nine 6-minute rest periods.

Results and Discussions

The ballistic flight and subsequent tests led to the conclusion that the major environmental factors affecting performance were the forces acting upon the subject during launch and reentry.

During both the ballistic and the orbital flights each of the subjects was performing the CA–DA tasks during the launch and reentry periods. Concerning the chimpanzee's performance of the CA task, the variability in response rate following launch was expected on the basis of exposure to simulated launch accelerations on the centrifuge. On the MR-2 flight, there was a sharp decline in rate, and immediately following launch, the subject received his first shock; however, it is believed that this shock was due to a malfunction in the timing apparatus since careful examination of the telemetry recording shows that the time between responses at this period of the flight was less than 15 seconds. This decrement was not observed in the MA-5 flight. It is possible that the reduction in response rate of the subject during the reentry period of the MR-2 flight was a function of the 17g experienced during the launch as compared with the two smaller accelerations (6.8g and 7.6g) for MA-5. However, in the MA-5 flight the performance immediately following launch was more variable than performance during this period of the MR-2 flight, and it was during this time that the subject received his first shock. Performance was not affected during the weightless portion of either flight.

During the reentry period of the MR–2 flight, a gradual decrement in the response rate was observed. There was no decrement in the MA–5 flight. This finding, as was true of the performance following launch, could be attributed to the differences in the magnitude of the accelerations experienced by the two subjects. During the MR–2 flight the animal was subjected to 14g for 5 seconds and 10g for 10 seconds during reentry; whereas a deceleration of only 7.8g was experienced during the orbital reentry. It may be that launch and reentry accelerations of the magnitude and duration of the MR–2 flight affected subsequent performance rate of the CA task. However, this statement is not without qualification. While it is true that a reduction in rate occurred, the number of responses for any 20-second period was never more than two standard deviations from the preflight mean. This fact becomes more striking in MA–5 flight. Here, performance of the CA task was essentially the same as during the preflight with very little variability.

An increase in the variance on the performance of the DA task was observed in the MA–5 flight. This increase did not occur in the ballistic flight. The subject received one shock for failing to respond to the fourth presentation of the blue light on the fourth DA session. However, in comparing the preflight with the inflight means, it was concluded that the visual monitoring or reaction time was unaffected.

The performance of the DRL task was also unaffected. In this regard, note that the malfunctioning of the center lever, which resulted in the subject receiving 35 shocks on the second session of the oddity problem, did not disrupt his subsequent performance on either the third DRL session or the third session of the CA–DA components. And likewise, the 41 shocks received during the third oddity session did not affect performance during the subsequent fourth session of the CA–DA tasks. Certainly, following a malfunction of this nature, it might be expected that behavior would be disrupted, but this was not in evidence.

Performance of the first FR session was extremely stable and the discrimination accuracy for the first oddity session was also close to the preflight mean. Unfortunately, the malfunctioning of the center lever made the measurement during the two subsequent sessions on both tasks meaningless.

In general, from a behavioral standpoint it can be concluded that, with the exception of the difficulty encountered with the middle lever, the flight was successful. The tasks selected proved to be adequate, but more important, the telemetry afforded continuous recording of the behavioral data. The MA–5 flight also provided the weightless environment necessary for testing both the pellet feeder and the water dispenser; neither of these showed any evidence of malfunction.

Conclusions

A chimpanzee was trained to perform a complex multiple operant task during the second animal flight in the Project Mercury program in which a spacecraft orbited the earth twice. As a result of this flight, it was concluded that:

1. Behavioral measurements should be made together with the usual physiological measurements if the status of an animal subject is to be fully appraised.
2. The noise and vibration accompanying launch did not affect performance.
3. Accelerations accompanying launch and reentry in excess of 7g had an immediate effect upon performance; however, recovery to a prelaunch level was rapid.
4. Performance decrements did not occur during weightlessness.
5. Adaptation to weightlessness took place during a 3-hour exposure.
6. Performance was maintained during the launch and reentry acceleration.
7. Eating and drinking can be accomplished during weightlessness.
8. The visual and temporal response processes and the continuous and discrete motor behavior were unaffected by the weightless state.
9. The pellet and water dispensers functioned excellently during weightlessness.
10. Despite serious distractions, young chimpanzees have served as highly reliable subjects in space flights.

References

1. Reynolds, Herbert H., Grunzke, Marvin E., and Rohles, Frederick H., Jr.: The Effects of Simulated Launch and Reentry Profiles on Chimpanzee Performance. Air Force Missile Development Center TDR–62–1, Mar. 1962.

2. Rohles, Frederick H., Jr., Reynolds, Herbert H., Grunzke, Marvin E., and Farrer, Donald N.: A Laboratory Model for a Fourteen Day Orbital Flight with a Chimpanzee. Air Force Missile Development Center TR–61–33, Oct. 1961.

3. Grunzke, M. E.: A Liquid Dispenser for Primates. Jour. Exp. Analysis of Behavior, vol. 4, 1961, p. 326.
4. Grunzke, Marvin E.: Feeding Devices for Use With Primates in Space Flight. Air Force Missile Development Center TDR-61-35, Dec. 1961.
5. Belleville, Richard E., Rohles, Frederick H., Jr., and Grunzke, Marvin E.: Behavior of the Chimpanzee on a Complex Multiple Schedule. Air Force Missile Development Center TR-61-27, Aug. 1961.

10. MEDICAL AND PHYSIOLOGICAL ASPECTS *of the* MA–5 FLIGHT

By William E. Ward*

The chimpanzee subject, No. 81, was purchased by the U.S. Air Force on April 3, 1960. From this time until November 27, 1961, it was subjected to six complete quarterly physicals and many other examinations in the course of various studies. All of the findings of these examinations including the blood-pressure observations, which were frequently elevated above the normal values of resting, relaxed humans, were within normal ranges for immature chimpanzees exposed to similar conditions of examinations under restraint. More comprehensive information on the blood pressure is presented in section 11.

In addition to extensive behavioral training, the subject was exposed to four data acquisition flights and two simulated Mercury-Atlas acceleration profile tests on the centrifuge at the University of Southern California (ref. 1).

The restraint system and physiological sensors were the same as those used during the MR–2 flight with the following three exceptions: All ECG electrodes were of the steel suture type, venous and arterial catheters were inserted for blood pressure measurements, and the subject was catheterized for collection of urine during the flight. Flight data were recorded continuously on the onboard tape (fig. 10–1) and telemetered to ground stations.

Results

Physiological data from the MA–5 flight are presented in figure 10–2. Total flight time from lift-off to landing was 3 hours 20 minutes 59 seconds. Data were recorded continuously from launch until 10 minutes after landing, and the flight data values include the postlanding period.

For the period 5 hours prior to launch, the mean heart rate was 94 beats per minute. During this time, the subject was lying quietly in the couch. The minimum heart rate was 82 beats per minute; maximum was 128 beats per minute (fig. 10–3).

At T—2 minutes, the behavior program was turned on. Heart rate rose from 86 beats to 111 beats per minute at 1 minute before lift-off. At peak acceleration in the first stage at approximately T+2 minutes, the heart rate was 130 beats per minute (fig. 10–2). During the first orbital pass, heart rate was labile, ranging from 102 to a momentary 153 beats per minute. The lowest rate recorded during flight was 100 beats per minute. Maximum rate was a momentary 180 beats per minute which occurred during reentry at approximately T+3 hours 13 minutes. Mean pulse rate during flight was 128 beats per minute.

Minimum momentary respiration rate recorded before the launch was 9 and the maximum was 28 breaths per minute. The mean respiration rate during the preflight period was 14 breaths per minute. With launch, the rate rose from a mean of 14 to approximately 30 inspirations per minute at T+5 minutes. It fluctuated during the flight from a minimum rate of 14 to a maximum of approximately 80 breaths per minute at 3 hours 13 minutes which was during peak acceleration of reentry. Mean respiration rate during the flight was 28 breaths per minute.

Eight hours prior to flight, the subject's rectal temperature was 99.4° F. Temperature dropped to approximately 96° F during the pre-flight countdown. At lift-off the temperature was 96.2° F. There was a gradual rise during the first orbital pass to 97.5° F. During the first 20 minutes of the second orbit, the temperature rose 1°. At 2 hours 50 minutes, the subject's temperature was 99.9° F. Ten minutes after landing, the rectal temperature was 100.1° F.

A number of premature ventricular contractions (PVC) occurred during the flight (fig. 10–1). The

---

*Captain, U.S. Air Force.

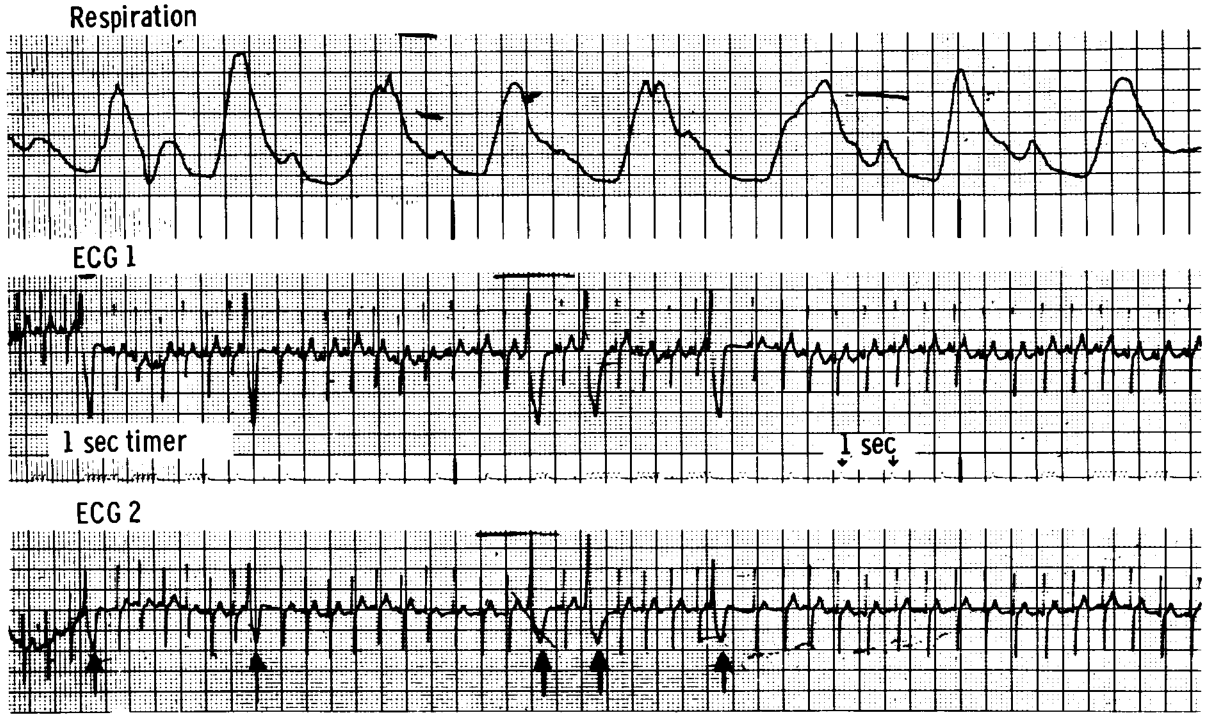


FIGURE 10–1.—Record from a monitoring station at T+94 minutes showing premature ventricular contractions (arrows). The respiratory record is shown above the two electrocardiograph leads.

first occurrence was 30 minutes after lift-off and was reported from Zanzibar. The irregularities were present throughout the flight. The PVC's are discussed in detail in section 12.

The subject did not land in the primary recovery area, and as a result the spacecraft was not picked up by the U.S.S. *Stormes* until 1 hour and 20 minutes after landing. There was a delay of 3 hours and 20 minutes in removing the subject from the spacecraft and couch. A cursory examination of the subject at this time resulted in the following findings: Rectal temperature, 102° F; respiration rate, 38 breaths per minute; blood pressure, 130/90 mm Hg; heart rate, 74 beats per minute. In addition, the subject had broken through the protective belly panel and had removed or damaged most of the physiological sensors. He had also forcibly removed the urinary catheter while the balloon was still inflated.

The subject was removed from the U.S.S. *Stormes* at approximately 7:00 a.m. e.s.t. on November 30, 1961, and taken to the Air Force hospital in Bermuda for examination. The findings were as follows: Rectal temperature, 97.6°F; respiration rate, 16 breaths per minute; blood pressure, 128/80 mm Hg; heart rate, 100 beats per minute. The subject weighed 39.5 pounds. Complete blood count and urinalysis indicated a bacterial infection of the bladder. ECG leads 1, 2, 3, and 2VR, 2VL, 2VF, and V_1, V_3, V_5 revealed no abnormal conduction patterns. The subject appeared to be fatigued but alert; the penis was slightly edematous, as a result of the forcible extraction of the catheter. Body X-rays indicated no abnormalities.

Discussion

Figure 10–2 is a composite plot of flight physiology from the subject and values obtained from the subject and four other chimpanzees during two series of centrifuge experiments prior to the flight. These experiments were conducted at the University of Southern California in September 1961, in order to determine the effects upon performance and physiological measures of the exposure of chimpanzee subjects to the lift-off and reentry accelerations anticipated during the MA–5 flight. (See ref. 1.) During the first 10 minutes of actual flight, the subject's heart and respiration rates and rectal temperature were lower than those recorded for the centrifuge tests.

During orbital flight, respiration rate remained below the centrifuge test values, but heart rate

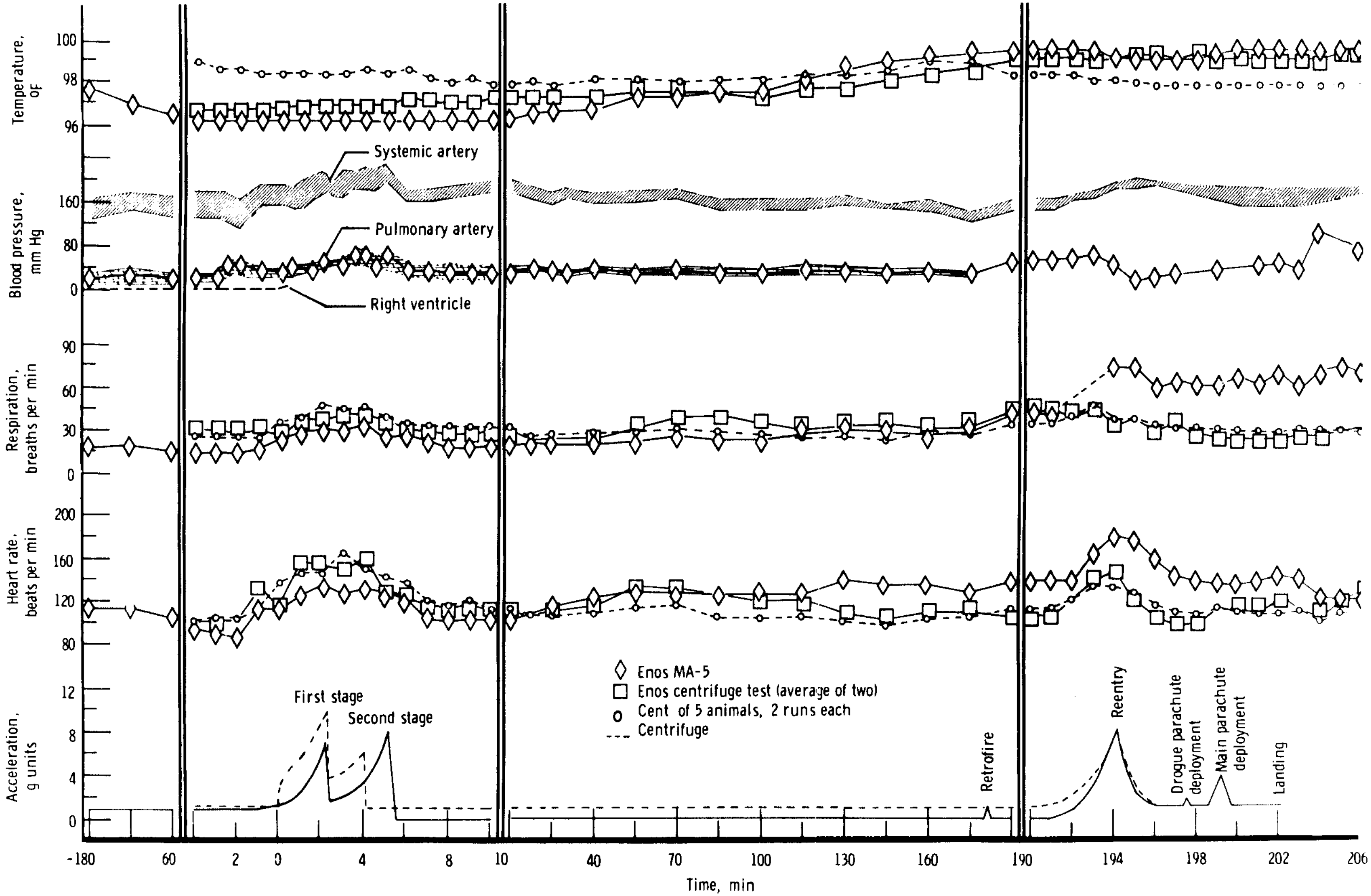


FIGURE 10-2.—Composite diagram of acceleration, heart rate, respiration rate, blood pressure, and temperature. The respiration rate only deviates from control during the reentry period when there is a good deal of oscillation on the parachute. The diamonds represent blood-pressure data as recorded by the galvanometer of low sensitivity. Some right-ventricular data were available for the first few minutes and then changed to pure pulmonary arterial pressure data as the catheter ceased altering position and stayed in the pulmonary artery. Above pulmonary arterial pressure is systemic arterial pressure. The pulse pressure is indicated by the shading. There is a return of systemic arterial pressure toward preflight control levels during the weightless period. Note that the pressure remained elevated throughout a 3-hour period of preflight observation. During the 1g and 0g phases of flight, arterial systoles exceeding 160 mm Hg were estimated from the slope of the wave.

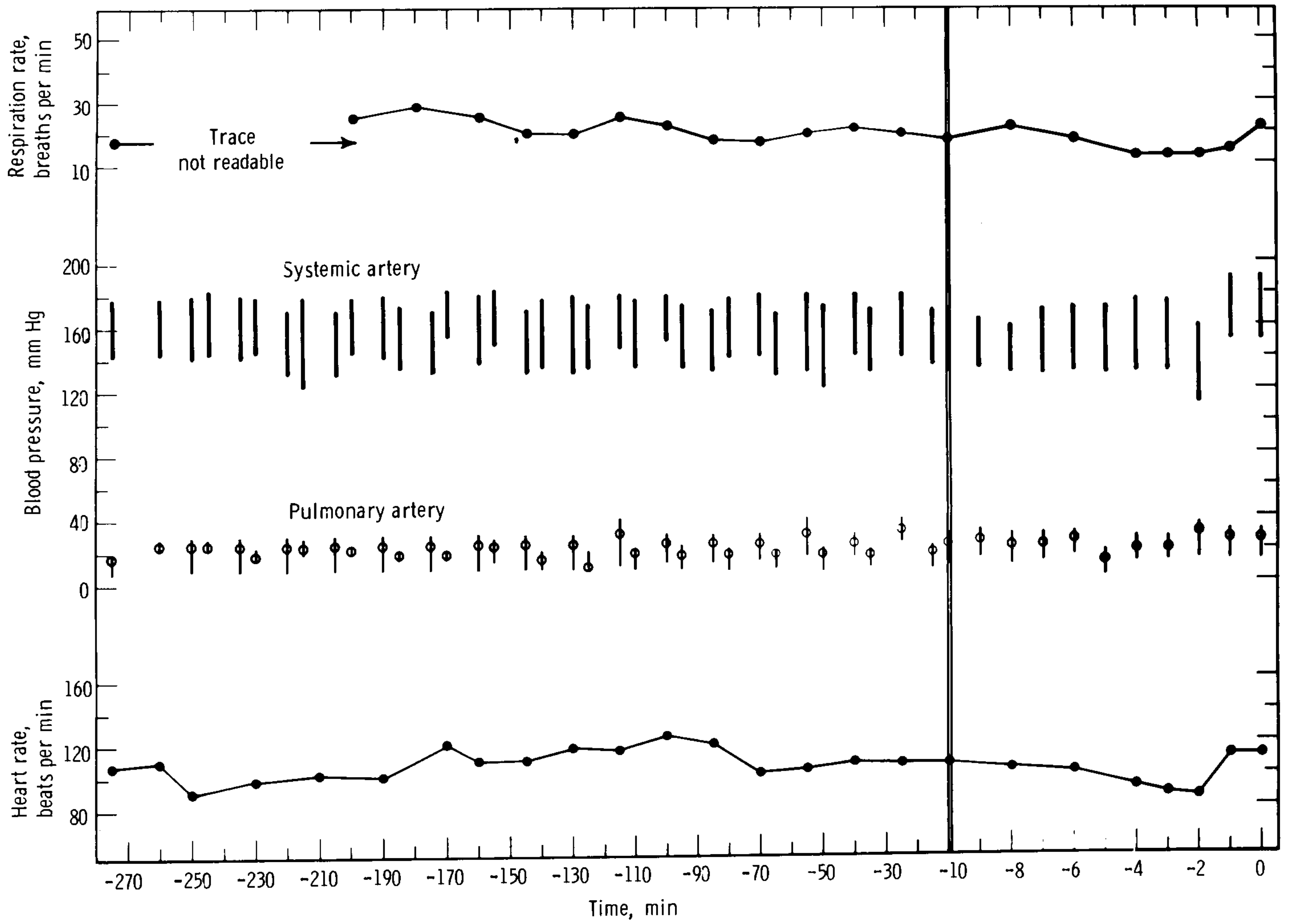


Figure 10-3.—Records of physiological parameters during 4½ hours of the launch-pad countdown time for the MA-5 subject. The first trace represents heart rate in beats per minute; second, pulmonary artery pressure. The circles indicate the pressure as measured with a galvanometer of low sensitivity. Vertical lines connect pulmonary arterial systolic and diastolic pressure as measured by a sensitive galvanometer. Systemic artery pressure is also registered by vertical lines connecting systole and diastole. Top line represents respiration per minute. All points on the graph are based on arithmetic means of all events for each minute.

increased. During the acceleration of reentry, heart and respiration rates rose well above those recorded during the centrifuge runs. Means and standard deviations of heart and respiration rates for preflight and flight periods are presented in the following table:

	Preflight	*Flight*
Heart rate:		
Mean, beats per minute	94	128
Standard deviation, beats per minute	8	15
Respiration:		
Mean, breaths per minute	14	28
Standard deviation, breaths per minute	2	15

The subject's heart and respiration rates were significantly increased during the flight but did not exceed control mean values established during an earlier ground test series. (See ref. 2.)

Probably the most significant change seen in the MA-5 flight subject was in the postflight hematological values. The differential white blood count showed a reversal of the neutrophile-lymphocyte ratio as after the MR-2 flight (table 10-I). Changes of this type, although not as severe, have been observed in subject exposed to other similar stressful conditions, as reported in references 2 and 3. The increase in white blood count may be attributed to a urinary infection as a result of trauma following the forcible removal of the catheter by the subject during the postflight period. All other findings were within normal ranges.

Concluding Remarks

During the MA-5 flight, heart and respiration rates of the chimpanzee subject increased significantly from prelaunch values, but did not exceed control mean values established for restrained chimpanzees. A 2° F rise in rectal temperature which occurred during flight and landing was not considered significant. Preliminary hematological findings indicate that the total flight and recovery situation including forcible removal of the catheter was stressful to the subject. The urinary infection which occurred immediately postflight complicated complete interpretation of hematological data.

References

1. Cook, James E., Fineg, Jerry, and Miksch, Eldon D.: Physiological Base-Line Studies of Zoological Specimens. Phase I: Hematological Values of Immature Chimpanzees. Air Force Missile Development Center TN-60-9, July 1960.
2. Archibald, Erwin R., and Ward, William E.: Chimpanzee Temperature-Humidity Tolerance Tests—Control Tests at 80° F, 50 Percent Relative Humidity. Air Force Missile Development Center TR-61-11, Apr. 1961.
3. Fineg, Jerry, Britz, William E., Jr., et al.: Physiological Base-Line Studies of Zoological Specimens—Clinical Observations and Methods Used in the Treatment of Young Chimpanzees. Air Force Missile Development Center TR-61-12, Apr. 1961.

TABLE 10–I.—*Preflight and postflight physical examination of MA-5 subject*

	Preflight examination T—24 hr	T—7 hr	Postrecovery examination, Bermuda on Nov. 30, 1961, at 9:00 a.m. e.s.t.	Cape Canaveral Dec. 1, 1961, 9:00 a.m. e.s.t.	Dec. 4, 1961	Dec. 7, 1961	Dec. 19, 1961	Jan. 18, 1962
Age, months	63	63	63	64				
Weight, lb	38.5	39.5	39.5	41				
Rectal temperature, °F	97.8	95.6	97.6	98				
Blood pressure, mm Hg	112/76	140/100	128/80	130/98				
Heart rate, beats per min	92	88	100	112				
Respiration, breaths per min	20	16	16	20				
ECG	All leads normal.	All leads normal.	All leads normal.	All leads normal.				
Complete blood count:								
White blood cells (200 cell count)	9,500		35,000	14,550	10, 950	19, 000	11, 650	12, 550
Neutrophiles, percent	64		66	51	38	45	30	21
Myelocytes, percent	4			3			4	2
Lymphocytes, percent	20		29	43	59	50	57	38
Monocytes, percent	4				[a] 1	3	[a] 1	[a] 1
Eosinophiles, percent	5		4				2	38
Sed. rate, mm	28		15	38	16	26	14	24
Red blood cells, millions per mm^3	4.93		4.88	4.38	4. 39	4. 37	5. 45	5
Hematocrit, percent	45		46	44	43	33	39	41

[a] June 1961.

11. BLOOD PRESSURE INSTRUMENTATION *for the* MA–5 FLIGHT

By John P. Meehan, M.D.,*
Jerry Fineg,** and
Charles D. Wheelwright***

In an effort to record arterial and venous pressures for the MA–5 chimpanzee orbital flight, and because time was a critical factor in the selection and development of instrumentation, it was decided to adapt standard techniques previously used for cardiovascular measurement in rocket flights. (See ref. 1.)

Since the overriding requirements were those of high reliability and safety to the chimpanzee subject, a system of sensing the pressures based on arterial and venous catheterization with very small tubing was employed.

Recording of the data was accomplished by means of a galvanometer oscillograph designed to use 16 mm motion picture film. The pressure sensing and recording system originally was required to be operable independent of external power source. This latter requirement was changed and the recording system was operated on electrical power provided in the MA–5 spacecraft. The pressure recording effort was designed to be done on a noninterference basis and whether it was used or not would not affect the overall mission.

Instrumentation

The pressure sensor system was mounted in the spacecraft between the leg restraint troughs of the MA–5 chimpanzee couch (figs. 2–2, 3–2, 11–1, and 11–2). The arterial pressure was measured by means of a Statham Model PM131TC transducer with a range of ±12.5 psi. A similar transducer, with a range of ±2.5 psi, was used for venous pressures. The pressure gauges were mounted in a lucite block that was machined to contain two cylinders, one for each gauge. Fittings were provided at one end of the cylinders for PE 50 polyethylene tubing. The cylinders were fitted with pistons which were driven by means of a small motor. Each gauge, then, had free communications to one cylinder and to one fitting for the polyethylene tubing (fig. 11–3). The cylinders were filled with dilute heparin solution (1 cc of 1,000 units/cc heparin in 50 cc saline). The motor drive to the pistons was such that the heparin solution could be perfused through each of the pressure sensing systems at a rate of approximately 2.5 ml/hour. A total of 20 continuous hours of operation was possible with the pressure sensing apparatus.

The electrical outputs of the pressure transducers were recorded by means of a specially designed galvanometer oscillograph (figs. 11–4 and 11–5). The oscillograph used 16 mm film moving at 5.7 inches per minute with a capacity of 500 feet. This recorder permitted continuous operation for more than 16 hours. The recorder itself was designed to be both water and gas tight and would operate when completely submerged.

The total power consumption for the transducer unit and recorder was 0.8 ampere at 6.0 volts. Calibration of the system was manometric and was conducted just prior to flight time.

Methods

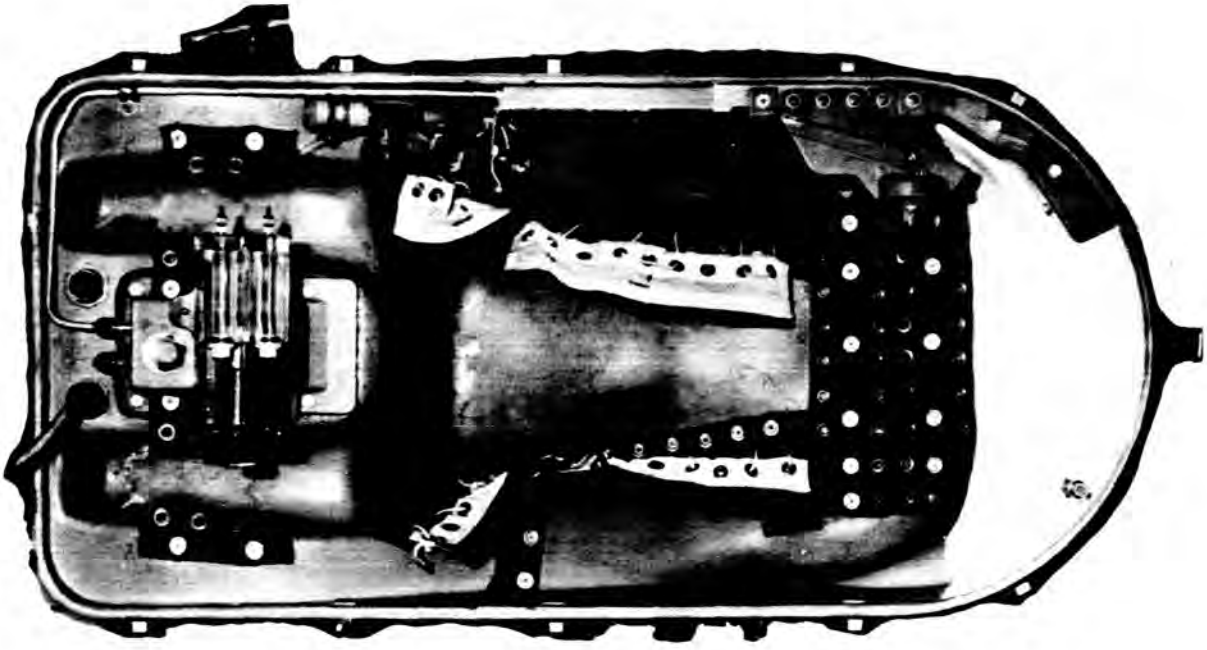
The anterior tibial artery of the chimpanzee subject was used for obtaining the arterial pressure. A length of 26 gauge, stainless steel wire was introduced into the vessel through a No. 21 thin-wall needle. The needle was then removed and fine PE 50 poly-

---

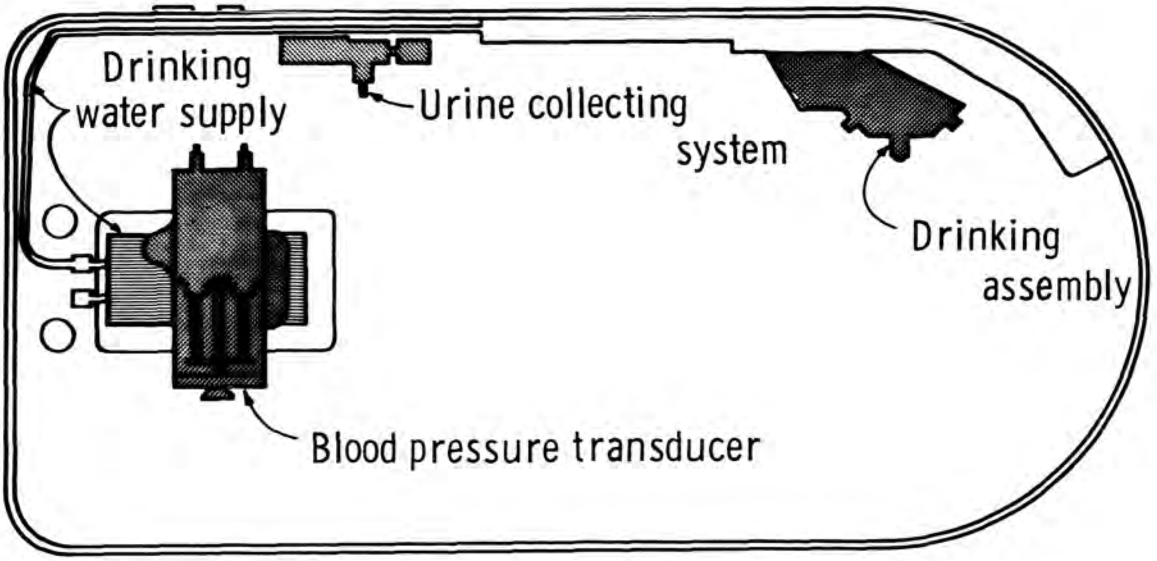
*Professor of Physiology, Univ. Southern California.

**Captain, Veterinary Corps, U.S. Air Force.

***NASA Manned Spacecraft Center.



(a) Photographs



(b) Schematic diagram.

FIGURE 11-1.—Orbital couch showing the blood pressure sensor system mounted on top of the triangular water tank sector between the leg troughs.

ethylene tubing whose diameter is approximately 1 mm with fitting, was slipped over the wire and advanced a few inches into the vessel. The wire was removed and the polyethylene tubing was suitably connected to the pressure sensing system.

The saphenous vein was used for the venous pressure. PE 50 tubing containing an appropriate length of 26 gauge stainless steel wire was introduced through a No. 18 thin-wall needle and advanced a distance considered sufficient to reach the inferior vena cava just below the diaphragm. The needle was then removed by threading backwards along the tube and the gauge fitting was then attached to the tube and connection established with the gauge. As demonstrated by the onboard pressure recordings recovered after the flight, the tip of the catheter came to lie in

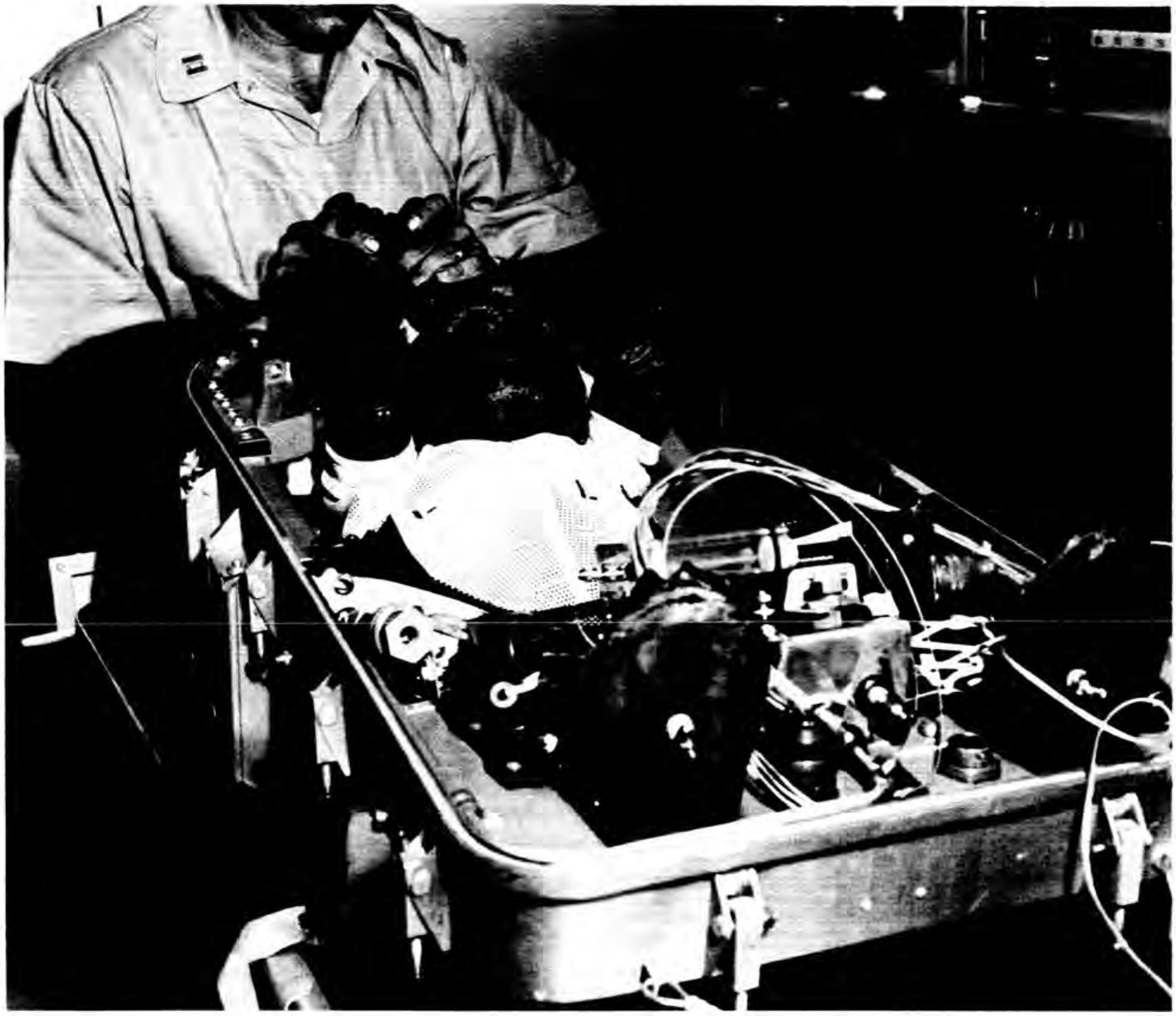
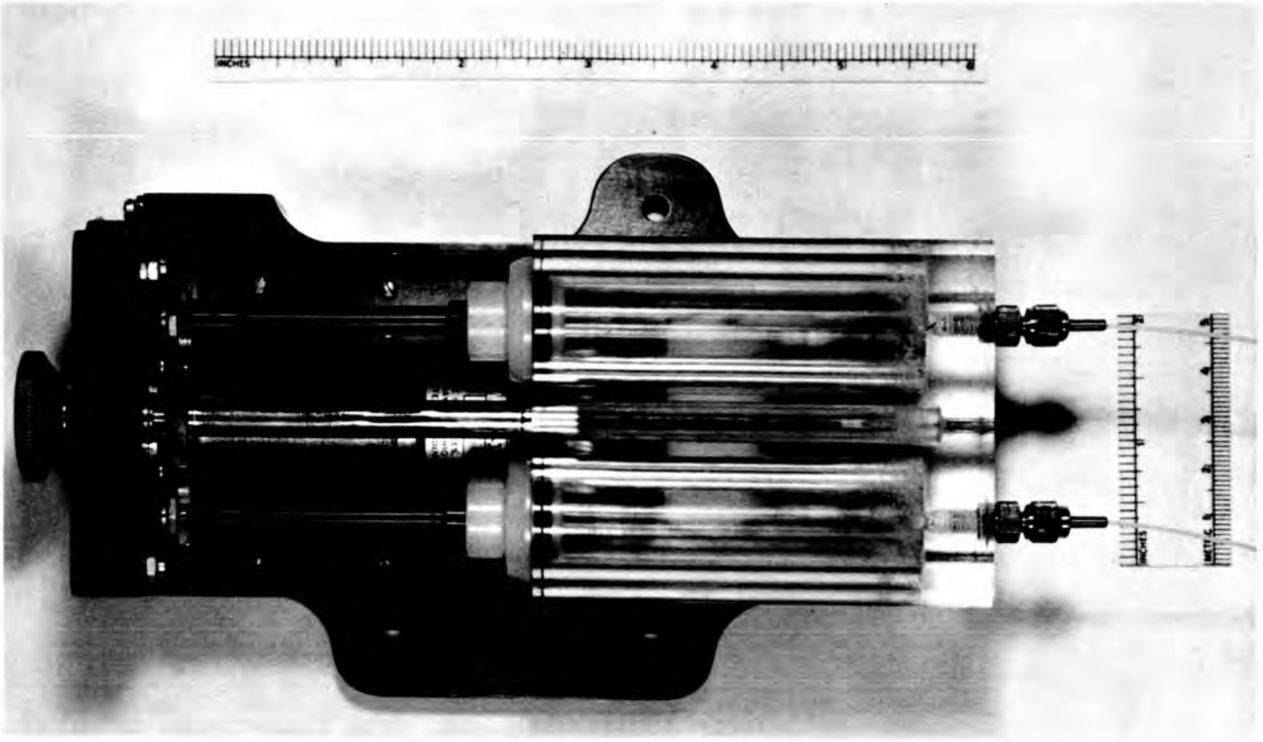


FIGURE 11-2.—View of the animal in the couch. The electrode attachment to the soles of the feet is visible. Between the legs is the water reward reservoir on top of which are mounted the syringes infusing the anticoagulant and the two pressure gages. The fine tubing leading to the vessels can be seen running in two loops from the fittings on the syringes toward the feet.

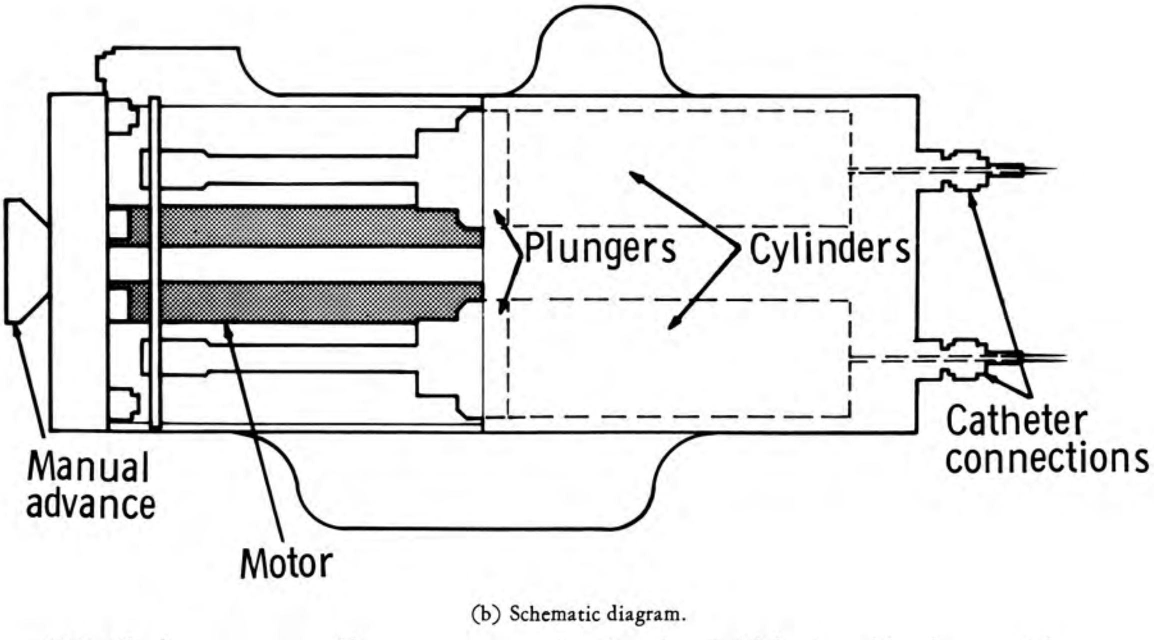
the right ventricle in such a position that it could move easily between the right ventricle and the pulmonary artery. The fact was not ascertained with certainty until the onboard pressure records became available for study.

Results

The vascular pressures were recorded from 288 minutes before lift-off to 10 minutes after landing. During the rest period on the launch pad, arterial pressures ranged from 168/133 mm Hg to 183/143 mm Hg (fig. 11-6). (Pressures over 160 mm Hg were estimated from the slope of the wave.) The subject's arterial pressures were responsive to events occurring outside the chimpanzee couch and showed variations when, for example, the Mercury spacecraft had to be reentered prior to lift-off. Pulmonary artery pressures ranged from 24/14 to 27/19 mm Hg. The ventricular diastolic pressure was 0 mm Hg. (See fig. 11-6.) During orbit, the mean systemic artery pressure approximated 150 mm Hg and ranged from a maximum of 200 mm Hg systolic to a minimum of 120 mm Hg diastolic while mean pulmonary artery pressure held constant at approximately 25 mm Hg. Because the peaks were not recorded on the film, all systemic arterial pressures over 160 mm Hg were

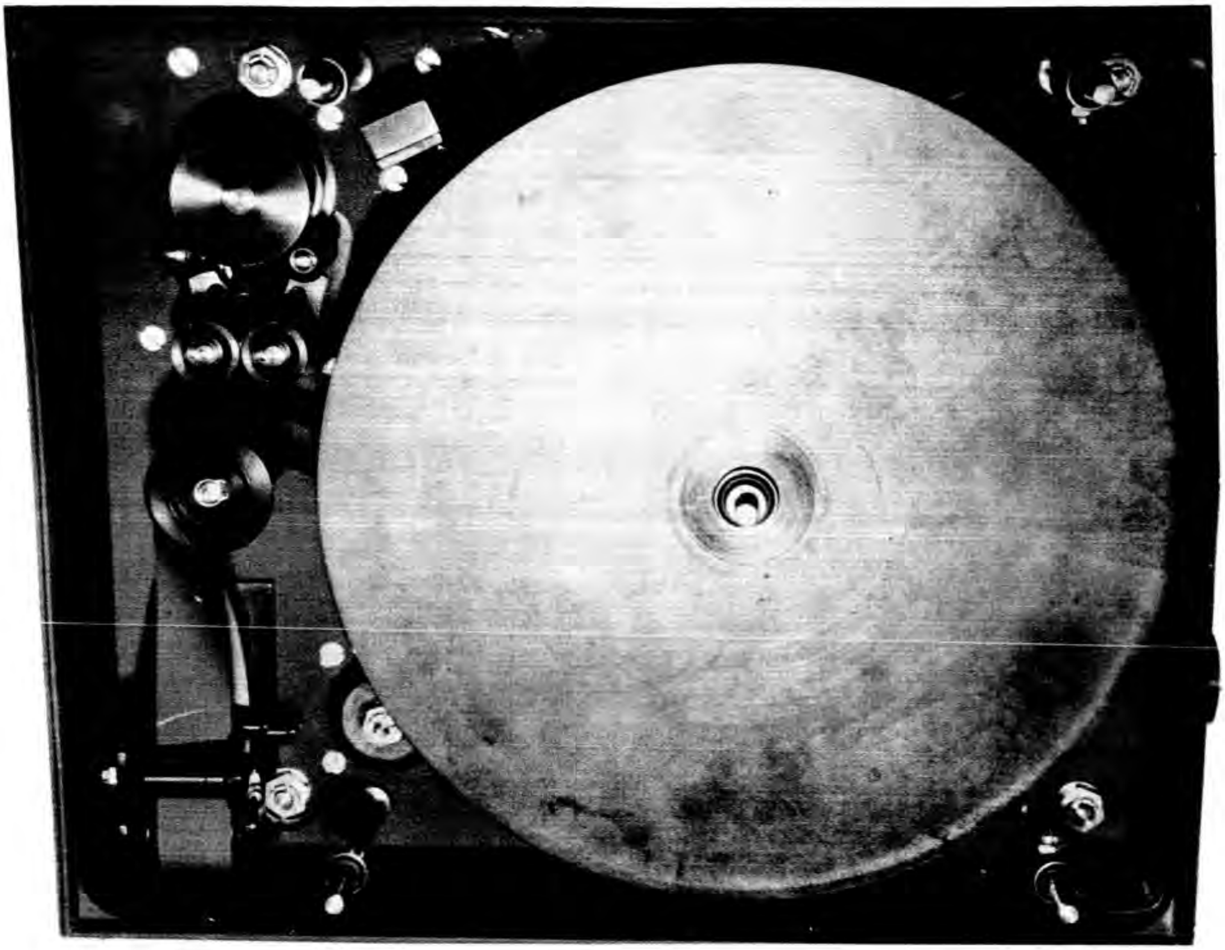


(a) Photograph.



(b) Schematic diagram.

FIGURE 11-3.—Blood pressure system. The pressure sensor consists of two heparin filled syringes driven by a geared-down motor so slowly that emptying required over 16 hours.



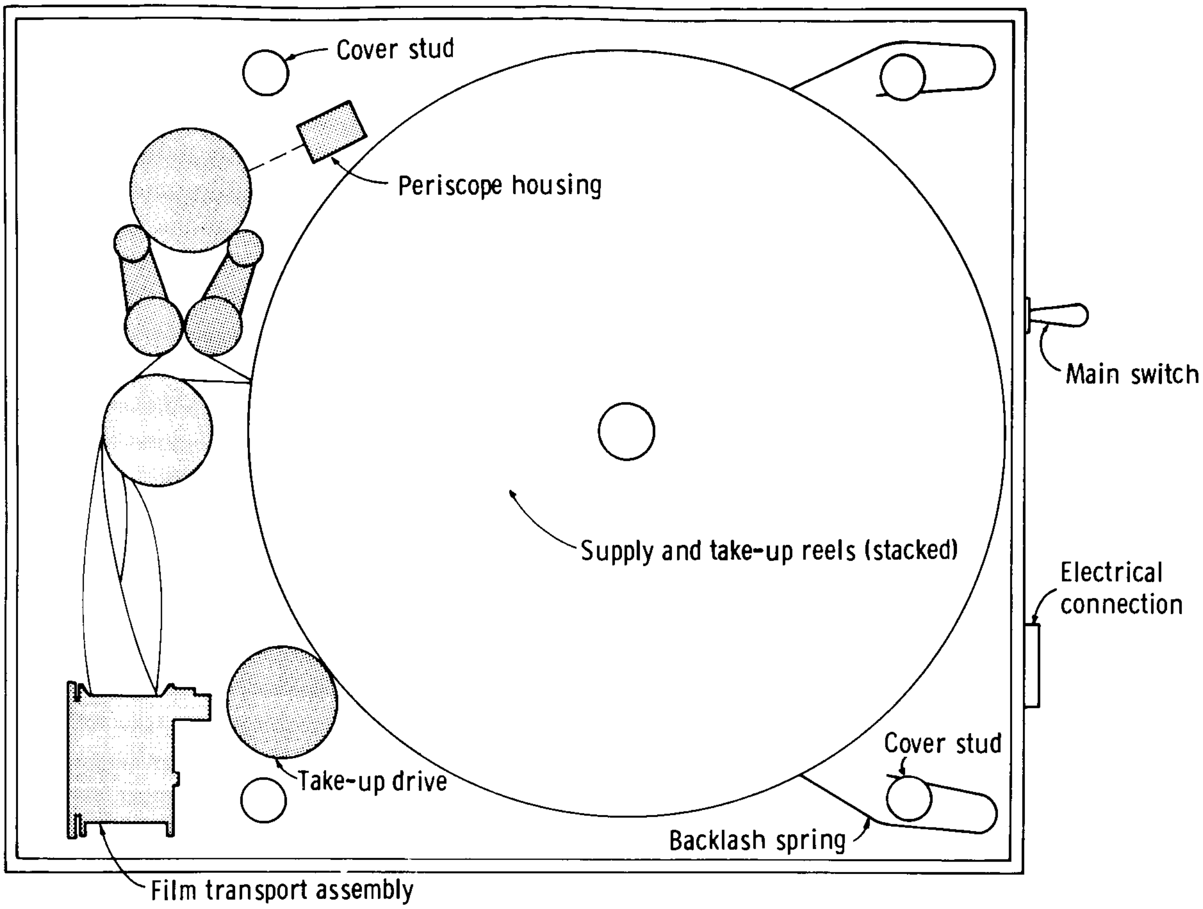
(a) Photograph.

FIGURE 11-4.—Oscillograph showing the bases of the two springs holding the film to the large 400-foot reels on the left side. The rubber-rimmed drive wheel is two-thirds visible at 8 o'clock on the spool. The film loop winds under a series of small spring-loaded rollers and passes over a large roller at the lower left to receive the beams from the galvanometers. This light is passed through from the reverse side of the oscillograph by the "periscope" seen at 11 o'clock on the reel.

estimated from the slope of the curve. Figure 10–2 is a composite graph of the physiological data including the blood pressure observations. It demonstrates that the ectopic beats experienced by the subject produced the anticipated insignificant momentary drops in the vascular pressures.

Discussion

The technique for recording the vascular pressures was entirely satisfactory. The data obtained are difficult to evaluate without further control observations on the flight subject and other chimpanzees. The diastolic and systolic systemic arterial pressure was high throughout the flight while the pulse pressure was low. It is a true observation and cannot be attributed to instrumental difficulties since the pressure recordings were uniformly good during the entire 3 hours of pad observation, and yet the values were of the same order as those obtained during flight. These high prelaunch arterial pressures were not peculiar to those obtained on the flight day but were within the range noted at times of physical examinations for this particular chimpanzee (fig. 11–7). Figure 11–7 shows the mean blood pressure of the five flight animals while in training at the Aeromedical Research Laboratory. The vertical bars indicate mean systolic and diastolic pressures. There is great variability in all values, including those for the quarterly physicals which run somewhat higher for the MA–5 flight subject than the rest of the group and fell well within the values obtained immediately preceding and during the orbital flight. The bars labelled Jim and Enos data acquisition flight indicate the responses of the flight subject (Enos) and one



(b) Schematic diagram.

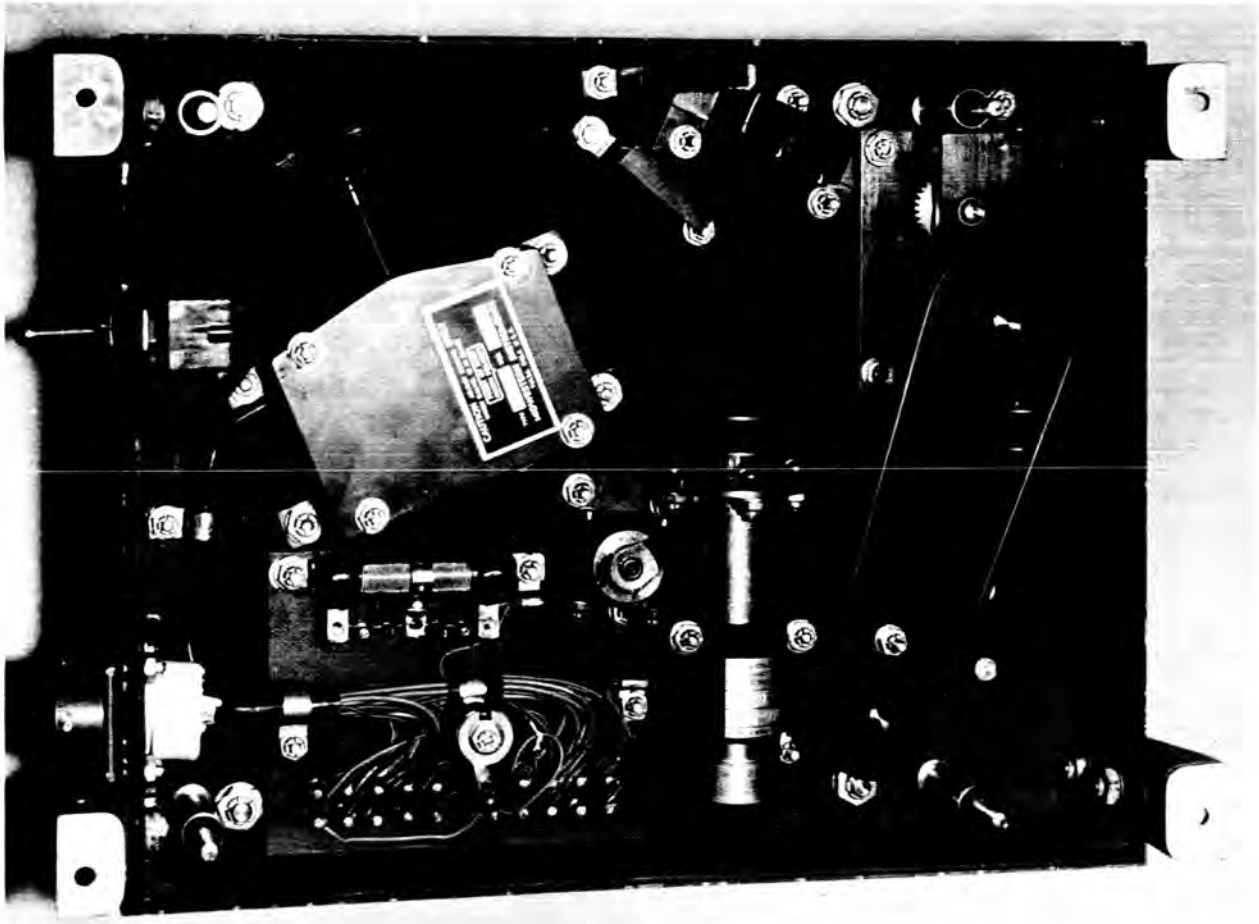
Figure 11-4.—Concluded

other animal (Jim) to aircraft flights with the animal in the couch. These flights were aimed at indoctrinating them to the distraction of rocket flight. The high data acquisition value in July 1961 corresponds to information gathered during the flight, and the low value following it corresponds to measurements made following return to his customary environment. The data of figure 11–7 indicate that the flight subject has a labile systemic blood pressure and that values of the order of 160 to 200 mm Hg systolic had been observed by sphygmomanometry during the 2 years preceding the flight. The animal had an elevated systemic arterial pressure at the time of the flight, and further investigation conducted on the centrifuge subsequent to the flight has shown that the subject continues to have an elevated systemic pressure. The data included comparative studies on and off the centrifuge both with and without arterial catheterization. It is not known to what extent the elevated pressure is due to the effects of psychological training and to what extent it is inherited.

The pulmonary arterial diastolic pressure was somewhat elevated with a consequent reduction in pulmonary arterial pulse pressure and there was a small but significant rise from the control period on the launch pad to the records obtained in flight. The pressures in the venous tree and the pulmonary vascular bed, appeared to be parallel. (See ref. 2.) Despite the rise of approximately 10 mm Hg in diastolic pressure, the data obtained from the pulmonary artery during this flight point to no gross abnormality in the functioning of the low-pressure portion of the cardiovascular system. The systemic arterial pressure responded normally to the periods of launch and reentry acceleration and, in fact, showed a moderate decline during the 3-hour period of weightlessness despite the failure of the center lever and the consequent repeated shocks.

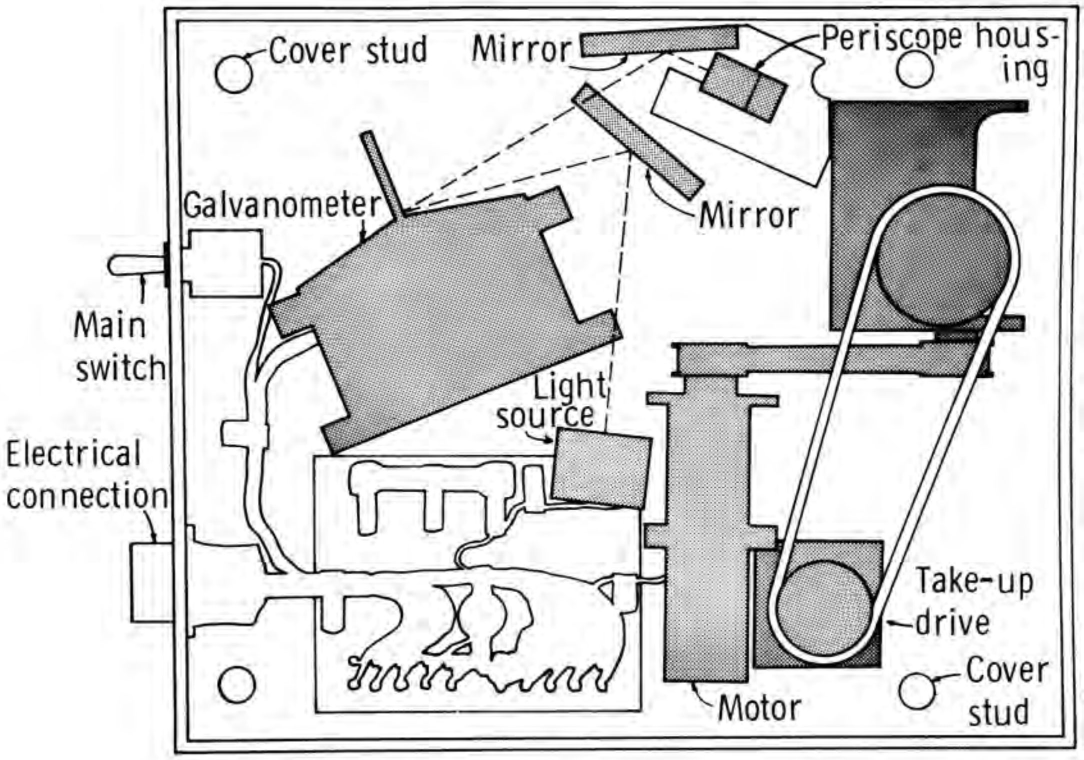
References

1. Henry, J. P., Ballinger, E. R., Maher, P. J., and Simons, D. G.: Animal Studies of the Subgravity State During Rocket Flight. Jour. Aviation Med., vol. 23, no. 5, Oct. 1952, pp. 421–432.
2. Henry, J. P., Bauer, O. H., and Sieder, H. O.: The Effect of Moderate Changes in Blood Volume on Left and Right Arterial Pressures. Circulation Research, vol. 4, 1956, p. 91.



(a) Photograph.

FIGURE 11-5.—Reverse side of the oscillograph showing the galvanometer block (middle upper left) with on-off switch nearby. At the lower left are the electrical connections for the galvanometers and the lamp. To the right and next to the lamp is the drive motor, with a flat rubber belt connecting it to the reduction gear which in turn actuates the rubber spool drive wheel by a round rubber belt. The two mirrors folding the beam and the "periscope" diverting the light to the other side of the oscilloscope are seen in the upper portion of the photograph between the drive gears and the galvanometer block.



(b) Schematic diagram.

Figure 11-5.—Concluded

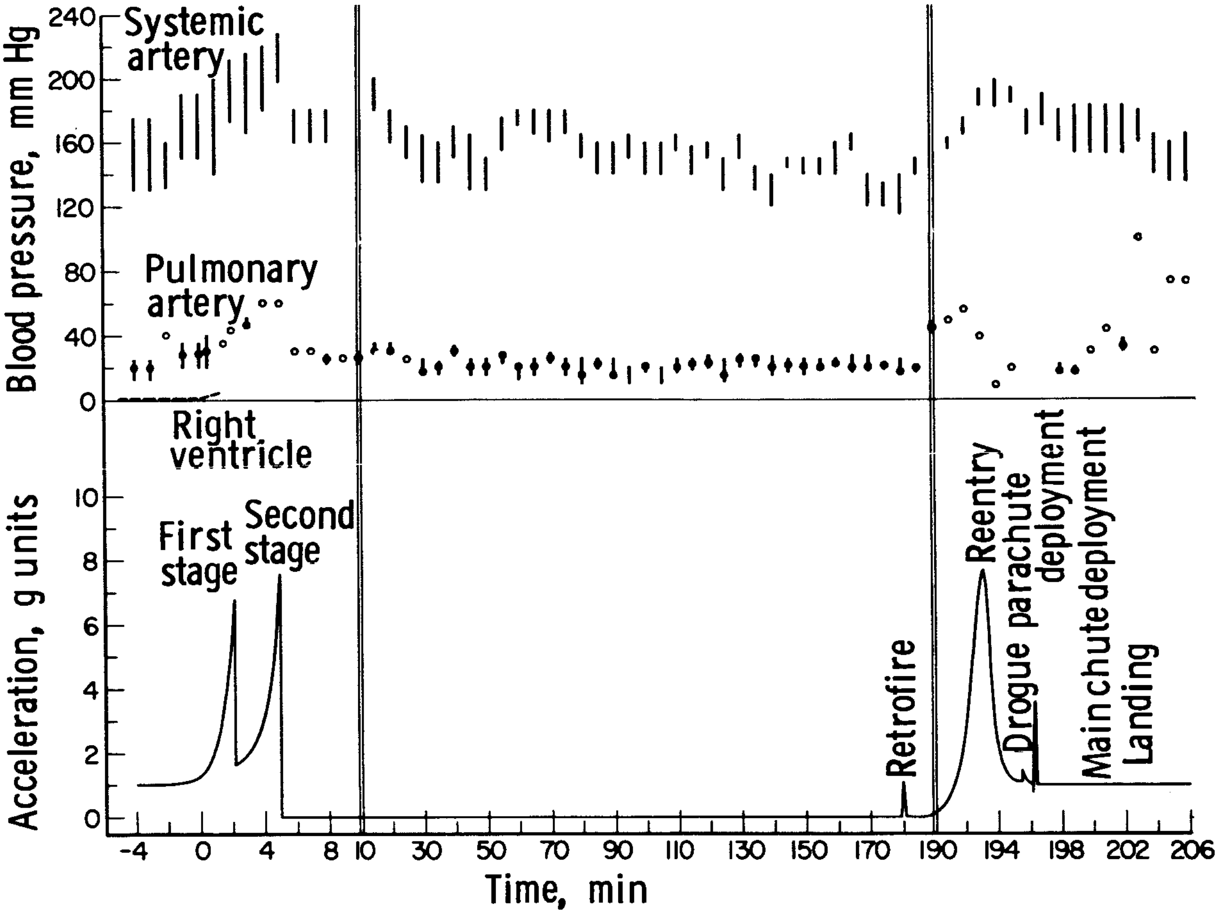


FIGURE 11–6.—Blood-pressure response of the MA–5 flight subject. The bottom trace is the record of the acceleration transverse to the animal's body. Above this trace are the pulmonary-artery and right-ventricular pressures. The vertical bars represent the pulmonary arterial systolic and diastolic pressures as read on the sensitive galvanometer and the circles the pressure from the less sensitive galvanometer which was connected to the same gage. Systemic arterial pressure which is depicted by the same convention is shown on the top row. Notice the normal return of the pressure to prelaunch values during the period of weightlessness and the rise to higher values following reentry. During the 0g period of flight, arterial systoles exceeding 160 mm Hg were estimated from the slope of the wave.

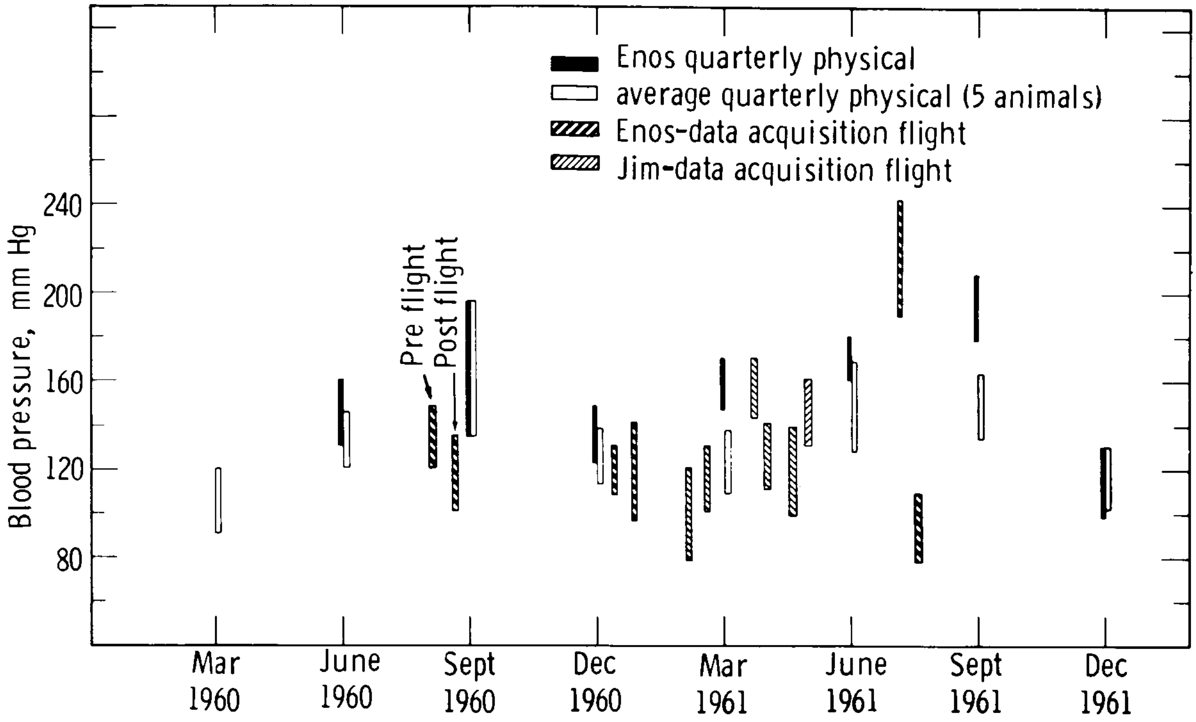


FIGURE 11-7.—Bar chart of the mean systolic (top end of the bar) and diastolic (bottom end of bar) pressures obtained during the period of training of the five flight animals at the laboratory. The values show great variability, and the range covers values for the MA-5 subject on the launch pad and flight. The bars labeled Jim and Enos data acquisition flights represent pressure measurements made during and after airplane flights indoctrinating the animals to the distracting noise and vibration while at work in the flight couch.

12. SUMMARY OF THE RESULTS *of the* MA-5 FLIGHT

By John D. Mosely, D.V.M.,* and
James P. Henry, M.D., Ph. D.**

The results of the data analysis have been presented in previous sections of this report; however, several of the inflight and postflight events warrant further comment. Premature ventricular contractions (see fig. 10–1) were first noted by the medical monitor at the Zanzibar tracking station at launch (T) plus 26 minutes. Since launch acceleration lasted for 5 minutes, the first premature ventricular contraction occurred after 21 minutes of weightlessness. The premature ventricular contractions continued singly, in pairs, and in runs until T+3 hours 15 seconds. At that time, the retrorockets were fired and from then on the subject was subjected to increasing accelerations. Continuous data on the subject covers the period from T−5 hours 30 minutes until T+3 hours 21 minutes. Premature ventricular contractions were present from T+26 minutes until T+3 hours 15 seconds. (See fig. 12–1 in which premature ventricular contractions are plotted against time.)

The subject's blood pressure was recorded onboard the spacecraft but was not monitored by telemetry; therefore, no data were available until after the flight. Although the blood pressure was high (figs. 10–2 and 11–6) it was not inconsistent with the preflight values which were also high nor was it inconsistent with some of the data obtained previously on this subject (fig. 11–7). Also presented in figure 11–7 are the blood-pressure data of five other chimpanzees trained for Project Mercury. These subjects received similar care and were exposed to the same training as the flight subject. It must be noted that the flight subject is one of the most excitable animals in the Aeromedical Research Laboratory in his age group and usually requires maximum restraint during a physical examination.

Figure 12–1 was prepared to determine if performance or shock was a factor in inducing premature ventricular contractions. It can be seen that they occurred at random during each task as well as during the rest sessions. It has not been possible to demonstrate any correlation with events during the flight except that the premature ventricular contractions only occurred during the weightless state. It may be speculated that they were associated with some changes in the position of the catheter in the heart during weightlessness. The physiological and psychomotor responses to the flight were as expected except for the sustained high blood pressure. This condition preceded the flight and was not due to the act of catheterization or to the presence of the catheters in the leg artery and vein. For example, subsequent studies have shown no increase in blood pressure, with values obtained being the same as those measured by sphygmomanometry.

The subject performed as desired throughout the launch and reentry acceleration and during the weightless state despite the unplanned stress caused by the failure of the center lever in the psychomotor apparatus which resulted in the numerous shocks during the oddity problem presentation. Subsequent to the oddity presentations, performance was within normal limits except during the peak acceleration of reentry. The data show no significant disturbance either in his behavior or physiology that could be attributed to the weightless state, to the other conditions accompanying the flight, or to the lever malfunction during the second orbital pass. As can be seen from figures 12–2 and 12–3, which show the orbital flight subject immediately before the countdown and just after recovery, his post-flight appearance supported the physiological and psychomotor data.

Nevertheless, the extra systoles and the high blood pressure do point up the importance of measuring the

---

*Major, U.S. Air Force, School of Veterinary Medicine, Ohio State University, Columbus, Ohio.

**Lieutenant Colonel, Aerospace Medicine Division, Brooks Air Force Base, Tex., with permanent duty station at Department of Physiology, University of Southern California, Los Angeles, Calif. (formerly at NASA Manned Spacecraft Center).

total subject response in terms of both behavior and physiology. Both approaches are required to evaluate the flight or any particular portion of it. That the psychological task recordings showed normal performance despite the cardiovascular irregularities was convincing evidence of the immediate value of the operant technique as a direct measure of the well-being and performance capability of the subject.

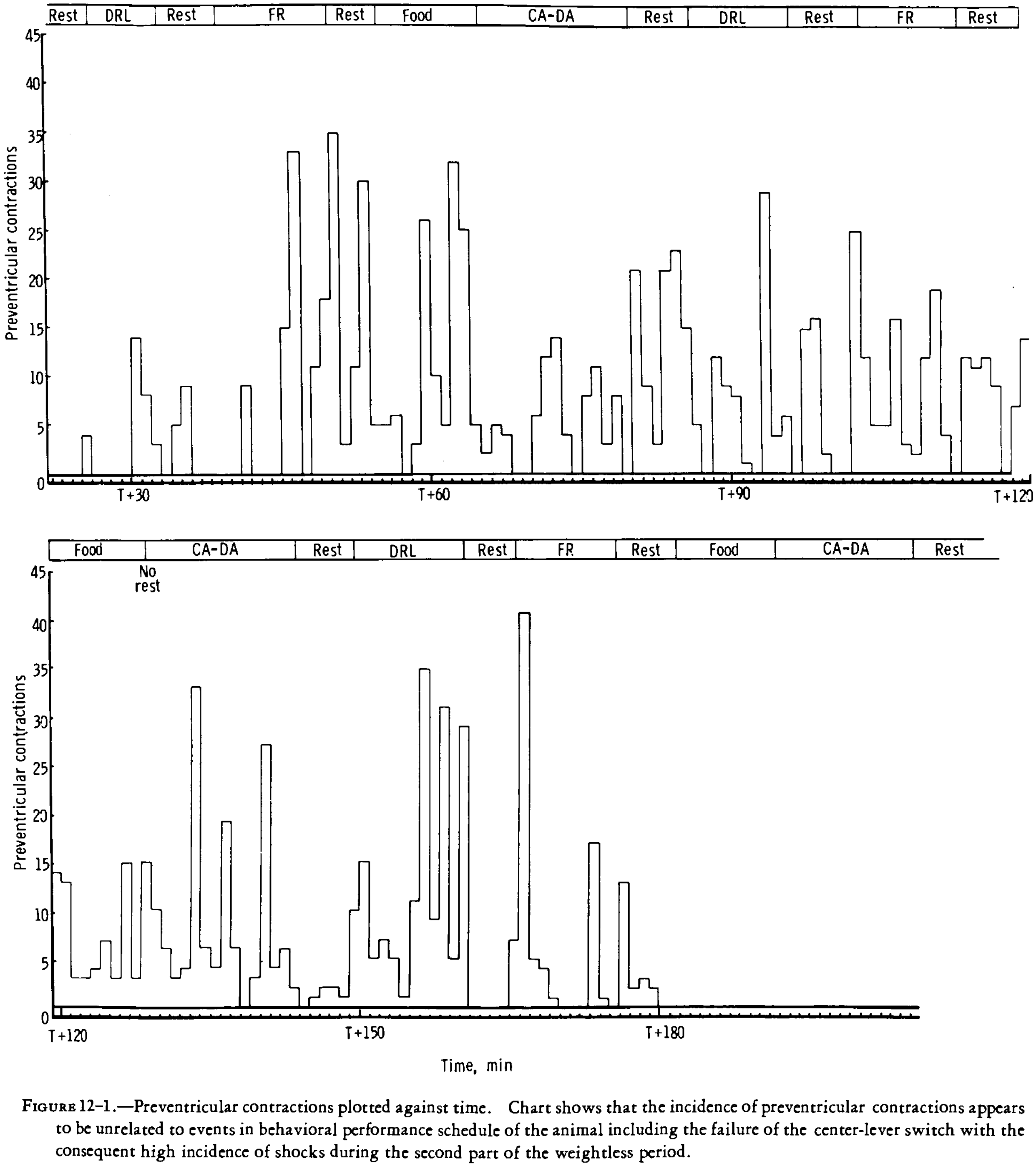


FIGURE 12-1.—Preventricular contractions plotted against time. Chart shows that the incidence of preventricular contractions appears to be unrelated to events in behavioral performance schedule of the animal including the failure of the center-lever switch with the consequent high incidence of shocks during the second part of the weightless period.

Figure 12-2.—The MA-5 flight chimpanzee immediately before the countdown. Note the restraint garment with its adjustments at the side.

Figure 12-3.—The MA-5 flight chimpanzee photographed at the launch site 2 days after recovery.

U.S. GOVERNMENT PRINTING OFFICE : 1963 O—696-439