II. Bio-Flight 2 Able

To obtain additional background data and experience for manned space flight, an experiment using a larger primate was desirable. As in the first experiment, the Jupiter cone which served as a vehicle for this experiment was a military ballistic vehicle not specifically designed for biologic experiments. The life support systems again had to be selected and designed to withstand the forces of such a missile flight profile.

The primate selected for this experiment was the common rhesus monkey *(Macaca mulatta)* in a weight range of six to eight pounds. This choice was made primarily because of the vast amount of basic information available about this species. In addition, previous experimentation indicated that the rhesus could probably withstand the stresses which might be expected.

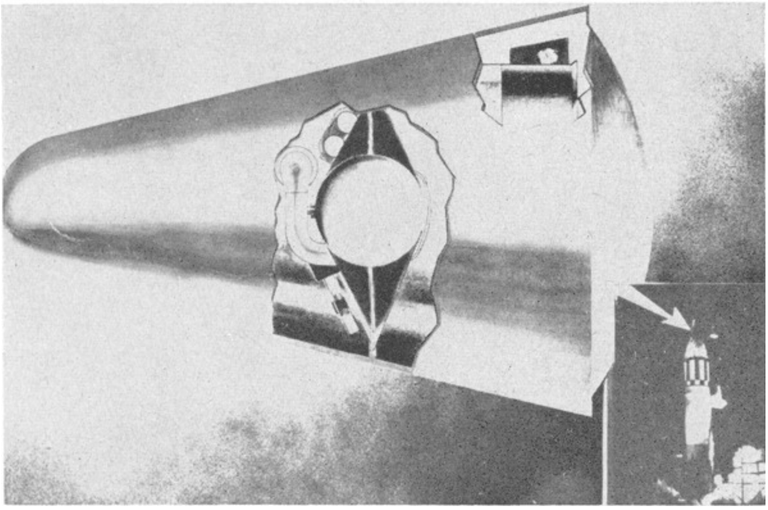

Fig. 11. Cutaway view of Jupiter nose cone. The relative locations of the Able and Baker biocapsules are shown graphically.

THE BIOCAPSULE AND ASSOCIATED EQUIPMENT

EXTERNAL CHARACTERISTICS

The basic unit of the biocapsule system was a hermetically sealed cylinder which housed the animal (Figs. 11, 12 and 13). This cylinder, constructed of 0.190 inch thick aluminum alloy sheet material, was approximately 18 inches in diameter, 41 inches long, and had a free volume of 10,000 cubic inches. Access to the interior was provided by an O-ring sealed door which was fastened to a plate welded to one end of the cylinder. A one inch thickness of glass fiber wool was placed over the interior surfaces of the cylinder to provide thermal insulation.

Circumferentially placed flanges and interconnecting braces were welded to the exterior wall of the cylinder to provide the desired mechanical strength and rigidity, and to permit the biocapsule system to be fastened to the interior structure of the missile nose cone. This reinforcement framework also served to mount those life-support and data collection devices which were not installed inside the cylinder. Those externally-mounted devices included: two oxygen flasks and associated mechanical and electrical valves which supplied oxygen to

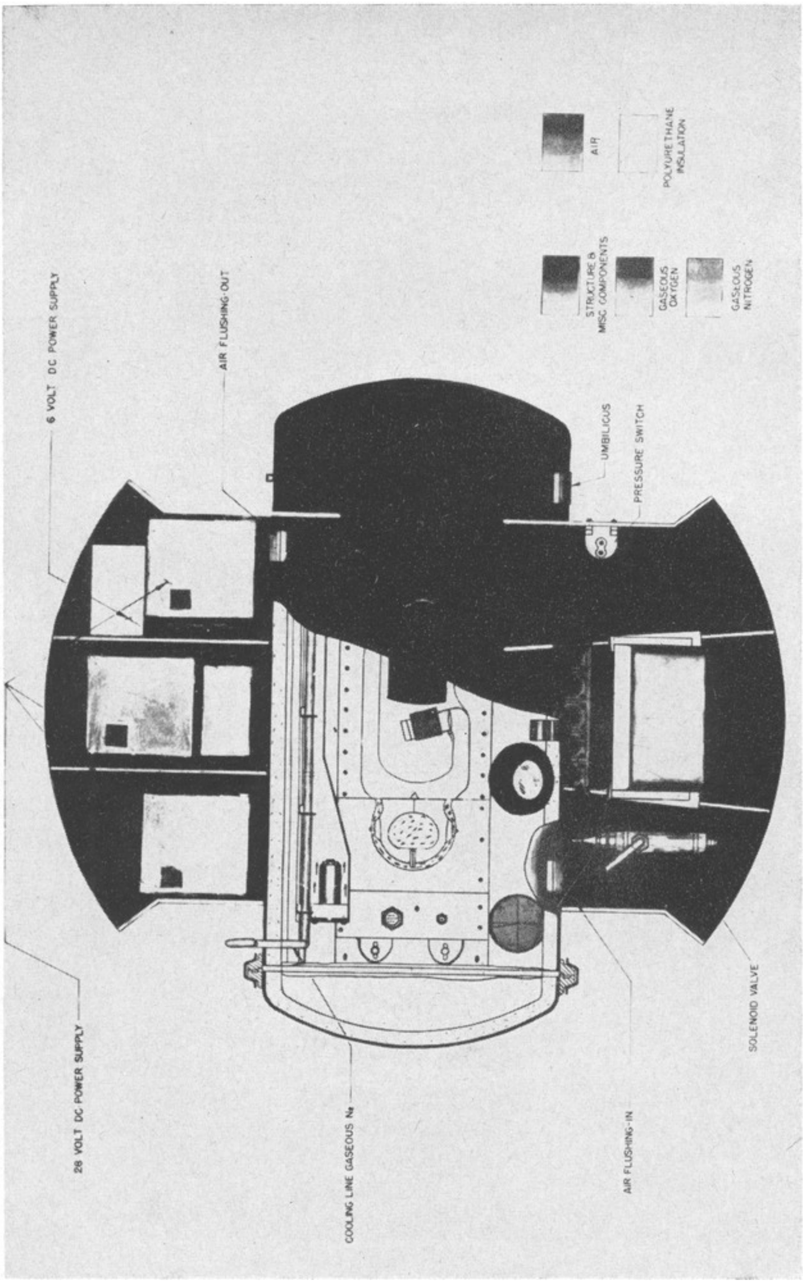
6 VOLT DC POWER SUPPLY
AIR FLUSHING-OUT
UMBILICUS
PRESSURE SWITCH
STRUCTURE & MISC COMPONENTS
GASEOUS OXYGEN
GASEOUS NITROGEN
AIR
POLYURETHANE INSULATION
28 VOLT DC POWER SUPPLY
COOLING LINE GASEOUS N₂
AIR FLUSHING-IN
SOLENOID VALVE

Fig. 12A

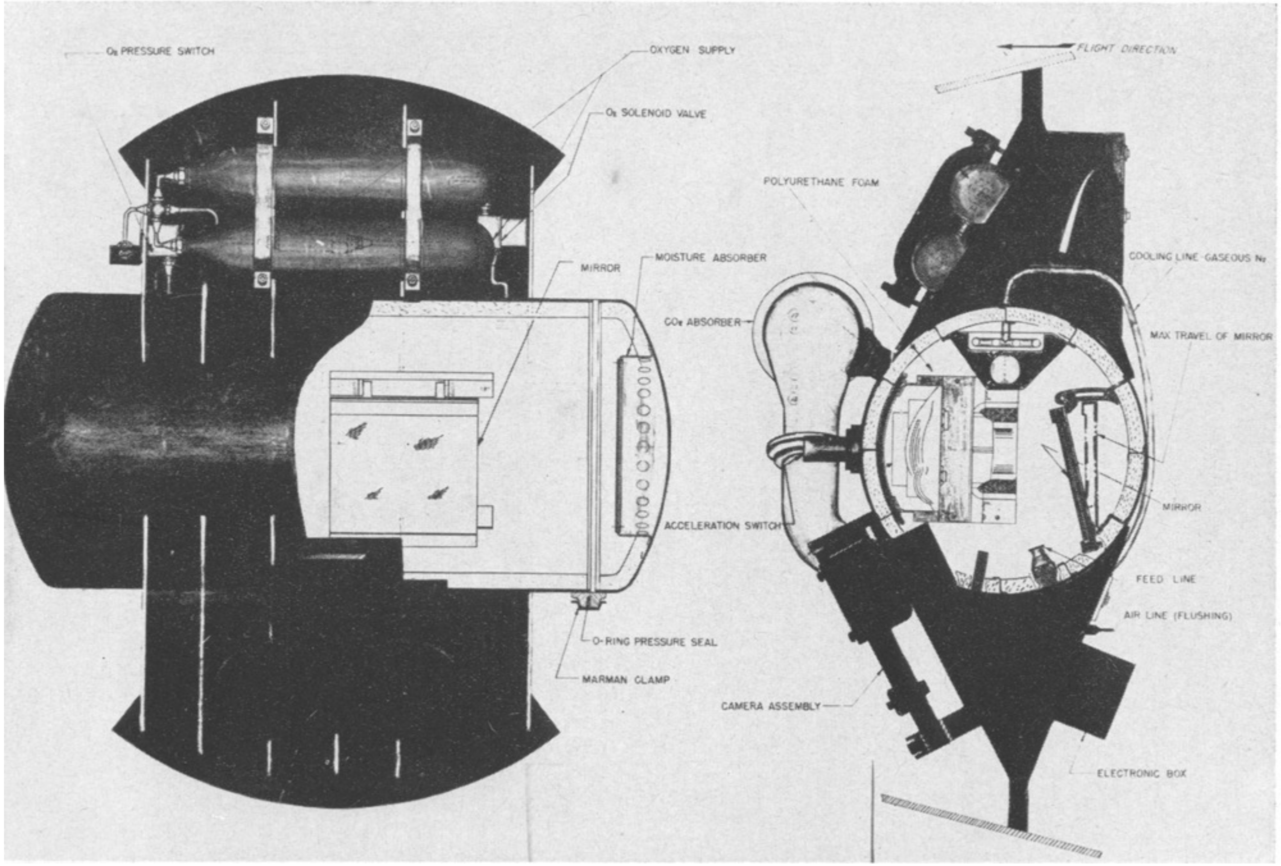

Fig. 12B

Fig. 12. Cutaway view of (A) bottom and (B) top and side of Able biocapsule system.

the biocapsule; the absorber unit to remove carbon dioxide from the capsule atmosphere; the electronic package containing all of the circuitry related to the telemetered measurements; battery power packs; and a motion picture camera used to film the animal during the flight. Pressure tight seals were used for the connection of these devices to the cylinder. The total weight of the biocapsule system, including the animal, was approximately 258 pounds.

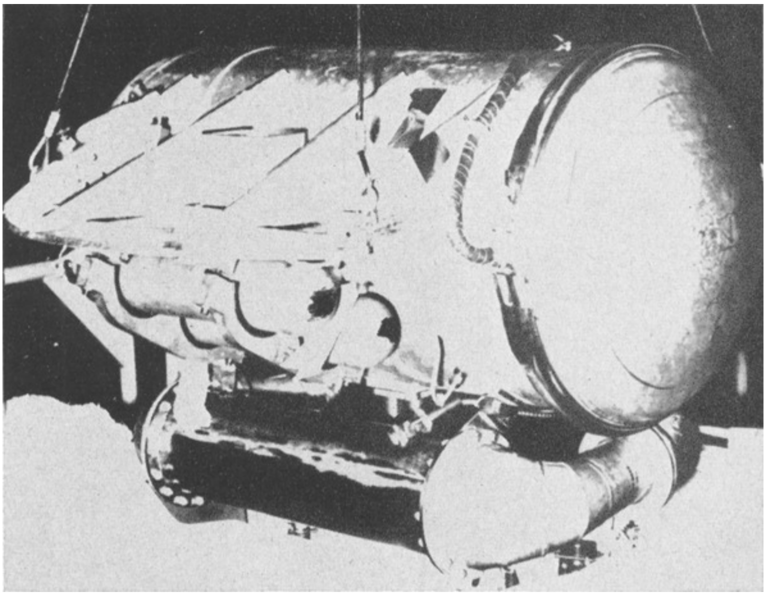

Fig. 13. Assembled biocapsule for Bio-Flight 2 Able.

BIOCAPSULE EQUIPMENT AND ARRANGEMENT

The biocapsule system was composed of four special systems: facilities for supporting and restraining the animal, the life support equipment, the electronic measuring devices, and the in-flight motion picture camera assembly.

Facilities for Support and Restraint of the Animal.—The principal element of the support system was an aluminum framework to which was attached a fiber glass couch which was molded to conform to the body contours of the animal (Fig. 14). This assembly could be inserted into the biocapsule through the access door and securely fastened by two machine screws. The outline configuration of the couch was such that the position and joint angles of the restrained animal were similar to those proposed in the Mercury capsule configuration. As with the Bio-Flight 1 system, the orientation of the couch relative to the missile nose cone was such that the deceleration forces occurring during re-entry acted on the animal in the anterior-to-posterior direction. A life-sized model of the animal was constructed to facilitate the design of the support couch. This model was made of a concrete-like molding compound, using foundry mold techniques. The couch was then formed over this model by the vacuum technique of fiber glass fabrication. To restrain the animal in the couch, the legs and abdomen were held in place with nylon mesh straps. A fiber glass chest plate was used to restrain the upper portion of the animal. A fiber glass helmet, individually fitted to the animals, served to fasten the head to the couch.

In order further to protect the animal, the three fiber glass parts were lined with a layer of 0.375 inch or thicker polyurethane foam material. This compound was selected rather than foam rubber because of its resilience properties. The rather slow "rebound" property of this material permits greater shock energy absorption during periods of high acceleration and deceleration. At the head end of the animal support frame were attached a set of quick disconnect type electrical connectors to further facilitate the installation and removal of the animal. All wiring for the physiological transducers was placed on the underside of the couch and cabled to the quick disconnect plugs.

Life Support Equipment.— Operational requirements of the missile launch dictated that the animal be installed in the nose cone sixty-four hours before launch. As a result of these requirements, two independent life support systems were provided. The first system provided an adequate atmosphere inside the biocapsule by means of a ground flushing unit located external to the nose cone. This system was in operation from the time of the initial insertion of the animal into the biocapsule until last access to the nose cone. At that time, the biocapsule was switched to a self-contained system which remained in operation until recovery of the nose cone.

Fig. 14. General configuration of animal support for Bio-Flight 2 Able.

The ground flushing system consisted of a standard 1.5 ton window air conditioner modified for this function. A carbon-vane pump was used to furnish cooled air through an insulated hose into the capsule. A removable umbilicus system was used to connect the flushing system to the capsule.

The oxygen supply system, operating on a constant pressure principle, was demand regulated. The system consisted of two high pressure oxygen flasks charged to 1500 psig, filters, a solenoid valve, a centered orifice, and an absolute pressure switch. This pressure switch was set to operate the electrical solenoid valve whenever the capsule pressure dropped below 14.57 psia. The action of the solenoid valve turned on the oxygen supply to the capsule and the pressure began to rise due to the incoming oxygen. When the capsule pressure reached 15.00 psia, the pressure switch de-energized the solenoid valve which turned off the oxygen supply.

As a safety back-up to this electrical system, a mechanical demand regulator was used in parallel with the solenoid valve. The pressure settings on the mechanical regulator were so adjusted that it would operate only in the event of failure of the electrical system. A pressure relief valve was installed in the capsule to maintain a safe upper pressure limit.

The carbon dioxide and water absorbers, baralyme and mobilbead, in the same form as in Bio-Flight 1, were used to remove the carbon dioxide and water, respectively, from the capsule atmosphere. The baralyme was placed inside the absorber tube which was mounted on the exterior surface of the biocapsule cylinder. Two blower fans, mounted inside the absorber tube, circulated the capsule atmosphere through the baralyme. One fan was operated from the 28 volt missile power supply. The other fan, operated from a 6 volt battery pack installed on the exterior surface of the cylinder, was designed to function after the loss of missile power and when the nose cone was in the water.

Originally, it was planned to install the mobilbead in the same absorber tube as that for the baralyme. However, during the testing phase, it was discovered that the mobilbead removed most of the water of hydration from the baralyme. In order to avoid the complete redesign of the absorber tube system, the mobilbead was placed in a separate container mounted on the access door of the cylinder. A polyethylene film covering was placed over the surface of the mobilbead container to conserve the capacity of this material during the long count-down period when the ground flushing system was in operation. This protective film was removed prior to launch by means of a rip cord leading to the outside of the missile.

Because of the extremely long period of isolation and restraint prior to launch it was necessary to provide the animal with some form of nourishment. Since normal rations and water could not be dispensed conveniently in the capsule, nourishment was provided by an intraperitoneal infusion of 5 per cent dextrose at the rate of 5 cc. given slowly once an hour. Although minimal, this was adequate to sustain life. Body wastes (feces and urine) were allowed to accumulate in diapers.

The temperature regulation of the biocapsule was accomplished by means of a thermostatically controlled heat exchanger. The operating temperature of the system was set to 68.4° F; a value selected as optimum for the animal considering the thermal properties of the restraint system.

The heat exchanger was mounted on the end of the biocapsule cylinder opposite the access door. A 6-volt miniature blower fan circulated air over the interior surface of the heat exchanger to reduce stratification and to give a more uniform temperature distribution within the cylinder. The exchanger was supplied, via an electrical solenoid valve, with cold nitrogen gas from a boiler located in the nose cone. Control of the solenoid valve was provided by a mercury thermostat installed inside the biocapsule cylinder. The missile power source, through a system of relays was used to energize the solenoid valve. After the thermostatic control system was placed in operation, the ambient temperature of the capsule atmosphere varied only slightly.

Electronics and Measuring Devices. —Provisions were made for the telemetry of six physiologic and four environmental measures. The physiologic measures were the electrocardiogram, respiration rate, chest sound, two electromyograms and body (colonic) temperature. The environmental measures were ambient temperature, ambient pressure, humidity, and per cent CO_2. The missile FM-FM telemetering system, previously described, was used to transmit this information to the various receiving stations. Provisions similar to those made for Bio-Flight 1, were included to record cosmic ray tracks and flash temperatures within the biocapsule cylinder.

Electrocardiogram. — Each of the electrodes consisted of a fine-mesh, silver-plated, stainless-steel screen in the form of a square with an approximate surface area of 35 square millimeters. These electrodes were implanted subcutaneously to minimize "noise" under circumstances of restraint and flight stress. The electrodes were connected to the differential input circuitry of the electrocardiograph amplifier. The voltage gain of this amplifier was 5000 and the frequency response was down 3 db at ½ cps and 1500 cps. The common mode rejection was 450 at 1 cps which increased to 1000 at 20 cps. For all frequencies between 20 cps and 1500 cps, the common mode rejection was greater than 1000. The input impedance between each of the differential input connections and ground was approximately 100,000 ohms. The overall signal-to-noise ratio of the amplifier was greater than 50 to 1. A wide-band telemetry channel with a frequency response to 220 cps was driven by the output stage of this amplifier.

Chest sounds. — This measurement utilized a variable-reluctance type diaphragm microphone which was coupled to the chest wall of the animal by means of elastic tape. The microphone amplifier was designed to have a flat frequency response down 3 decibels at 20 cps and 2000 cps with a maximum voltage gain of 1500. An input resistance of 1 megohm allowed the amplifier to be used with other types of microphones. The output stage of this amplifier drove a wide-band telemetry channel with a frequency response to 1050 cps.

Respiratory Rate. — This measurement was identical to that described for recording the breathing rate of Old Reliable except for the method of fastening the transducer in front of the nostril. The transducer lead wire, coated with an epoxy compound, was sutured from the anterior surface of one nostril to the posterior zygomatic region.

Electromyogram.—The two electromyogram measurements utilized two insulated needle electrodes to obtain the potentials generated by muscular action of the animal. Each of these electrodes consisted of a 20-gauge hypodermic needle with a completely epoxy-insulated wire embedded within the bore of the needle. The exterior surface of the needle, other than its leading edge, was also insulated with an epoxy compound. After insertion in the desired muscle of the animal, the needle was connected to the input circuitry of the electromyogram amplifier. To prevent the possibility of ground-loop difficulties, a third needle electrode was not used for the common ground connection of the two electromyograph amplifiers. Instead, the implanted ground electrode used for the electrocardiograph amplifier also served as circuit ground for the two electromyograph amplifiers.

Each of the two electromyograph amplifiers utilized single-ended input circuitry with an effective input impedance of 100,000 ohms. The amplifiers were designed to provide a maximum voltage gain of 800 with a frequency response within 1 decibel from 10 cps to 2000 cps. The signal-to-noise ratio was greater than 30 to 1. One amplifier drove a telemetry channel with a frequency response to 650 cps, while the other amplifier drove a channel with a frequency response to 790 cps.

Body Temperature.—This measurement, which recorded the colonic temperature of the animal over the range of 90° F to 110° F, was the same type as that used in Bio-Flight 1.

Ambient Temperature.—This measurement of the capsule atmosphere temperature provided full scale telemetry output for the range of 10° C to 60° C. Because of this relatively narrow temperature span, the output of the thermistor transducer circuitry was raised to telemetering level by means of a simple direct-coupled amplifier.

Ambient Pressure.—Ambient pressure was measured with a pressure actuated potentiometer type transducer with a range of 10 to 45 psia.

Carbon Dioxide.—The device measured the concentration of CO_2 (over a range of 0 to 7.0 per cent) by means of the change in thermal conductivity of the gas mixture.

Because of the poor thermal conductivity of CO_2, its concentration affects the conductivity of a mixed atmosphere to a much greater degree than the absolute temperature, pressure, or air motion, over a reasonably small span of these variables. Fortunately, a small span could be obtained in this capsule system. Water vapor had a serious effect and was removed prior to analysis. One thermistor was exposed to the gas to be analyzed; another was in a sealed chamber and was used as a reference. The transducer was placed in a stream of slowly moving air developed by a ventilating fan. Air entering the right end of the passage was dried by moisture-absorbing material and slowed to a speed barely above stagnation. The thermistors, arranged as adjacent legs of a bridge circuit, were self-heated by the excitation voltage.

Differential heat conductivity away from the thermistors caused a change in the bridge output.

The use of thermistors as sensing elements to give the device high sensitivity had one disadvantage. Variations in the highly non-linear characteristics of thermistors introduced a thermal shift in the measurement. This shift could be offset by a third thermistor. Embedded in close thermal contact with the aluminum housing this thermistor was included in the output circuit of the bridge in such a way as to compensate the circuit over the expected ambient temperature range.

The mode of operation chosen was direct current excitation of the bridge circuitry in conjunction with a chopper amplifier and demodulator. Alternating current excitation would yield simpler circuitry in the amplifier, but the frequency would be required to be on the order of 10 kc to avoid any possible interference with other measurements. At these frequencies, reactive balance of the bridge circuit became a problem, so it was decided to use the 10 kc oscillator to drive a semiconductor chopper, operating the bridge with direct current applied. The amplifier design was fairly conventional and straightforward.

The system described will measure per cent CO_2 over the following ranges of conditions with errors less than 3 per cent of the 0-7 per cent CO_2 span: ambient temperature (transducer) 60° to 75° F, (amplifier) 0° to 50° C; pressure 10 to 45 psia.

Motion Picture Camera System.—To facilitate further the study of the performance of the animal, an inflight film record was obtained. A 16 mm motion picture camera, operated by 28 volts direct current with a consumption of about 2 amperes, was used to photograph the upper chest-head area of the animal. The total weight of the camera and magazine, exclusive of mounting facilities, was almost 18 pounds. The camera shutter operated at 16 frames per second, which for a maximum magazine capacity of 400 feet of film, permitted about 17 minutes operation. The magazine was of the "rabbit ear" type, attached to the main camera body by a centrally located knurled screw. The correct exposure for the specific type of film used (Super Anscochrome, tungsten type 226) required a shutter speed of 1/40 second per frame. This shutter speed and a lens opening for an exposure index of ASA 200 gave the maximum possible depth of field. Because of space and mounting considerations, two first-surface mirrors were required to bring the subject into the field of view of the camera. View finding and focusing functions were facilitated by a bore-sight which showed a magnified image directly through the camera lens.

There were two lighting systems in the capsule. One was a background light source which was on whenever power was applied to the nose cone. The other was the camera light which was on only when the camera was operating. Background illumination was provided by a pilot lamp mounted in the approximate center of the capsule and kept the animal from being in total darkness. This light also minimized the glare of the camera light coming on at lift-off and therefore made the films more realistic than if the animals were suddenly exposed to light after several days of total darkness.

The camera light furnished illumination for the motion picture camera. The lamp used was a 40-watt aircraft running light. It operated when the camera was running. However, there was a thermostat in the lamp circuit to turn off the light if the ambient temperature rose above 81° F. Two lamps were installed, but only one burned at a given time. The second lamp was a "back-up" lamp; that is, it came on if the first lamp burned out. A transitor switching circuit was used for this purpose.

Timing was accomplished by a digital counter which operated from a 28 volt, direct current, motor-driven clock mechanism with an accuracy of one second in two hours. It was located in the field of view of the camera next to the head of the animal and recorded running time of the camera from lift-off.

DEVELOPMENTAL AND EXPLORATORY PROCEDURE IN PREPARATION FOR THE FLIGHT

TESTS OF CAPSULE AND EQUIPMENT

As described for Bio-Flight 1, extensive testing procedures were followed for all components of the assembled flight and spare biocapsule systems. Considerable effort was expended to design and construct a pressure-tight biocapsule cylinder configuration which would withstand the physical forces of an intermediate range ballistic missile (IRBM) flight. It was necessary that the capsule and the life support systems be completely self-sustaining throughout a period of five hours before launch, the flight into the vacuum of space, re-entry, and submersion in salt water to a possible depth of 70 feet for several hours. The first requirement dictated by these conditions was that the capsule be completely leakproof. The capsule was hydrostatically tested to 22 psig to check for weld pin holes, and further tested with air upon completion. A leak in the system would permit water to enter the capsule if the nose cone were submerged, with the possibility of inactivating the absorbers and even drowning the animal. Leakage to the exterior atmosphere would cause oxygen enrichment of the internal atmosphere to an undesirable level. In addition, all electrical systems supporting the operation required special waterproofing to ensure that they would function in salt water. Finally, in the design and construction of the capsule it was necessary to ensure that the structure itself would withstand the pressure variations as well as the loads due to acceleration and deceleration.

PRELIMINARY CLINICAL AND PHYSIOLOGICAL INVESTIGATION

Because the rhesus monkey has long been used in biological and medical research and much is known about its basic physiology it was not necessary to perform extensive fundamental research preparatory to this experiment.

Clinical Studies. — A number of clinical tests were made on monkey Able prior to preparation for launch. Results of these tests were remarkably similar to those performed on two similar candidates for the experiment and within the normal range.

Hematology.—Red cell counts and hematocrit showed a significant decrease during the preflight period. White cell and differential counts showed only slight variations. These changes were attributed to rapid changes in environment from Fort Knox, Kentucky, to Cape Canaveral, Florida.

Parasitology.—The animal was found to be infested with *Trichomonas, Endomoeba histolytica* and hookworm.

Microbiology.—Blood cultures were negative for bacterial growth. Throat cultures showed the presence of alpha and beta hemolytic staphylococci, but were negative for diphtheroids. Rectal cultures were negative for *Salmonella* and *Shigella* organisms.

Physiologic and Environmental Studies.—It was necessary to establish empirically certain basal zones because of the numerous variables within the capsule which could not readily be assessed theoretically. The importance of establishing these basal zones lay in the assumption that the animal would be in an artificial environment for approximately three and one-half to four days. Tests on two nine-pound rhesus monkeys established the following values: (1) thermal neutrality under restraint: 19-25° C; (2) sudomotor neutrality under restraint: 45-65 per cent relative humidity; (3) atmospheric oxygen tension not to exceed 25 per cent at 16 psia, and (4) atmospheric CO_2 tension not to exceed 1 per cent at 16 psia.

LAUNCH AND RECOVERY PROCEDURES

Ground support of the operation at Cape Canaveral was accomplished in a mobile laboratory built in a standard 5-ton trailer. The interior was fitted with cages, storage cabinets, sinks, bench space, refrigerator, and incubator. The animals were housed in the forward section, preparation of the animal was accomplished in the center section, and restraint of the animal was performed in the rear section. Electronic and mechanical checkout of the complete capsule was accomplished in the hangar ordinarily used for checkout of missiles.

At approximately sixty-nine hours prior to launch, the animal was prepared for flight. ECG electrodes were implanted, the respiration and body temperature thermistors were attached, the infusion tube implanted and the animal was diapered. Following this, the animal was restrained in the couch and secured in the capsule. The electronics package was checked out, the capsule sealed, and pressure tested. The capsule was then turned over to personnel of the Missile Firing Laboratory for installation in the nose cone and transfer to the launching pad. A control animal was prepared exactly like the experimental animal and placed in a spare capsule. This capsule was kept in an air-conditioned room with the access door open for direct observation. A third animal was merely restrained. Neither the experimental or the control animal had been previously restrained in the capsule. Intraperitoneal infusion was given slowly every hour until eight hours prior to lift-off. Between sixty-four hours and four hours prior to lift-off the capsule of the experimental animal was air-conditioned by external means. Between four hours before lift-off until some three hours after impact, the capsule was a self-contained system.

During the sixty-four hours, prior to lift-off, colonic temperature, capsule temperature, heart rate, and respiration rate of the experimental monkey and the control monkey were recorded.

Recovery procedures began as soon as the biocapsule was exposed after the nose cone had been brought on the deck of the USS *Kiowa*. At this time a portable flushing system, using compressed air in cylinders metered at a constant rate, was connected to the biocapsule and flushing commenced. Shortly thereafter the electronic monitoring system was connected and a recording made. After the capsule had been removed from the nose cone on deck the access door was removed and the animal, still restrained on the support couch, was taken out. Release and examination of the animal was then accomplished in the laboratory facilities set up in the ship's wardroom. A preventive injection of penicillin was given at this time and food and water provided.

RESULTS

TEMPERATURE RELATIONSHIPS

Figure 15 gives the body (colonic) temperature, capsule (ambient) temperatures, heart rate, and respiration rate of Able and the control monkey prior to launch. The count-down period was tolerated well with minimal deviations from usual physiological values.

The fall in body temperature which occurred at fifty-six hours before lift-off was probably due to the fact that the intraperitoneal infusion of 5 cc. of 5 per cent dextrose was given at the same time that the recording was made, no physiologic significance can be ascribed to this change. Although a diurnal pattern could be seen in both experimental and control animals, there was very little suggestion of the occurrence of restraint hypothermia until about nine hours prior to lift-off when both animals showed some evidence of hypothermia. It was more marked in the experimental animal and some correction was obtained by raising the capsule temperature. Although the control animal had a steady and higher ambient temperature with no apparent disturbance, the experimental animal showed signs of disturbance in the early stages of countdown by a rise in cardiac rate and respiration rate every time the capsule temperature rose to levels above 23° C. The peaks of increased heart rate in the control animal appeared to correlate with the times of greatest human activity in its immediate area.

Since neither of these animals had previously experienced restraint, it was surprising that they showed little evidence of restraint hypothermia until after fifty-five hours confinement.

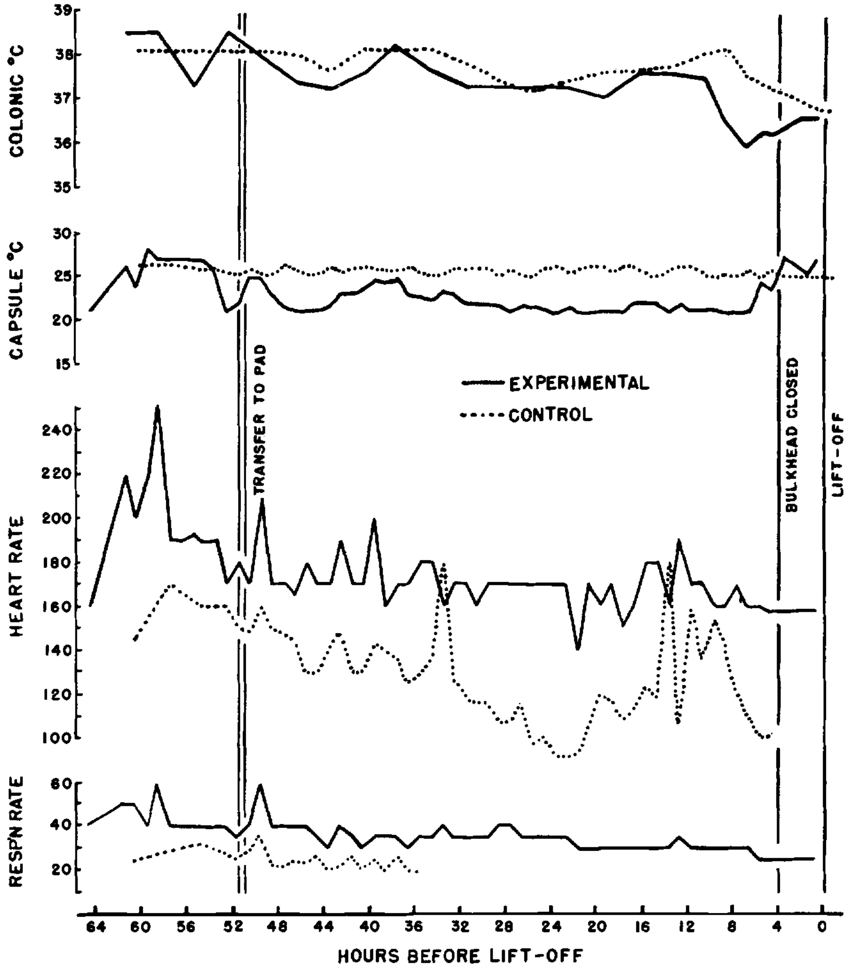

Fig. 15. Representative pre-launch data from Bio-Flight 2 Able. Physiologic and environmental measurements made during actual Able count-down are compared with data on a stand-by control animal.

The data collected during the flight are summarized in Figure 16. At the time of spin-up a shift in the telemetering baseline occurred. This artifact is observed as a simultaneous change in the baseline of the lower three curves. Taking this into account the record shows only slight variations in the body temperature, ambient temperature and ambient pressure throughout the flight.

CARDIORESPIRATORY FINDINGS

Although provision for taking the electrocardiogram was made, the ECG was not recorded beyond five hours prior to launch. Unfortunately one of the electrode wires somehow became

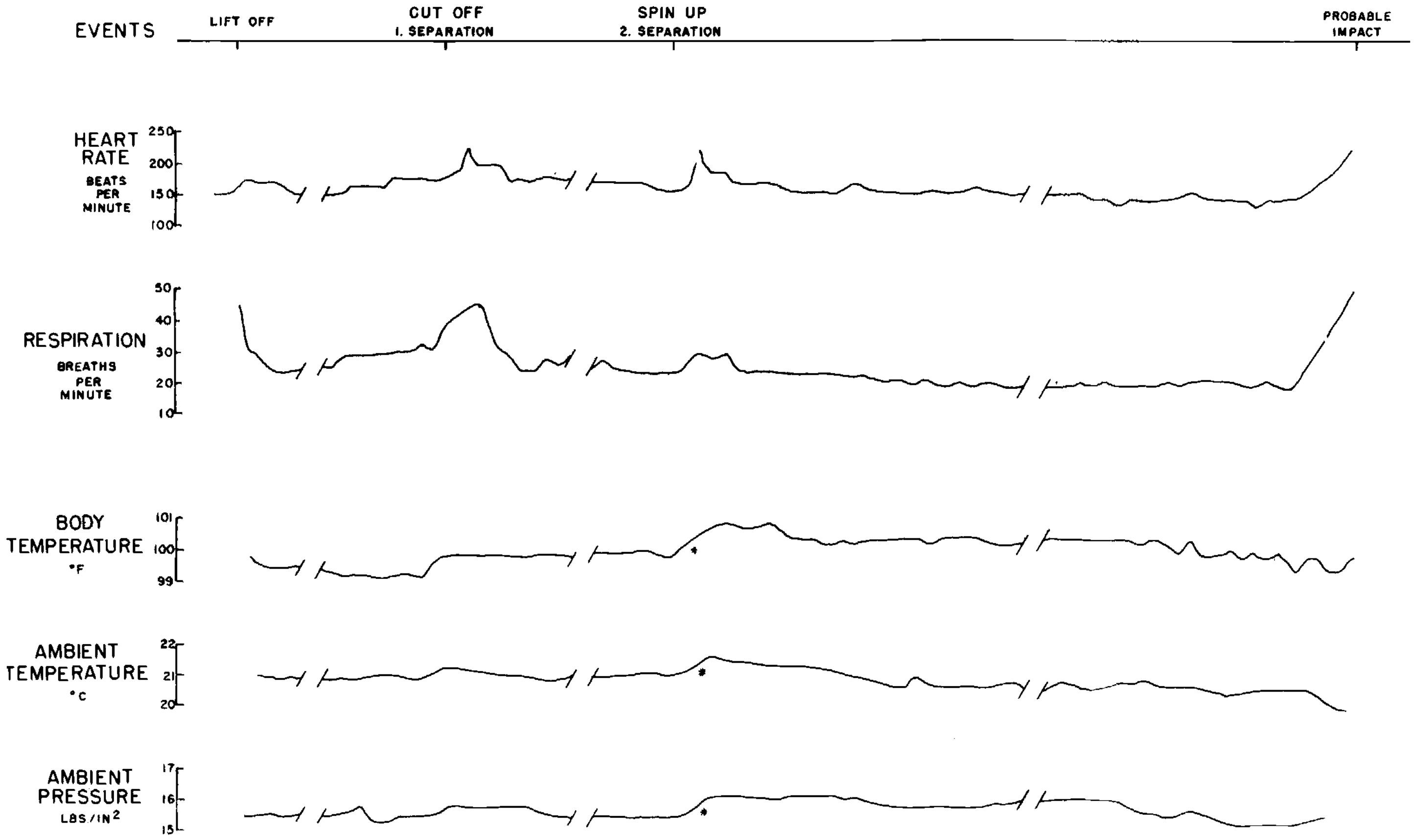

Fig. 16. Telemetered flight data: Bio-Flight 2 Able. Physiologic and environmental data shown in relation to major events of flight. Data curves have been interrupted but time scale is accurate for portions shown. The asterisk on the three lower curves locates the baseline shift at spin-up referred to in the text.

detached. This caused the amplifier to act as an oscillator with subsequent loss of signal. Beyond this point heart rate was determined from the recording of heart sounds.

The microphone over the heart picked up extraneous noise and vibrations, which, although occasionally masking the heart sounds, were useful indicators of major events in the flight. The first heart sound could usually be identified and was found to vary in amplitude with phasic variations in respiration. It was thus useful in determining respiratory rate when that signal was weak.

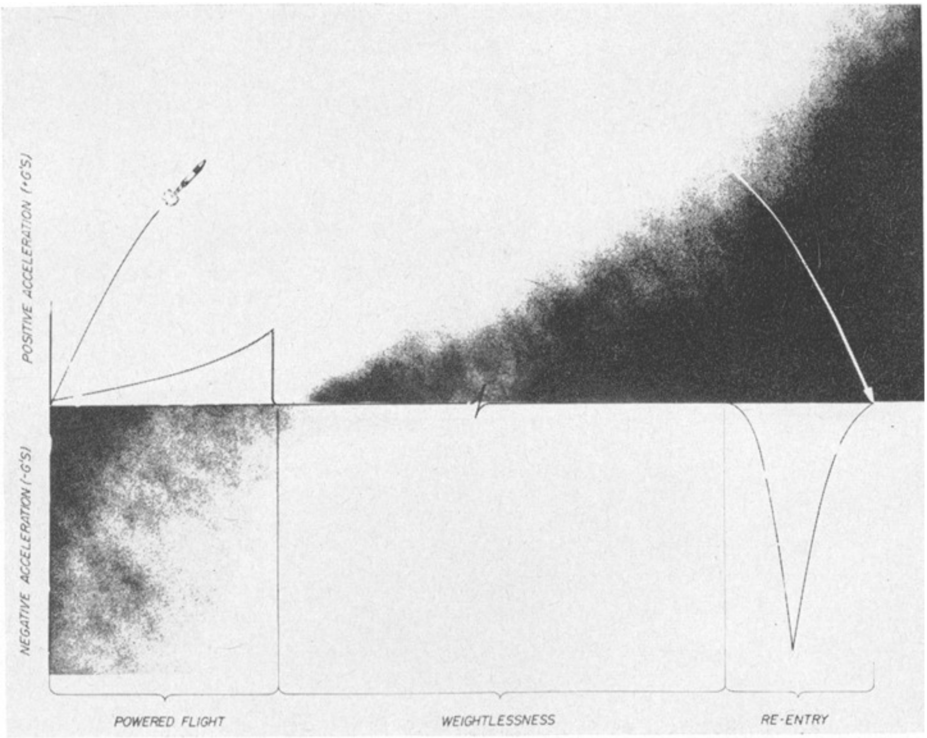

Fig. 17. Typical G curve for Jupiter intermediate range ballistic missile (IRBM) flight.

Pre-launch.—Throughout the long pre-launch period the heart rate was 170±20 and the respiratory rate 30±5. Nine hours before lift-off both rates fell paralleling a fall in body temperature. To offset the decline in body temperature, the capsule temperature was raised. At lift-off the heart rate was around 150 and respiratory rate about 27.

Transition at Lift-Off.—At lift-off the respiratory rate increased from 27 to 44 but fell to 30 within five seconds and shortly thereafter to 24. The heart sounds were obscured during the first 3.5 seconds after lift-off, after which the heart rate was 176, representing a rise of about twentyfive. Both the cardiac and respiratory rate fell during the first minute but thereafter rose.

Acceleration Phase. — Figure 17 shows the acceleration-deceleration profile of the flight. After the initial response at lift-off, both cardiac and respiratory rate rose, at first gradually, then steeply, but never reaching high levels. Respiration was regular save for two quick breaths just before cut-off. The heart sounds could not be identified with certainty during the last twenty-eight seconds of the boost phase because of increasing missile noise. The average heart rate shortly before cut-off was probably 176.

Transition at Cut-Off.—After cut-off both heart rate and respirations rose slightly, then fell; respirations returned to the pre-launch level and heart rate to levels moderately higher than pre-launch.

Periods of Zero Gravity.—Following the transition period at cut-off there was little change in the cardiac and respiratory rate until shortly before spin-up when there was a slight fall. During this interval the animal was experiencing near zero gravity, and it is worth noting that the heart sound record displayed little artifact, indicating that the animal was quiet and the environment peaceful.

Transition at Spin-up.—Inasmuch as Able was near the axis of rotation, spin-up produced only a small G-loading on the animal so that near-zero gravity conditions continued until re-entry. The response to spin-up is clearly shown in Figure 16 and consisted of a brief rise in cardiac and respiratory rate.

Post Spin-Up Period.—During this interval, there was a slight fall in cardiac and respiratory rate possibly influenced by a concomitant slight fall in body temperature. The heart sound record was quite free from artifact indicating that the animal was quiet. In-flight motion pictures, however, showed that the animal was awake. (See below).

Re-Entry Period.—There was little change in cardiac and respiratory rates until the onset of deceleration after which there was a continuous rapid rise; respiratory rates more than doubled and heart rate increased by eighty beats per minute. It is worth noting that the sharp rise and fall of the deceleration pattern was reflected only by a rise in the cardiac and respiratory curves.

Post-Recovery. — Electronic monitoring was possible two and one-half hours after impact at which time the heart rate was 144 but the respiratory rate uncertain because of low signal strength.

IN-FLIGHT PHOTOGRAPHIC RECORD

The in-flight film field of view was approximately 5 by 8 inches, the longest dimension being along the spinal axis. The head of the animal was visible plus a portion of the chest plate. Table II is a record of the movements of the animal during flight. There is some correlation between the movements and missile events.

Results of measurements of relative

humidity and the recording of the electromyograms await analysis and are not included here.

POST-FLIGHT EVENTS

Upon recovery, the animal was given a thorough physical examination and found to be in excellent condition. There were several slight abrasions on the temples where the helmet had rubbed. The animal was flown to the Walter Reed Army Institute of Research where a total body radiation count was made. Following this the animal was flown to the Army Medical Research Laboratory, Fort Knox, Kentucky, where the implanted ECG electrodes were to be removed. During the operation the animal suffered anesthetic death. Autopsy findings did not reveal any evidence of injury.

DISCUSSION

The outstanding finding of this experiment was the satisfactory condition of the animal after a long period of confinement and the stresses incidental to the flight. The count-down period of sixty-four hours, during which the animal was lying face downward and nourished with dextrose given by peritoneal injection was poor conditioning for the stresses to follow. Indeed, the count-down probably represented at least as great a stress as the flight itself.

From lift-off until impact the evidence suggests that the animal was in a satisfactory condition and was capable of responding to stimuli. Inflight movies demonstrated that the animal was active on and off throughout flight. The cardiac and respiratory rates remained at or near pre-launch values save for the variations at critical points in flight.

The initial response at lift-off, when the acceleration was very small, suggests a reaction to startle and to some extent this was a factor present during following events. However, the more sustained responses during the last portion of the boost phase and at reentry suggest the operation of physical factors as well.

TABLE II. SEQUENTIAL EVENTS AND MOVEMENT BY ABLE (FROM IN-FLIGHT FILM)

Event	Movement
Acceleration	Head back in helmet
	Intermittent swallowing
	Head movement
	Intermittent swallowing
	Head pushed far back in helmet
	Swallowing
	Gulped, appeared to cry out
	Moved head out of helmet so that eyes showed
	Blinking, swallowing
	Opened mouth, closed mouth
	Moved head, rolled eyes
Free flight	Started moving head back in helmet
	Completed moving head back in helmet
	Swallowing
	Started moving head out of helmet
	Completed moving head out of helmet
	Blinked, rolled eyes
	Started moving head back in helmet
	Completed moving head back in helmet
	Pushed head far back in helmet
	Pulled head partially back out
	Pushed head far back in helmet, then pulled head out
	Blinked intermittently
	Gradually pushed head back in helmet
	Swallowing
	Moved head further back in helmet
Spin	Abruptly pulled head out of helmet; eyes visible
	Started moving head back in helmet, completed moving head back in helmet
	Head far back, intermittent swallowing
	Rapid swallowing
Re-entry	Head far back, intermittent swallowing
	Pulled head out of helmet, head vibrating in rapid nod-like motion
	Pursed lips in characteristic manner as if hooting; being forced far into polyurethane foam
	End of film

The satisfactory condition of Able at recovery allows some backward extrapolation, and it is certain that the stresses of flight and impact were well tolerated. This statement is also supported by subsequent post-mortem findings which revealed no evidence of injury.

It is unfortunate that some of the measurements for which provision was made were unsuccessful. The difficulties arose in the bio-technical preparations and not in the telemetry system. This emphasizes the importance of using different but interrelated methods for obtaining vital measurements as insurance against loss of data; for example, although Able's electrocardiogram was lost, heart rate was obtainable from the heart sound recordings.