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ENVIRONMENTAL PHYSIOLOGY LABORATORY

RESULTS FROM THE EPL MONKEY-POD FLIGHT EXPERIMENTS CONDUCTED ABOARD THE NASA/AMES CV-990, MAY 1976

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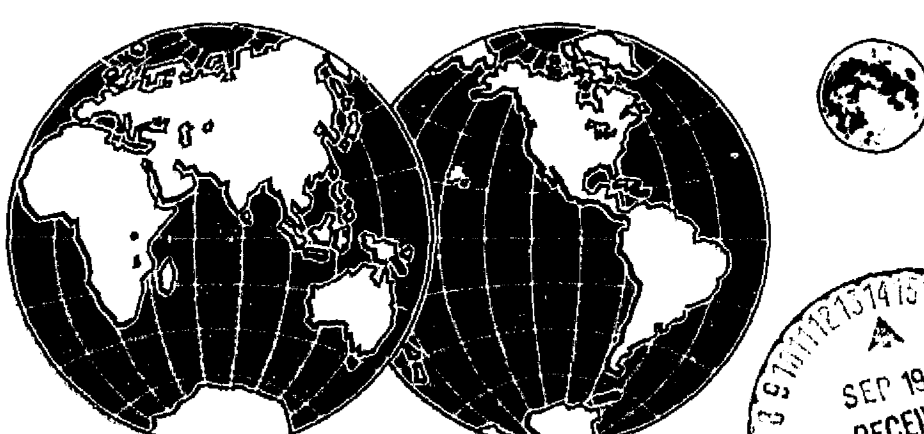

UNIVERSITY OF CALIFORNIA - BERKELEY

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RESULTS FROM THE EPL MONKEY-POD FLIGHT EXPERIMENTS CONDUCTED ABOARD THE NASA/AMES CV-990, MAY 1976

Work performed under NASA Grant NGL 05-003-024

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30 July 1976

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1.0 Introduction and Purpose of Report

This report documents the participation of the Environmental Physiology Laboratory (EPL) of the White Mountain Research Station (WMRS), University of California, Berkeley (UCB) in the preparation for and the conduct of Monkey Pod experiment flights within an aircraft on an operational mission, the NASA CV-990 airborne laboratory, "Galileo II" based at the Ames Research Center, Moffett Field, California.

2.0 Applicable Documents

Semi-Annual Status Reports 18-27, 1 August 1970 to 31 July 1975, NGL 05-003-024.

NASA CV-990 Airborne Laboratory Experimenters' Handbook prepared by Staff, Airborne Science Office, NASA Ames Research Center, Moffett Field, California 94035. April 1973.

Galileo II Data System. Prepared by Robert M. Munoz, NASA Ames Research Center, Moffett Field, California 94035. November 6, 1973.

EPL 74-1. Results from the EPL Monkey Pod Experiment Conducted as Part of the 1974 NASA/Ames Shuttle CVT II. Report prepared by D. F. Rahlmann, A. M. Kodama, R. C. Mains and N. Pace. 10 June 1974.

EPL 74-2. Results from the EPL Monkey Pod Experiment Conducted as Part of the 1974 NASA/MSFC CVT/GPL III. Report prepared by D. F. Rahlmann, A. M. Kodama, R. C. Mains and N. Pace. 15 October 1974.

A Monkey Metabolism Pod for Space Flight Weightlessness Studies. Pace, N., D. F. Rahlmann, A. M. Kodama, R. C. Mains, and B. W. Grunbaum. In: COSPAR Life Sciences and Space Research XII, P.H.A. Sneath, editor. Akademie-Verlag, Berlin, 1974, pp. 149-157.

Physiological Studies in Space with Non-Human Primates Using the Monkey Pod. Pace, N., D. F. Rahlmann, A. M. Kodama, R. C. Mains and B. W. Grunbaum. Presented at the Non-Human Primates in Space Conference, NASA Ames Research Center, 2-4 December 1974.

A Multichannel Implantable Telemetry System for Flow, Pressure and ECG Measurements. Fryer, T. B., H. Sandler, W. Freund, E. P. McCutcheon and E. L. Carlson. J. Appl. Physiol. (in press).

Power Sources for Implanted Telemetry System. T. B. Fryer. Biotelemetry 1: 31-40, 1974.

Skids for CVT GPL Mark II. PF04(74-163) To Ames Research Center Attn: Code LF/Dr. Richard D. Johnson from PF04/Manager, CVT Project Office MSFC.

Proposal for a CV 990 Systems Interface Test and Procedure Analyses of the Monkey Pod Restraint, Support Equipment and Analyses Electronics. B. D. Newsom and D. F. Rahlmann, July 1975.

Spacelab Simulation Tests Procedures. B. M. Elson. Aviation Week & Space Technology, 14 July 1975.

NASA Testing Delayed Flap Approaches. B. M. Elson. Aviation Week & Space Technology, 1 Dec 1975.

A Urine Collection Device for Use with the Male Pig-tailed Macaque. D. F. Rahlmann, R. C. Mains and A. Kodama. Lab. Animal Sci., 1976 (in press).

SSO: 211-12 Letter to Prof. N. Pace, Director of the White Mountain Research Station, University of California, Berkeley from C. L. Muehl, CV 990 Facility Manager NASA/ARC, Moffett Field, California.

EPL Documentation Files and Log for Monkey Pod-CV990 Interface Test. 1976.

Strip Chart Records, Tape Recordings and ADDAS Printouts from CV 990 Flights. May 1976.

An Inductively Powered Implantable Multichannel Telemetry System for Cardiovascular Data. E. P. McCutcheon, R. Miranda, T. B. Fryer and E. L. Carlson. 3rd Int. Biotelemetry Cong., Pacific Grove, CA, 1976.

3.0 Background

3.1 Interaction between EPL/UCB and NASA/ARC 1974-1975

As an outgrowth of activity between the University of California and the National Aeronautics and Space Administration, Dr. Donald F. Rahlmann, Environmental Physiology Laboratory, University of California, Berkeley (EPL/UCB) accepted an assignment to the NASA Ames Research Center (NASA/ARC) under the Intergovernmental Personnel Act of 1970. This interchange in part involved coordinating the completion of a second monkey pod and investigating the possibility of life sciences participation in the ASSESS program. In addition, his presence afforded the opportunity for incorporation of biotelemetry-implanted monkeys into the monkey-pod experiment system.

On 28 January 1975, an adult male pig-tailed monkey #396, Lovel was shipped from EPL/UCB to NASA/ARC as a potential surgical candidate for the chronic implantation of a cardiovascular telemetry device which derived its power input from an exterior energizing coil rather than batteries, thus prolonging its useful life. Following an appropriate quarantine, this monkey was successfully implanted on 23 February 1975 under the direction of Dr. E. McCutcheon of NASA/ARC. Through the months of March 1975 to April 1976 electronic checkouts were made on the T/M monkey system. On two occasions during this time period the test subject was restrained within the EPL/UCB pod and electronic signals for left-ventricular pressure (LVP), aortic pressure (AP), electrocardiogram and hear rate were obtained, and these parameters were recorded on strip chart.

With the experience gained from this initial non-human primate trial, some design modifications were made in the T/M device and a second monkey, #337, Simple was shipped from EPL to NASA/ARC on 17 July 1975. This monkey was considered as an excellent candidate for T/M implantation, having participated in monkey-pod trials at EPL/UCB and Shuttle Spacelab Concept Verification Tests at NASA/ARC and NASA/MSFC. Associated parallel efforts at EPL/UCB included modifying bioinstrumentation of the monkey pod system to allow commutation of data acquisition between two pods, a method for obtaining timed urine samples uncontaminated by feces, and extending continuous pod tests to 15 and 30 days duration. The second monkey pod was delivered to EPL/UCB following completion of fabrication at NASA/ARC, bench tested, and finally incorporated into a two-pod integration test.

On 7 November 1975, EPL/UCB representatives were afforded the opportunity to fly on the CV-990 during a Delayed Flap Program flight, consisting of a route from Moffett Field to Sacramento with 9 landings and takeoffs at

Sacramento and returning to Moffett Field. Professor Nello Pace and Mr. R. C. Mains of EPL/UCB conferred with Mr. C. Muehl, NASA/ARC CV-990 facilities manager, and compiled notations which would have a potential impact on a monkey-pod experiment conducted within the framework of a similar flight pattern.

3.2 Preparation and Submission of Proposal

Contacts with the Airborne Science Office of NASA/ARC were made by Dr. B. D. Newsom, Scientific Monitor at ARC for the EPL/UCB grant. With the assistance of the IPA representative from EPL, Dr. D. F. Rahlmann, additional information was obtained in regard to the preparation of a proposal for this purpose. This activity included gaining a knowledgeable acquaintance with the "NASA CV-990 Airborne Laboratory Experimenters' Handbook" and on-site visits to building N-211 Flight Support Facility at NASA/ARC, where preparations for various experiments on aircraft are carried out. On 10 January 1975, life scientists, Dr. H. Sandler, B. D. Newsom, R. Johnson from NASA/ARC, and D. F. Rahlmann from UCB met with Mr. D. Mulholland, then Chief of the Airborne Science Office (SSO) and 6 members of his staff to discuss the feasibility of a monkey pod flight.

Considering the concept, size and procedural protocol of a multiple-pod monkey trial, the CV-990 appeared to be the aircraft of choice rather than a Lear Jet or a C-141. It was anticipated that one or more of the trial subjects would be implanted with biotelemetry units. Initial flow diagrams, schedules and interfacing plans of the pod within the aircraft were compiled. A document entitled "Proposal for a CV-990 Systems Interface Test and Procedure Analyses of the Monkey Pod Restraint, Support Equipment and Analyses Electronics" authored by B. Newsom and D. F. Rahlmann was completed in July 1975 and submitted for approval through appropriate NASA channels.

3.3 Interim Activity and Meetings Prior to Flight Instrumentation Build-Up, 1976

Approval for the monkey-pod flight experiment proposal was received in the final quarter of 1975. Under date of 30 January 1975, a letter to Professor Nello Pace, Director of the White Mountain Research Station from C. L. Muehl, CV-990 Facility Manager at NASA/ARC, indicated that the monkey-pod system would be scheduled for flights in May 1976. During the following week a standard 2-bay "highboy" instrumentation rack was received at EPL/UCB. On 9 February 1976, Dr. B. Newsom, C. Muehl and S. Kurasaki, aerospace engineer of NASA/ARC, met with the EPL scientific team on the UCB campus. With the aspects of air worthiness in mind and a shortage of mechanical and electronic expertise at EPL needed to efficiently accomplish the instrumental transition from ground based laboratory to aircraft, it was decided to center this activity at Bldg. 211 NASA/ARC. Meetings were held at NASA/ARC with Mr. S. Kurasaki, responsible for mechanical interfacing, and Mr. J. Connally, responsible for the electronic portion of experimental build-up.

3.4 Movement of EPL Major Equipment and Test Subjects to NASA/ARC

On 11 February 1976 a contract hauler moved the EPL instrumentation racks to NASA/ARC. The potential test subjects, #337, Simple, shipped to NASA/ARC on 17 July 1975 (Para. 3.1) was surgically implanted with a T/M device on 24 March 1976; #422, Bushy, was shipped to NASA/ARC on 17 March 1976 and surgery performed on 6 April. Both of these monkeys were considered to be flight candidates. For initial checkout of electronic equipment #396, Lovel was also available. A control monkey, #174, Exeter, was selected from the EPL/UCB colony to be the non-surgically implanted control subject and was transferred to NASA/ARC 21 April 1976. All of the subjects had previous pod restraint experience.

4.0 Pre-Flight Experiment Operations

4.1 Flight Schedule and Integrated Experiment Procedures

During the latter part of April 1976 an activity schedule of the Delayed Flap Program flights for the CV-990 was presented to the experimenters by C. Muehl, CV-990 facility manager. It was understood that cancellations could occur and exact times of takeoff and return might vary between flights. However, standup meetings conducted in the N-211 Airborne Science Laboratory would be held each morning at 0815 hours which would more precisely define the daily activities in regard to the aircraft.

The Delayed Flap Program flights where a portion or all of the monkey-pod experiment system could be on board were indicated to be within a time frame from 3 May to 21 May 1976. Three flights per week were scheduled. Within the constraints of the proposed aircraft activity, a daily schedule was formulated with a preliminary estimate of a nominal 1000 takeoff time. The daily schedule is included in this report as Appendix A.

Detailed protocols were also compiled for the varied aspects of the total experiment. Appendix B contains the step-by-step procedures for insertion and removal of the test monkey from the pod enclosure, for on- and off-board loading of the pods, and for positioning of the pods for application of lower body negative pressure (LBNP). Insertion of the test subjects into the pod was planned for Monday, with removal and transfer to a cage environment on Friday following the last flight of each week. Pre-flight calibrations required for measurement of respiratory gas exchange and certain cardiovascular measurements are shown in Appendix C. Appendix D contains the procedural steps which needed to be taken for the respiratory gas-exchange instrumentation during ground to aircraft power transition, in-flight data collection, and shut-down.

Starting operations on the respiratory gas-exchange instrumentation are outlined in Appendix E. The calibration of the respiratory gas-exchange instrumentation and its integration with the data-acquisition network of strip-chart recording, tape recording and the ADDAS computer are detailed in Appendix F. While a detailed discussion of the biotelemetry system will be found in another report to be submitted by NASA/ARC, an outline of its operation is shown in Appendix G.

EPL/UCB generated the initial data-recording requirements for the experiment, as shown in Table 1. Plans for the experimental module internal airworthiness buildup and integration into aircraft racks are considered in paragraph 4.3 to 4.3.6.

4.2 Plan for Experimental Layout in Aircraft

The monkey-pod experiment system was nominally to occupy space within the aircraft over and aft of the wing section. A floor plan is shown in Figure 1. The position of the various elements of experiment system were located as follows:

1) Two monkey pods mounted in a rack on the port side of the aircraft (STA 970-1015) comfortably restrained the test subjects, 2 adult, male, pig-tailed monkeys. One of the monkeys (inboard) was surgically implanted with a telemetry device developed at NASA/ARC which measured heart rate, aortic pressure, left ventricular pressure, and body temperature. Heart rate from the other monkey, serving as a control, was obtained by body surface ECG electrodes. Both pods were identical in all other respects in that they were divided into an upper and lower portion by a rubber membrane. Thus, excreta could be collected for subsequent analysis even in the weightless state, without contamination of the upper pod. The upper pod allowed each test monkey to breath fresh cabin air. The exhaust atmosphere from the upper pods was measured continuously by mass spectrometer for oxygen, carbon dioxide, nitrogen and water vapor, and was discharged into the aft cargo bay. The difference in the gas concentration

between the inflowing and outflowing air stream permitted an accurate estimate of the metabolic rate of the monkey. Food and water were accessible to the monkeys on demand. In addition, provision was made to tilt the test subjects from the vertical to the horizontal position for application of lower body negative pressure.

2) Mounted to the immediate rear (STA 1027) of the monkey-pod subsystem was the UCB bioinstrumentation rack interfaced with appropriate gas and electronic lines. This highboy rack contained the mass spectrometer with controls for continuous measurement of the metabolic gases, devices for measuring upper- and lower-pod temperatures and pressures, air flow controls, voltage regulator controls for the application of lower body negative pressure (LBNP), a test for cardiovascular deconditioning, a water reservoir, nutrient intake indicator and signal conditioners [illegible] interfacing with the data recording system.

3) Immediately [illegible] the UCB bioinstrumentation rack operator and observer seats, was a CP 100 analog tape recorder (STA 1118) mounted on a lowboy rack.

4) A highboy rack (STA 1177) to the rear of the tape recorder contained the instrumentation for the NASA/ARC telemetry data acquisition. This rack made provision for mounting an oscilloscope, power supply, digital voltmeter, demodulator, F/M receiver and strip-chart recorder.

5) Across the aisle on the starboard side (STA 1027) opposite the UCB bioinstrumentation rack a standard highboy rack was located which contained a strip-chart recorder for the data output of respiratory gas-exchange and cardiovascular parameters.

The vacuum pumps associated with the UCB bioinstrumentation rack (element 2 above) and the monkey pods (element 1 above) were positioned in the aft cargo bay (STA 1249-1297). If needed, the access hatch between elements 3 and 4 could be utilized for servicing. Calibration gas bottles were not placed on board the aircraft as originally planned.

4.3 Experiment Module Interfacing

4.3.1 Monkey Pods

4.3.1.1 Monkey Pods - Mechanical

The design requirements for the pod stands and rack were furnished by EPL/UCB personnel to Mr. Seth Kurasaki, the cognizant project aerospace mechanical engineer. This input included sketches, direct verbal communication, access to assembly drawings of the updated version of the Mark III pod generated by the Flight Experiment Office at NASA/ARC and direct observation and handling of the pod shells (designated for this experiment as #1 and #2). The #1 pod has been identified in other reports as Mark III-1 which was completed at NASA/ARC during 1975. Unfortunately while in the sheet metal shop at ARC a crack developed in the upper pod rim. However, this condition was corrected and restored to better than original strength by replacing the balsa wood core in this area with fiber glass. The #2 pod (Mark III) was the one which was completely fabricated at EPL/UCB prior to 1975. This pod had to be modified to provide fiber glass bosses to allow air venting on the right and left sides. The fiber glass additions in both cases were made by the Model Shop in Bldg. N-212.

As an initial result of the above action, 9 engineering fabrication drawings were made under the direction of Mr. Kurasaki. A detailed list of these drawings is shown in Table 2. While most of the drawings lose some detail when reduced to 8.5 x 11 inches for purposes of this report, the main installation drawing (Identification No. A 57127602 M009) is shown as Figure 2.

The 2-pod rack remained in position secured to the interior of the aircraft during the test period. Each monkey pod with attached stand could be positioned in this rack, removed from the rack when desired and conveniently transported to other locations on- or off-board the aircraft. While the pods were mounted within the rack, the monkey pod could be positioned either in the vertical or horizontal position by means of appropriately placed .250-inch diameter quick-release pins.

As in previous tests, the feeder was mounted within the upper pod shell. However, the constraints of the aircraft dictated a reduction in dimensions of the water reservoir and, for the purposes of this test, the reservoirs were placed on top of the bioinstrumentation rack (refer to paragraph 4.3.2.1) and interfaced by connecting fluid lines to metal nipples mounted in the upper pod sections.

Provision for a television camera to be mounted in front of the monkey pods or a seat facing aft to observe and monitor behavioral activity was requested by the EPL/UCB experimental crew. However, this was not provided because of safety considerations and the limited time and cost restraints for which other aspects of the project received priority.

4.3.1.2 Monkey Pods - Electronic

Mr. James P. Connolly of NASA/ARC was designated as the cognizant project electronics engineer and as such had considerable interaction in all the elements of the total monkey-pod experiment. The main electronic considerations in regard to the pod subsystems were with the activation and transmission of signals from the feeder, waterer, and temperatures from upper and lower pod. The major portion of the electronic expertise was utilized with other elements of the experimental package and in the interfacing of all elements including the pods, and will be considered in more detail in following paragraphs.

4.3.2 EPL/UCB Bioinstrumentation Rack

4.3.2.1 Mechanical

Preliminary sketches were compiled by Dr. A. M. Kodama and Mr. R. C. Mains of EPL/UCB for accommodating the modular components in a standard highboy rack to provide efficient access to hand controls, and to comply with air worthiness considerations by mounting the heaviest components near the bottom of the rack to reduce the overturning moment. Several changes were made in the orig'nal concepts following consultation with Mr. Seth Kurasaki. Special shelv.. and bracketry were also fabricated by the NASA/ARC Metal Fabrication Shop. Some delays were encountered in the procurement of the correct shelves and bracketry which impacted on the electronic work and hence on the projected time schedule allowed for the completion of the air worthiness of this instrumentation rack. Thus it was not put in place aboard the aircraft until Saturday, 8 May 1976. The final dimensions, including weights of the modules associated with this rack, are shown in Table 3. The weights distributed with the inboard and outboard bays are well within the limits specified in the NASA CV 990 Airborne Laboratory Experimenters' Handbook (Section 5.3.2.).

4.3.2.2 Electronic

In the transfer of the instrumentation modules to the aircraft racks all the power cabling, with the exception of the lines to the vacuum pumps located in the cargo bay, was installed as in the EPL laboratory model. However, it was estimated that signal cables associated with the respiratory gas instrumentation had to be 90% replaced and all of the wiring for lower body negative pressure (LBNP) plumbing and controls completely redone. The vacuum pumps used in the laboratory for LBNP were considered a fire hazard on the aircraft, and considerable time and effort was consumed in attempting to provide suitable substitutes.

Approximately 2 months prior to the first scheduled flight the ARC aircraft electrical inspector indicated that the existing LBNP pump and voltage controller would not pass aircraft electrical inspection. Both items were deemed unacceptable because of the possibility of sparking. An attempt was made to find a substitute LBNP pump both within and outside of ARC. Three pumps were obtained for testing: a 28 VDC axial, a 28 VDC three-phase, and a 110 VAC single-phase centrifugal type, all supplied by ARC. All 3 pumps subjectively appeared to provide less airflow and have less capability to develop a significant pressure differential than the original LBNP pump, but this comparison was made difficult because of large differences in pump orifice sizes.

After consultation with ARC electrical and mechanical engineering staff, it was decided that 2 of the 28 VDC axial pumps mounted in parallel might provide enough capacity to conduct the LBNP test. A manifold system which provided a single inlet and outlet was designed and fabricated at ARC. A 28 VDC power supply was adapted so that output voltage to the pumps could be controlled from 0 to 28 VDC. This system, during testing, was able to produce only about 10% of the pressure differential produced with the original LBNP pump; consequently, approval was obtained to use the original LBNP pump and voltage controller on the CV-990 for ground-based LBNP tests. The aircraft-approved 28 VDC pumps were mounted in the UCB bioinstrumentation rack and used during flight to simulate an LBNP test and verify the adequacy of the electrical power and data interface for this subsystem. For the CV-990 flights a new 2-pod LBNP control panel was designed and fabricated, which provided for the independent application of LBNP or fixed flow rate ventilation to the lower half of either pod as desired. These factors and the delay in delivery of appropriate shelving and bracketry caused an additional last-minute rush to complete the wiring in this rack.

An additional module not incorporated in the EPL bioinstrumentation laboratory rack was the signal conditioners interfacing the sensed physiological parameters with the data acquisition system of strip-chart recorders, the CP100 14-channel analog tape recorder, and the airborne digital-data acquisition system (ADDAS). While the commutation of information from 2 pods had previously been demonstrated at EPL/UCB, the measurements of respiratory gases were multiplexed for one channel input for the strip chart and tape recording, while the ADDAS received these signals separately. The signals were identified by code to indicate from which pod they originated. A 6-channel multiplexer was also incorporated for temperature measurements: (1) M/S inlet temperature, (2) upper pod #1, (3) lower pod #1, (4) upper pod #2, (5) lower pod #2, and (6) for reference and calibrations.

The total number of parameters identified by the signal conditioner are listed in Table 4. Table 5 shows the distribution of the data to ADDAS, the CP-100 tape recorder, and the 2 Brush strip-chart recorders.

4.3.3 EPL/UCB Data Acquisition Rack

4.3.3.1 Mechanical

Table 6 contains the list of modular components included in the EPL/UCB Data Acquisition Rack (Standard Highboy). The Tektronix R-4010-1 console, an ADDAS teleprinter with keyboard, was mounted initially in this rack t during the course of the flights was removed for use on another experimental aircraft. No untoward complications arose as a result of mounting this equipment. The total weight of these modules were within recommended limits. Bracketry for the recorder and strapping for the packaged Gould Brush Couplers were fabricated by the sheet metal shop. Although chart paper pickups were available, they were not mounted on the recorders due to time limitations. The strip-chart recorders were mounted in the outboard bay at a height where a seated experimenter could reasonably make notations on the chart paper during flight.

4.3.3.2 Electronic

Cabling from the signal conditions in the EPL/UCB bioinstrumentation rack provided the interface with the EPL/UCB Data Acquisition Rack. Problems were encountered in the multiplexed temperature recordings, particularly in regard to the reference temperature which drifted in relationship to the ambient temperature within the aircraft.

4.3.4 NASA/ARC Tape Recorder CP-100

4.3.4.1 Mechanical

The Ampex CP-100 analog tape recorder was mounted on a lowboy rack in the manner shown in Figure 5.2.g of the Experimenters' Handbook. This instrument weighed 97.6 kg and measured 84x48x31 cm. No preflight mechanical problems were experienced, as this device had a reliable history of flight aboard the CV-990.

4.3.4.2 Electronic

Fourteen channels of physiological data with provision for voice recording were planned as outlined in Tables 1 and 5. Provision was also made to identify portions of the tape for playback and comparison with Brush strip-chart recording.

4.3.5 NASA/ARC Biotelemetry (T/M) Data Acquisition Rack

4.3.5.1 Mechanical

The dimensions of the modular components of the NASA/ARC biotelemetry system are shown in Table 7. No untoward difficulties were encountered with the shelf-mounting, bracketry or placement within a standard highboy rack.

4.3.5.2 Electronic

A summary of the operational aspects of this system is shown in Appendix G. A more detailed description of the system and its operation will be found in other reports resulting from the flight experiment.

4.3.6 Input to ADDAS Computer

Several meetings were held with representatives from Informatics, the contractor responsible for the operation of the CV-990 computer. Mr. Don Wilson of Informatics assigned Mr. Steve Nelson to write to program needed to accomplish the experiment data objectives. Mr. Jim Connally of NASA/ARC maintained close liaison between the experimenters and Informatics to assure the electronic integrity from signal conditioners to the data acquisition systems. EPL/UCB experimenters submitted detailed information in regard to their measurement and computer printout requirements. This input is shown in Appendices H through M for the on-line computation and data reduction for the RGE measurements (H), mass spectrometer inlet pressure and upper pod pressure (I), on-line computation of lower pod pressure (J), mass spectrometer inlet, upper and lower pod temperatures (K), heart rates (L), and nutrient intakes (M).

5.0 Performance

5.1 Monkey Pods

5.1.1 Insertion Procedures

The procedures for insertion of the test subject in the couch and pod were outlined in Appendix B, and for the purposes of this test were initially carried out on the T/M implanted monkey #337, Simple, 5 May 1976 in Bldg. 236. The restrained monkey and pod were then transported to the Airborne Science laboratory in Bldg. 211, where they remained ready for flight participation. The same procedures were performed for 2 monkey test subjects, #337, Simple (T/M implant) and #174, Exeter (skin ECG leads) serving as a control on 10 May 1976 and again on 17 May 1976. Three people were involved in this activity, Dr. D. F. Rahlmann and Mr. R. C. Mains of EPL/UCB, and a NASA/ARC representative, either Mr. R. Miranda or Mr. G. Hoggess. Mr. N. Donnelly of Northrop, NASA/ARC contract support acting as an observer, and Mr. R. Carnahan of the Photo Technology Branch, NASA/ARC were present on several occasions.

In general, the assembly of parts and insertion of the test subjects proceeded without major difficulty. For several weeks the 4 available test subjects had consumed food rations in excess of maintenance requirements. As a result, #337, Simple in particular was extremely obese in relation to his overall stature. Despite this condition, the mid-piece subassembly and the restraint jacket were able to accommodate his abdominal dimensions. The placement of the external T/M energizing coil for #337, Simple was carefully monitored electronically during the insertion procedures to provide the optimum location between the jacket and the external thorax. Thus, the T/M monkey took slightly longer to enclose completely in the pod than did the control animal with cutaneous ECG leads.

From preliminary post-surgical evaluations of all the biotelemetry implanted monkeys referred to in Table 8, #422, Bushy (designated as #604 by NASA/ARC) was considered to transmit the best quality signals. It was planned to utilize this animal in the last week of the flight series when all experiment systems would potentially be in full operation. However, on 17 May 1976, when this animal was scheduled to be inserted in the pod, an area of infection requiring clinical care was noted on the thorax near the surgical wound. It was deemed advisable to delete this animal from the experimental schedule. #337, Simple was again placed in pod restraint for this flight period.

5.1.2 On-board Installation

Prior to each flight the monkey pods were separated from the ground based laboratory environmental support apparatus in the Airborne Science Laboratory. The support consisted of water and food reservoirs and provision for air exchange in the upper pod. Air flow for the lower pod was also available but it was not used during the experiment, as excreta odors were minimal. Urine was removed from the collection bag each morning at 24-hour intervals prior to movement of the pods to the aircraft.

Although a preliminary schedule of estimated takeoff times was issued, it was not known precisely when the events would occur until the "stand up" meetings held each morning at 0815 in the Airborne Science Laboratory. It was also advantageous to move the pods on board at a time which would minimize the possibility of prolonged environmental changes due to power outs, pre-flight activity of support personnel, and cabin temperature build up while the doors were still open on the aircraft. In addition, the majority of the instrument calibrations associated with the monkey pod system could be made without the pods installed on board. Therefore, movement of the pods to the aircraft was scheduled to correspond as close as possible to door closure which, in turn, was approximately 0.5 hour before takeoff.

Upon reaching this milestine, the pods were placed on platform dollies and then loaded onto a forklift vehicle and moved to the aircraft. The location of the aircraft at this time varied with each scheduled flight day, being either within the Bldg. 211 hangar or just outside on an adjacent ramp. In both situations, the time on the forklift did not exceed 5 minutes. As an emergency backup, an EPL/UCB furnished, lightweight, foot-controlled air pump with line attachment was available for pod use at all times. The device was not used during the course of these trials as the maximum time period where air flow to the upper pod was not provided never exceeded 20 minutes.

Pod loading on board was accomplished through the aft cabin door with the designated outboard position pod entering first, dollied forward in the aisle, and secured to the rack. The inboard pod was then secured in a similar manner. Two trained and skillful employees of the aircraft metal shop were instrumental in the accomplishment of the task of loading and securing the monkey pods aboard the aircraft.

5.1.3 During Flights

As a result of preliminary meetings, it was deemed advisable to check out the biotelemetry system for any aircraft electronic interference, and this was done satisfactorily during a preliminary flight on 30 April 1976. The pods, without test subjects and secured in the pod rack, were also subjected to a mechanical engineering check-out flight on 4 May 1976. The pods, while in flight, were adjusted to both the horizontal and vertical positions without difficulty, and all requirements for the pod in-flight hardware specifications were deemed to be adequate.

Two flights with one pod and a telemetry implanted monkey followed on 6 and 7 May. When the EPL/UCB instrumentation rack was finally installed aboard the aircraft, 2 monkey pods with test monkeys (one control and one T/M implanted) were flown on 11, 13, 17, 19 and 21 May 1976.

A summary of the monkey-pod experiment CV-990 flights is shown in Table 9. Appendix N contains a copy of the flight plan for 21 May 1976, in which zero-*g* maneuvers were executed.

Throughout the total flight activity involving more than 50 takeoffs and landings, the monkey pod as an element of the total experiment package incorporated in an aircraft on operational mission functioned well. A few of the specifics in relation to operation and performance are noted below:

a) No delay in on-board loading of the pods with experimental monkeys was noted. The pods were ready for transfer without interfering with other flight operations, even though non-experiment related, last-minute, schedule changes occurred each day.

b) It was demonstrated that the monkey pods provide a comfortable and feasible restraint device for a non-human primate that can be used as a surrogate for man in investigating aerospace-related physiological phenomena.

c) Safety aspects of the pod were evident, both with respect to the test subjects themselves, and in relation to the immediate attendant personnel. In addition, visitors to the area, either in the ground-based laboratory or on board the aircraft with little or no knowledge of biology were able to be in proximity to the animals with minimal impact on the experiment. While it is realized that constraints on the presence of humans during the performance of certain aspects of a controlled physiological experiment may be necessary, it is also evident that emergency situations can arise which may involve the interaction of inexperienced personnel with the test subjects, and which could be remedied without trauma to person or animal.

d) Trouble-shooting of pod experiment-module malfunctions proved to be feasible without removal of the monkey. As an example, the feeder jammed during a portion of the test period. As presently designed, this subsystem requires the separation of the upper pod hood for installation and most major repairs. This was accomplished with both pods on several occasions in the ground laboratory area after all other approaches had been tried without corrective results.

The following notation is a record of this activity.

Date	Monkey	Time of Hood Removal	Remarks
12 May	#174, Exeter	1400-1550	Mechanical malfunction feeder -- removed, cleaned, air-dried and replaced.
	#337, Simple	1500-1610	Feeder cleaned and replaced.
13 May	#174, Exeter	0830-0950	Inspection of feeder mechanism. Monkey hand-fed while hood removed.
18 May	#174, Exeter	0850-1205	Lightly tranquilized with Ketamine(R) HCl (60 mg) I.M. and subcutaneous ECG leads refurbished.
20 May	#337, Simple	0845-1145	Feeder electronic check.

e) Collection of 24-hour, clear, uncontaminated urine samples was made from both test monkeys by a method which feasibly should function in a weightlessness environment. Further discussion will be found in paragraph 6.6, Excreta Collection and Handling, under the test results of this report.

f) Tilting of the pods within the aircraft-mounted rack was accomplished without difficulty on the ground and in flight. Landings and takeoffs occurred while the pods were in either the horizontal position where increases in the $\pm G_z$ direction were experienced, or vertically with an increased $+G_x$ load. Components of the pod and interfacing electronic, gas, and water lines remained integrally sourd in both these situations, as well as during short periods of weightlessness.

5.2 EPL/UCB Bioinstrumentation Rack

5.2.1 During Flights

Power supplied to this rack from Station 17 was single-phase 60 Hz 115 VAC aircraft source. An internal power supply located within the rack, as shown in Table 3, provided direct current for the M/S control unit, calibration gas solenoid valves, the 4-way valve and 2 heating tapes. This power supply was set at 25 VDC. All other components operated on alternating current.

While it was noted that the 4-way valve for alternately sampling the upper-pod exhaust gases vibrated considerably when takeoffs and landings were executed by the aircraft, it continued to function satisfactorily throughout the test period.

During flight, the protocols shown in Appendices H and I were followed for operating the respiratory gas exchange modules. The signal-conditioner system was not switched on until all the modules, including the mass spectrometer, were in an operating mode. Conversely, the signal conditioners were switched off prior to shut-down of the respiratory gas-exchange apparatus.

The signal-conditioner module carrying the transmission of the mass spectrometer inlet pressure data (parameter #6) had to be powered after the remaining modules were switched on due to an apparent incompatibility with the mass spectrometer electronics. If this sequence was followed, no interference with other parameters was noted and reliable signals were obtained. Corrective action attempted by electronic support personnel during the course of these trials failed to alleviate the situation.

Some difficulty also arose with the commutated temperature-signal outputs. The calibration or reference temperature appeared to drift with changes in aircraft cabin environment. This, in turn, may have had some impact on the accuracy of pod temperatures recorded during the test.

Eating and drinking activity signals were not reliably recorded due to electronic incompatibility, and attempts made to correct same were not completely satisfactory. Spurious signals emanated from one feeder, while the other did not register feeding-lever manipulations by the monkey subject. The feeder and waterer, which had functioned satisfactorily during previous tests, were dismantled during the course of instrument preparation for these tests. Some of the components were utilized with additional parts in fabricating a modified system which would conform to the constraints of the aircraft. With limited time and personnel involved and other facets of fabrication given higher priorities, the system was not given a substantial base-line test. However, backup provision for food and water dispensing was adequate to maintain the physiological integrity of the test subjects. During actual flights, access by the monkeys to food pellets was limited and the water allowance was controlled by a hand valve.

5.3 EPL/UCB Data Acquisition Rack

5.3.1 During Flights

This rack was powered from station 6 with single-phase 60 Hz 115 VAC. Problem areas arose in the interfacing of the NASA/ARC furnished biotachometers. The condition improved, however, with each successive flight. The cardiovascular signal input from the telemetry-implanted monkey was not of optimum quality when compared to that received from the cutaneous ECG leads. Further discussion will be found in paragraph 6.3 of this report and in additional reports to be submitted by NASA/ARC. The parameters associated with respiratory gas exchange were recorded within acceptable limits.

There appeared to be no other major problems specifically associated with the components within this rack. A strip-chart paper pickup would have been desirable; one was provided but not mounted on the recorder. With the recorder running at slow speed for the majority of the time, folding of the data paper was easily accomplished by manual manipulation.

5.4 NASA/ARC Tape Recorder CP100

5.4.1 During Flights

Power to this analog tape recorder mounted on a lowboy rack in the aircraft was supplied by the 400 Hz electrical outlet at station 17. Fourteen data channels of respiratory gas-exchange and cardiovascular parameters (both Control and T/M) were selected for inputs to this recorder. A voice channel identified specific locations on the tape corresponding to the direct strip-chart recordings. Post-flight playbacks to a strip-chart recorder were made to compare data output and acquisition resulting from the two methods. Further consideration of the tape recorder will be discussed under the results section of this report.

During the last flight of the series on 21 May 1976 an experimental PCM recording device was incorporated into the lowboy rack containing the CP100 recorder. An analysis of its performance characteristics was to be made by Mr. James Connolly of the Electro-Systems Engineering Branch at NASA/ARC.

5.5 NASA/ARC Biotelemetry (T/M) Rack

5.5.1 During Flights

As shown in Table 9, a preliminary flight with certain components of the biotelemetry system including an implant module were tested aboard the CV-990 for the possibility of any radio frequency interference (RFI) or electromagnetic interference (EMI) between the aircraft or the unit itself. When the total instrumentation package, including receiver, demodulator, strip chart recorder, power supply and ancillary equipment, was flown in a standard highboy rack it apparently functioned as predicted. Data dropouts during portions of the flight were attributed to shifts in position of the externally placed energizing coil. Adjustment of the aortic pressure tracing on the strip-chart recording channel was frequently required. No doubt this was due to the design requirement of having the aortic pressure transducer a-c coupled to prevent zero drift. Further details of the biotelemetry portion of the flight activities will be found in reports originating from NASA/ARC.

5.6 ADDAS Experimental Input and Output

The initial printouts obtained from the ADDAS computer were fragmentary prior to the flight of 17 May 1976. On this flight, data outputs were shown successfully as voltages. On the final two flights of 19 and 21 May the parameters were printed in physiological units. On-line problems encountered, which were partially alleviated in progressive flights, were the adjustment of input calibration voltages and corrections of programming bugs. In Appendix O is shown a sample of the ADDAS printout with added explanatory notes of the monkey pod experiment parameters. The "report" or printout was obtained from the ADDAS once every minute and lists the computed mean value based on a sampling frequency of 1 per second for all parameters except water and food intake. Drinking and eating activity were sampled 10 times per second in order that the occurrence of events would not be missed.

6.0 Test Results

6.1 Experimental Subject Behavior

In a strict experimental protocol sense, it was difficult to control all aspects of the test subjects' environment. However, this project did extend the base line of previous ground tests in relationship to form, fit and function in integrating a sophisticated biological payload within an aircraft on an operational mission. Some of the factors in this exercise which were beyond experimenter control and impacted on monkey behavior can be listed as follows:

a) Light and dark cycles were not strictly adhered to on a 12L:12D basis with lights on at 0600 and off at 1800.

b) Temperature and humidity in the ground-based Airborne Science Laboratory were controlled. However, the levels were different from thos experienced aboard the aircraft and in transport between areas of activity.

c) Ambient pressures within the aircraft during flight varied from the equivalent of less than 300 meters in altitude to over 2100 meters.

d) An unscheduled extended ground situation occurred at Edwards Air Force Base on 11 May 1976 when the monkeys were subjected to elevated ambient temperatures. An auxiliary temperature and humidity control unit was not readily made available, and temperatures in excess of 37°C were recorded in the upper pod. As has been demonstrated in an environmental chamber at EPL/UCB (see S.R. #23, p. 17-19), temperatures of this nature above 35°C in conjunction with the low humidities indigenous to the Edwards Air Force Base area are known to be of a stressful nature for the pig-tailed monkey. To improve the monkey environment, remedial measures such as shading the aircraft windows with lab coats, increased allowances of water intake, and adding water to the air inlet of the upper pod were employed. Subjectively, the monkeys appeared to appreciate such action and did not make attempts to struggle against their restraint system, which would have no doubt further compromised their thermal equilibrium.

e) For reasons described in paragraph 5.1.3 of this report, the upper hood was removed on several occasions during the test period.

All of the preceding actions were accomplished as contingency measures to carry out the full experimental program. The operational versatility of the pod system in coping with emergency situations and allowing experimenters to perform tasks of obtaining physiological data without totally compromising the trial objectives was demonstrated.

6.2 Respiratory Gas Exchange

Respiratory gas-exchange measurements were carried out in-flight on the two test animals, Exeter (#174) and Simple (#337), by alternate sampling of the upper-pod exhaust air streams every 15 min for respiratory gas analysis by a mass spectrometer. As indicated earlier, the EPL/UCB Bioinstrumentation Rack, including the mass spectrometer was placed on-board the CV-990 for a "shake-down" flight on 11 May 1976. Respiratory gas-exchange data were recorded on strip charts starting with the flight of 13 May 1976, and including the flights of 17, 19, and 21 May 1976. Simultaneous recordings of the data on analog tape and elements of ADDAS were progressively incorporated into the test system during the final weeks of flights.

Inasmuch as strip charts were the only recorders previously available for use with the EPL/UCB monkey-pod system, this recording system, albeit with its limitations, was considered the primary source of physiological data for the CV-990 flights. The strip-chart data also served as a frame of reference for the new experience of analog tape recording and computer-processed data acquisition. As mentioned above, the analog tape recorder and ADDAS were introduced stepwise into the data-collection scheme during successive flights, and near-completion of a fully operational data system was not realized until the final flight on 21 May 1976. Accordingly, most of the test results for respiratory gas exchange reported herein were derived from post-flight analysis of strip-chart records. Opportunity for comparisons between recording systems was provided by the data yield from the flight of 21 May 1976.

Respiratory gas-exchange data are typically collected in our laboratory over anywhere from 3 to 30 days and reported on an hourly basis as liters/hr. However, because the CV-990 flights were only of 2 to 3 hours duration, the results were computed instead on a minute-by-minute basis in cm^3/min. Figs. 4-7 show such records of respiratory gas exchange for the flights of 13, 17, 19 and 21 May 1976 respectively. Since the principal aeronautics objective of the flights concerned new landing techniques, the minute-by-minute values of cabin pressure (upper pod pressure) were also included in the figures to indicate the most obvious environmental variable during the course of the measurements.

As can be seen from the results, there was a fairly large variability in respiratory gas-exchange rates; however, some relationship with the flight profiles may be discerned. The response time of the gas analysis system is of the order of several minutes, whereas the notable events in the flight profiles were relatively transient, lasting perhaps no longer than a minute. The Kepplerian maneuvers resulted in a zero-*g* condition of a few seconds, as shown in Fig. 8. As judged by the continuous strip-chart records of cabin pressure, most of the landing and takeoff maneuvers were initiated from level flight at low altitudes and were complete in approximately one minute. Hence, anything less than major responses of the animals to the aircraft maneuvers tended to be damped out by the buffering effect of the response time of the system.

Tables 10-13 show the overall mean values of respiratory gas exchange for the 2 animals during each of the flights of 13, 17, 19, and 21 May 1976. In apparent contrast to the heart-rate data, there was no clear trend in the results to suggest an adaptation by the monkeys to the experience of aircraft flight. In fact, the mean values of O_2 consumption and CO_2 production rates were highest in both animals during the last flight of 21 May 1976. However, as mentioned previously, a variety of extraneous stimuli were operative throughout the course of the flights, and may be expected to have contributed to a variability in the results, particularly considering the short duration of the flights.

The one systematic finding in the respiratory gas exchange data was the consistently higher respiratory quotient of Exeter (#174) compared to that of Simple (#337). Simple (#337) consumed less food during the flights and as noted earlier, was clearly overweight. The low R.Q. observed for Simple (#337) would seem to suggest he was drawing heavily on his fat reserves to meet his energy requirements during this time.

At the conclusion of the series of CV-990 flights, the analog tape of the data from 21 May 1976 was replayed in the laboratory and recorded on strip charts to evaluate the quality of transcription. A representative 20-min segment of the playback was selected for comparison with the corresponding segment in the original, direct strip-chart recording. As can be seen in Table 14, the values obtained from reading the original and transcribed strip-chart records were quite comparable. Some 60 Hz noise detracted somewhat from the aesthetic quality of the tape transcription in a few of the channels, but had no impact on the reading of the records which were otherwise very faithfully reproduced.

The reduction of strip-chart data for respiratory gas-exchange measurements involves a laborious and highly subjective procedure of reading the records, conversion of the readings to physiological units, followed by a series of simple yet time-consuming arithmetic operations. For the CV-990 flights, opportunity was made available to us to utilize the on-board capability of the Airborne Digital Data Aquisition System not only to digitize and log the signal outputs from all of the instrumentation, but to automatically average and convert the raw voltages to physiological or engineering units. Further, the system was programmed to take the respiratory gas-exchange parameters in physiological units and carry out the several secondary arithmetic operations to yield the final results; i.e., the O_2 consumption and CO_2 production rates, in-flight on essentially a real-time, minute-by-minute basis.

Table 15 shows a comparison of O_2 consumption and CO_2 production rates of the 2 test animals for the flight of 21 May 1976, computed on the one hand from post-flight analysis of strip chart records, and on the other, by ADDAS on a real-time basis during flight. The mean values of O_2 consumption rate were reasonably close. The CO_2 production rates, however, were surprisingly dissimilar, with that computed by ADDAS some 10-15% lower than that calculated from the strip charts. Inasmuch as the respiratory quotients obtained from the strip-chart data appear to be within reasonable limits, while those computed by ADDAS seem low, one is inclined to attribute the discrepancy to an underestimate of CO_2 production rate by ADDAS. It is clear, however, that the problem is experimenter induced, and not associated with the soft- or hardware.

Following verification of input/output voltages and de-bugging of programs during earlier flights, the on-line computation of respiratory gas exchange was given a final checkout just prior to the last flight on 21 May 1976, using sample calculations such as shown in Appendix P. The NASA/ARC signal conditioner was used as a multi-channel, constant-voltage source to simulate the simultaneous signal inputs from the mass spectrometer and mass flowmeter to ADDAS. Having first entered the calibration factors for the parameters, cabin air composition was entered as voltages, converted to gas fractions and stored as constants. The computer was then placed in the "run" mode and a set of voltages representing the mass spectrometer signal outputs for the gas fractions of pod exhaust air and the mass flow of air through the pod were generated by the signal conditioner. At the same time, the signal outputs were monitored and recorded from a digital voltmeter for manual calculations. Given the same calibration factors and constants, the raw voltages reduced by hand to respiratory gas-exchange values yielded results which were identical to that reported by ADDAS, thereby assuring correct on-line computations during flight.

Owing to a limitation in the number of channels available, the signal outputs for the respiratory gas fractions from the mass spectrometer were multiplexed and recorded on a single channel of the strip-chart recorder. Each of the 4 gas fractions was measured for 15 sec out of each minute. ADDAS, on the other hand, had no limitation on the number of channels and recorded the gas fractions individually and continuously. Thus, the 2 sets of data are, in fact, not really identical. The difference in CO_2 production rates, however, would appear to be much larger than could be accounted for by a difference in sampling duration.

It is possible that the calibration factors, units/volt for ADDAS and units/chart division from the strip charts, were not exactly equivalent for the gas fraction F_{CO_2}, with that of ADDAS erring on the low side. For example, the voltage readings taken during the pre-flight calibration period for the full-scale value of CO_2 may not have been sufficiently representative, with the result that the calibration factor entered and stored in ADDAS may have been inaccurate. "Representativeness" is more obvious on a continuous trace of a strip-chart record.

Even more suspect, however, is another constant entered in the computer, namely, the gas fraction F_{CO_2} for cabin air. Again, the voltage reading from which the CO_2 content of cabin air is derived and stored, was taken during the pre-flight calibration period and may not have been appropriate for use during flight. In addition to the ever-present spectre of operator error, there is the distinct possibility that the cabin air composition was actually different before and during flight. The experiment area on the aircraft was typically congested with traffic and activity during the pre-flight period. Given the relatively small and unventilated cabin space of the parked aircraft, the F_{CO_2} may well be expected to have been somewhat high. The strip-chart record for cabin air composition was obtained while the aircraft was taxiing and during the first few minutes of flight before the gas sampling system was switched over to monitor the gas outflows from the pods. With the aircraft now on its own power and air conditioners in operation, the cabin air composition may then have been more typical. In fact, the F_{CO_2} of cabin air used by ADDAS was 0.0012, while that for the calculations from the strip charts was 0.0005. For a F_{CO_2} of 0.0090-0.0100 in the exhaust air from the monkey pods, the difference in cabin air F_{CO_2} would introduce a discrepancy of nearly 10% in the ΔF_{CO_2} and hence in the CO_2 production rate.

In less unusual circumstances, under more controlled conditions - free of the distractions attending power interruptions, without the operational constraint requiring completion of calibration procedures before aircraft door closure, etc., greater care can be taken to ensure reliable calibration factors and constants for the on-board computer. Given accurate information, a system such as ADDAS is clearly a far superior data system than strip-chart records. In addition to the obvious advantage of obtaining processed and finished physiological data on a real-time basis, its fidelity may be as much as 2 orders of magnitude better than that of a multi-channel strip-chart recorder, which necessarily will result in better data. In any case, the above problems notwithstanding, useful information was gained from the CV-990/ADDAS experience and the evaluation of these test results.

6.3 Cardiovascular Measurements.

Heart rate was obtained from monkey #174 by the application of bi-polar silver/silver chloride ECG leads to the thorax just prior to insertion into the pod. Heart rate from monkey #337 was obtained from the telemetry ECG output signal. Both ECG signals served as inputs to Brush biotachometers which gave heart rate as output signals to a strip-chart recorder.

A variety of minor electronic and mechanical interface problems during the flights resulted in spotty heart-rate data return. The usable minute-by-minute heart rates from the 2 animals during the 4 flights on 13-21 May are plotted in Fig. 9. While the results are far from being totally satisfactory, nonetheless they are sufficient to demonstrate that the physiological condition of the animals was generally stable during the flights. It may also be concluded that with more time and attention in system preparation than was available in the present circumstances, totally satisfactory in-flight heart-rate recording could have been achieved readily.

The on-line computation of both heart rates and the upper/lower pod differential pressure was accomplished by the ADDAS system according to a technique described in appendices I, J and L of this report. Sixty samples per second of signal voltage outputs were read by the ADDAS system and used to compute minute averages for each of the 3 parameters. These averages were initially printed out on a CRT display and later in the flight as hard copy on a line printer located on the EPL/UCB Data Acquisition Rack.

The program for the computation of heart rate was to have included high and low heart rate limits selected by the experimenter, beyond which values would not be included in the computation of the minute rate. The number of values used in the computation (60 or less) of the average was to be printed also. The final program included only a high heart rate limit and this was selected to be 250 beats/min (full scale) throughout the flights. The program for heart rate worked well during the flights, as shown in Table 16. Mean heart rates from the ADDAS and the strip-chart records differed on the average by only 3 beats/min for both pods, with the ADDAS values usually lower than the estimates from strip chart records. The high-limit cut-off on heart rate helped to prevent ECG artifacts from being included in the heart rate computation. A similar low-limit cut-off at about 100 beats/min would have helped eliminate the inclusion of values in the computation when the cardiotachometer was not able to count R waves due to a poor ECG signal input.

During the preparation of this report, strip-chart records of the biotelemetry data were made available and an interpretation of the cardiovascular data output in regard to heart rate, left ventricular and aortic pressures was made. Assuming that the nadir of the ventricular pulse represented zero torr and that the extent of the zero-cal span represented 100 torr and 180 torr respectively, regardless of the sensitivity setting on the recorder channel, a peak left-ventricular pressure could be determined. This peak pressure would in turn be the same as the aortic systolic pressure, and by calibration with the indicated zero-cal span on the aortic pulse-wave channel, aortic pulse pressure and diastolic pressure were estimated. Heart rates were determined by counting the number of pulses per unit time during the identical period that the pressures were calculated.

Some data on all parameters were derived at various stages of flight activity. Heart rates ranged from a low of 129 to 216 beats per minute, peak left-ventricular pressure from 118 to 200 torr, aortic diastolic pressure from 81 to 127 torr, and aortic pulse pressure from 32 to 55 torr. The higher levels of these observations were obtained either during the first week of the flights, or when the monkey struggled against his restraint following initial placement in the supine position and the application of lower body negative pressure. These extremes were of a transient nature.

A summary of telemetered cardiovascular measurements for a series of observations on 11, 17, 19 and 21 May made under similar conditions of level flight while the pod was positioned upright with the monkey relatively undisturbed is shown in Table 17. It would appear that the test subject became more accustomed to the environment with successive flights. Table 18 contains a summary of observations obtained during delayed flap maneuvers of the CV-990.

Although initially there seemed to be some differences in cardiovascular performance during the 3 aspects of this maneuver, that is, the descent, touchdown and subsequent ascent, the mean values for 10 observations showed very slight or no change. On the other hand, the levels of these measurements did decrease with each succeeding flight day, as did those observed during level flight. However, they tended to be higher on the average than those observed during level flight.

6.4 Monkey Condition and Nutritional Intake

The procedures for monkey insertion and removal have been discussed in previous paragraphs. In consideration of monkey behavior (paragraph 6.1), it was noted that both monkeys were subjected to environments which would not usually occur in the conduct of an optimum experiment without the constraints of time encountered. These situations were reflected to some extent in the physical condition of the monkeys, particularly in their body weight when compared to previous trials. Both animals were over-conditioned prior to initial insertion in the pods. Rates of weight loss were greater from 5-14 May than during the last week of the flight schedule, as shown in Table 10. However, recovery periods in the cage following removal were within normal limits, and no leg edema or loss of kinesthetic activity was evident.

On 7 May 1976, upon removal from the pod, a mid-dorsal skin lesion (5 cm x 5 cm) was noted on #337, Simple. The abrasion was treated with Furacin(R) ointment. The causative factor was believed to have been mechanical or thermal resulting from the placement of the external energizing coil or the power oscillator module of the biotelemetry subsystem. For the next insertion of this monkey the power oscillator was mounted in a more posterior position on the couch. The energizing coil terminal to connecting electronic wiring had several abrasive areas. As a palliant this junction was wrapped with several layers of tape. In addition, the application of power input in activation of the system was minimized to prevent overheating. No further decrement of the skin lesion occurred during the balance of the period when he was placed within a pod from 10-14 May and again from 17-21 May. On 17 May, #422 Bushy, who was originally scheduled for the final week of flights, required clinical attention and was deemed unsuitable for pod insertion.

As has been mentioned in previous reports from this laboratory, one of the problems encountered with the present feeder is a malfunction which occurs due to the breakage of food pellets. The Purina Monkey Chow (PMC) 5040 pellets, which are commercially available, have a tendency to crumble unless they are carefully selected and handled. Under spring loading, which may be a solution to a functional feeder capable of operation in zero-*g*, the potential disintegration of the pellets would be accentuated. Pellets of a slightly smaller dimension have been obtained from NASA/ARC, which appeared to have the consistency and hardness to withstand the action of a spring loaded feeder. These pellets were manufactured for NASA by Stanlabs, Inc. of Portland, Oregon for use in the Orbiting Primate Experiment (OPE). Acceptability was satisfactory to a number of caged monkeys in the EPL colony. When used in the pod feeder they were not as readily accepted as the PMC 5040 pellets by the test subjects, particularly in an abrupt transition from the monkey chow ration offered under cage conditions.

A hardness test was conducted with 10 randomly selected pellets sized for use in the present pod feeder and the results are shown in Table 20. "Brand X" pellets were the result of supplying a manufacturer with regular 15% crude protein monkey chow and requesting a pellet of the size to be used with the feeder. As may be noted, the force required to break the "Brand X" pellets was even less than the PMC 5040 pellets which have been used extensively in ground-based trials. Thus, mechanically, it would seem that the ideal food pellet should be able to withstand a breaking force of at least 10 kg. Other aspects of the diet which need further study are the reduction of the excessive crude protein and calcium levels presently contained in commercially available non-human primate rations.

Due to the malfunctioning of the feeder system in relationship to food intake activity, a precise record was not obtained. However, a record was kept of the total number of food pellets given to each monkey either by feeder or on occasion offered by hand when the pod hood was removed. Both monkeys also had troubles in actuating the water dispenser, although they had had previous training in the pod without problems. The pressure sensor, located farther away from the nipple in this test, undoubtedly contributed to the difficulty. As a result, hand watering by gravity flow was resorted to in order to prosecute the experiment. A food and water intake summary is shown in Table 21. It is apparent that #174, Exeter consumed considerably more food than #337, Simple. This situation is further exemplified in the respiratory gas-exchange data where #337 was no doubt utilizing more of his body fat stores for maintenance than #174.

6.5 Application of Lower Body Negative Pressure (LBNP)

As part of the objective of making cardiovascular measurements during the CV-990 flights it was planned to record the heart-rate response to lower body negative pressure (LBNP) on both monkey subjects during flight. LBNP produces a redistribution of blood from central to peripheral reservoirs and thereby serves as a provocative stress to the cardiovascular system under both 1- and zero-*g* conditions. LBNP is typically applied with the subject in the supine position at 1-*g* so as to induce a postural redistribution of blood. At zero-*g* the response to LBNP is independent of body position and is an effective and simple technique for assessing the state of the reserve capacity of the cardiovascular system.

The heart-rate and blood-pressure response of the pig-tailed monkey to

LBNP and upright tilt has been described in the report "Physiological Studies in Space with Non-Human Primates Using the Monkey Pod" (see Applicable Document section of this report). During these previous studies it was determined that an incremental LBNP test consisting of 5 min each of 40, 50 and 60 torr was sufficient to produce a significant heart-rate increase during at least one pressure level for any individual monkey. It was also determined that a 15 min control and recovery period was necessary to define the base-line heart rate and to allow return to that base line after LBNP. After tilting each subject to the supine position, a 30 min period, prior to beginning the collection of control data, was allowed for stabilization of cardiovascular parameters since the tilt process itself is a stressful event for some subjects. This protocol as it was adapted for 2 pods is documented and included as an appendix to this report (Appendix Q).

The capability for tilting each pod to the horizontal position for conducting the LBNP test was included in the design requirements for the monkey pod rack. The maneuver was accomplished simply by removing a holding pin, tilting the pod and replacing the pin in another hole. This system worked very well throughout the flight. Even though the urine collection system (paragraph 6.6) was designed to collect all the urine, the possibility existed of some urine leakage at the monkey/catheter interface with the pod in the horizontal position. To prevent any excreta from entering the lower pod air inlet port during tilt, polyvinyl chloride tubes were inserted into the ports from inside of each pod during pod assembly to act as a standpipe. No excreta entered the ports during the flights.

In-flight LBNP tests were performed during 2 flights of the series. On 13 May a preliminary 5 min test was completed with the control monkey, #174. During this test it was determined that the 28 VDC LBNP pump was able to generate a maximum upper/lower pod differential pressure of only 6 torr. On

21 May, 5 min of 5 torr LBNP was applied to both monkeys during flight to test the data interface with the ADDAS system.

Ground-based LBNP tests on board the CV-990 were conducted on both monkey subjects on two occasions. The incremental LBNP test, following the protocol described in Appendix U,was performed pre-flight on 19 May. Several 2-3 min tests at 60 torr LBNP were conducted post-flight on 21 May.

A summary of the heart rate responses to LBNP during ground-based tests on the 2 monkeys is shown in Table 22. These data appear similar to test results typically obtained at EPL/UCB from monkeys only minimally conditioned to supine LBNP and/or under circumstances where environmental disturbances (noise, proximity to humans) produce behavioral effects on heart rate. Control heart rates recorded previously on these 2 subjects during 3-5 day pod tests in the upright position, but under less disturbing conditions, were 35-40 beats lower than those seen during the supine LBNP test control period or in the upright position on the CV-990. Both monkeys exhibited signs of being stressed (struggling, chewing on feeder handle, etc.) during the supine control and LBNP periods.

The incremental LBNP test conducted pre-flight on 19 May was conducted under conditions unfavorable for obtaining good data. During the LBNP tests several persons were actively involved in calibrating portions of the instrumentation directly adjacent to the pods. The rather erratic and minimal heart rate response to increasing negative pressure levels seen during this test may have been partially due to the effect of leg muscle contraction during struggling, which would lessen the quantity of blood pooled.

The post-flight LBNP tests conducted on 21 May took place with the CV-990 mostly empty and relatively quiet and the quality of the heart rate data was improved. On this final flight day there was not enough time post-flight to conduct the full 100 min 2-pod LBNP protocol as planned because of the CV-990 schedule requirements. Also, the monkey with implanted biotelemetry, #337, was providing cardiovascular data output only intermittently because of positioning problems with the external energizing coil. A series consisting of four 60-torr LBNP tests of 2 min duration was conducted on this subject in an attempt to gather control and LBNP data during the short periods of adequate data output. It was hoped that the higher pressure level would give a significant cardiovascular response during the shorter duration.

Sequential applications of LBNP at 60 torr produced heart rate increases in monkey #337 of 65, 50, 35 and 50 beats/min for an average increase of 50 beats/min. Monkey #174, during a single identical test, had this same heart rate increase. Previous studies at EPL/UCB with a group of 5 normal pig-tailed monkeys tested 3 times each, showed a mean heart rate increase during 5 min of 60-torr LBNP of about 50 beats/min (range of 30-75).

The in-flight LBNP tests at 6 torr conducted on two occasions (see section 6.5.3) did not produce any significant cardiovascular changes due to the low pressure differential. These tests were useful in testing the ADDAS on-line computation of upper/lower pod differential pressure during flight (see Appendices I and J).

Both monkeys serving as subjects had previously experienced LBNP. The most recent test, however, had occurred 9 months prior to the CV-990 flights and because of various experiment constraints these tests had to be conducted at low pressure in the upright position. Thus neither subject had been conditioned to supine LBNP. Scheduling constraints relating to hardware development, the implantation of telemetry devices and limitations on personnel time precluded the possibility of pre-flight LBNP conditioning trials. This factor no doubt had an effect on the quality of the heart rate data obtained.

A preliminary look at the telemetry cardiovascular data from monkey #337 on 19 May suggested decreases in aortic systolic and pulse pressures proportional to the level of LBNP applied. Further discussion of the effect of LBNP on the telemetry data will have to be postponed until ARC staff have completed the analysis of this data, and will hopefully be included in their separate report on this portion of the experiment.

6.6 Excreta Collection and Handling

As a part of the monkey insertion procedures, a silicon tube was placed over the penis and secured distally to a urine collection bag (Curity$^{(R)}$ 2,000 ml Bag Code No. 3057) mounted on the back of the lower leg section of the couch. A drainage tube with spring-clip occluder led from the bag and connected with a fitting on the lower-pod anterior central aperture. To collect a clean, timed, uncontaminated urine sample, the fitting was removed, the drainage tube occluder released, and the urine removed. In an attempt to utilize a system which should function in zero-g, a syringe was used to evacuate the urine sample. A summary of the timed urine collections is shown in Table 23. With daily lower-pod window observations and upon monkey removal from the pods, there was no evidence that leakage occurred. In addition, this separation of the urine from feces tended to reduce the production of obnoxious odors. When the silicon tube was detached, no evidence of irritation to the penis was apparent. The silicon tubes following use from 10 to 14 May were cleaned and replaced on the same monkeys for collections of 17 to 21 May.

Low-ash Eaton Dikeman blotting paper was used to line the lower-pod interior for excreta collection. However, it is conceivable that this material would not be needed if urine can continually be separated satisfactorily and the integrity of the lower pod interior is maintained. Thus, quantitative analysis of the feces could be accomplished without the background of absorbent material. For use in zero-g a filter would have to be incorporated in the exhaust gas line of the lower pod.

With the limitations of cost, time and personnel, the urine and feces samples were not saved for chemical analysis although the feasibility of accomplishing this activity was again demonstrated.

7.0 SUMMARY AND CONCLUSIONS

The time interval allowed for the mechanical and electronic integration of the laboratory functioning modules to an airworthiness condition within the instrumentation racks was inadequate to carry out all aspects of a controlled physiological experiment. In addition, the monkey-pod experiment was essentially riding "piggy back" on the primary mission of the CV-990 flights of 3 May through 21 May 1976. Nevertheless, the opportunity to evaluate the performance of a sophisticated biological experiment on an aircraft during an operational mission proved to be a valuable learning experience for all personnel concerned and furnished the extension of previous base-line data for the monkey pod experiment system. A series of 6 photographs encompassing a portion of the flight experiment is shown in Figure 3.

Certain highlights of the activity reported in this document which can be considered as a furtherance of qualification of the monkey-pod experiment system over that previously reported for the Shuttle CVTs (EPL 74-1 and 74-2) are considered in the following paragraphs.

The total system functioned effectively under an aircraft environment with changing temperatures, altitude, vibration and *g* loadings, including a short period of weightlessness. In effect, the handling procedures for interfacing pods containing monkeys with the balance of the experiment system were similar to those proposed for future Shuttle Spacelab flight experiments. All instrumentation racks, with the exception of the pods, were set up previously in the aircraft, access to which was limited. This was analogous to the Spacelab constraints, which dictate that pre-launch access might be limited for periods up to 9 days. The pods were kept at a ground-based laboratory and, when appropriate, were moved and interfaced with the instrumentation. Thus, simulation of Shuttle protocols was carried out wherein experiment organisms would be maintained at a ground laboratory or on the Orbiter prior to loading into Spacelab. Unloading procedures also paralleled those proposed for Shuttle payloads. The procedures used permit the pods to be ready for loading at any time, regardless of holds or slips which may arise with any flight program. Furthermore, loading on the aircraft and connecting to the appropriate instrumentation was accomplished without impacting on aircraft flight preparation.

On most flights, the number of experiment-related personnel was maximized in order that they could gain full familiarization and carry out trouble-shooting if needed. For the actual in-flight experiment instrument manipulation fewer people were needed than those listed in Table 9. There is every reason to believe that one payload specialist could fulfill the in-flight experimental tasks within 2 hours each day. A preliminary schedule of daily in-flight activity for a Shuttle mission would be as follows:

0600	- Lights on for monkeys
0800-0830	- Animal status checks Change 24-hr urine collector Food and water status checks
1400-1435	- LBNP tests on 2 monkeys
1435-1530	- Instrumentation calibration checks
1800	- Lights off for monkeys

In addition, the experimental racks containing all the elements used on board the CV-990 flights reported here would be more optimally located for individual observation in the Shuttle configuration. In actuality, on the aircraft flights, the operation of the respiratory gas-exchange instrumentation was conducted step by step from a typed protocol by a person who had had minimal training for this activity. Therefore, a qualified payload specialist could readily perform this task. After setting the respiratory gas-exchange instrumentation in an operating mode, there was ample time for one person to observe the activity or make adjustments for the other racks involved in the total experiment system. In the case of a power outage while the mass spectrometer was in operation, remedial measures must be taken by closing the M/S sample inlet valve as soon as possible. Power outage did occur during flight operations and the appropriate steps were taken without damage to the instrumentation.

A wide variety of data-retrieval links, including strip-chart recording, analog and digital tape, computer printouts, telemetry and hand-written observational notes were utilized with the monkey-pod experiment. In all instances compatibility was demonstrated.

Mechanical and electronic upgrading of the experiment modules to accept aircraft standards did not cause any overall detrimental or diminutional effects in regard to data acquisition.

The collection technique for clean separation of pig-tailed monkey urine from feces was satisfactorily demonstrated. Thus, excretion rates of physiologically important metabolites can be accurately evaluated under a variety of environmental conditions.

The compatibility of the airborne monkey-pod experiment system with an inductively powered, implantable, multi-channel telemetry system expanded the return of viable cardiovascular data. The implantable portion of the units are well tolerated by pig-tailed monkeys, as is exemplified by #396, Lovel who was surgically implanted on 23 February 1975, and from whose signal output heart rate could still be derived during the month of May 1976. No losses resulted from surgical implantation and all 3 of the male pig-tailed monkeys survived thoracic surgery. As a result of these studies, improvements in the design are in the offing to reduce the power requirements, improve the stability of the pressure transducers, and allow greater latitude in energizing coil placement. More detail on this matter will be found in report documentation by NASA/ARC.

For the conduct of a Spacelab flight experiment no major obstacles appear to exist, although several portions of the experiment system will require further development effort. Consideration should be given to the following tasks:

1) Considerable miniaturization of existing electronic instrumentation can be made to effect significant savings in weight and volume for the total system.

2) A pod des[illegible] change that will make possible ready blood sampling from the animal occupant should be implemented and tested. This change will not only improve the proposed experiment protocol, but will also make in-flight blood sampling feasible.

3) If exhaust gases are not to be dumped overboard, a scrubbing device should be incorporated into the pod system.

4) The fabrication and testing of a nutrient dispensing system capable of functioning in weightlessness is needed. Concepts and preliminary evaluations of various systems which have flown or have the potential to function at zero-*g* have been considered.

Non-hygroscopic food pellets able to withstand a breaking force of 12 kg, and still be acceptable and consumable by the test monkeys, would permit a wider choice of food-dispenser design concepts. Most of the ingredients contained in a Purina Monkey Chow formulation could be used as a base for the food ration. On the basis of the commonly listed content of this diet, it would be possible to diminish or eliminate the use of dried skim milk and calcium carbonate and thus lower the levels of nitrogen and calcium intake. Both of these elements are unnecessarily high for maintenance of the adult male monkey, and interfere with accurate assessment of elemental metabolic balances.

The water dispenser should be modified to a state which will simplify its function in zero-*g*.

5) A LBNP pump and vacuum control system is needed which will satisfy aircraft safety requirements, and which could be used during both ground-control and Spacelab flight experiments. A regenerative-type pump has been identified (Duplex #SF4A2F, Rotron, Inc., Woodstock, N.Y.) which can provide high vacuum (to 90 torr) and eliminates the necessity for brushes or commutators and associated RF noise. This pump has a 60 Hz, single-phase, 110 V AC motor. Pressure would have to be regulated with a variable-leak valve installed in the LBNP pump inlet line because the pump has a minimum allowable flow rate of 10 CFM.

6) It will be necessary to complete the development of the NASA/ARC multichannel telemetry system to incorporate a sonomicrometer channel for left-ventricular dimension measurement. Although the transducer element is available separately, it is not presently part of the multichannel system. Inclusion of this transducer channel would provide needed data for continuous estimation of left-ventricular stroke volume and hence cardiac output.

7) A pool of healthy, adult pig-tailed monkeys to serve as potential Spacelab flight candidates in the early 1980's should be acquired as soon as possible. On-going testing and training of these animals in the pod and couch with base-line physiological protocols should be initiated as soon as possible. For example, to conduct a 2-pod flight experiment entitled "Monkey Metabolism and Cardiovascular Function in Zero-*g*", recently proposed for the First Spacelab Mission, 24 monkeys of the type described above would be needed.

FIGURES

Fig. 1. Floor Plan, Revision B, DAS/Monkey Pod CV-990,
3-21 May 1976.

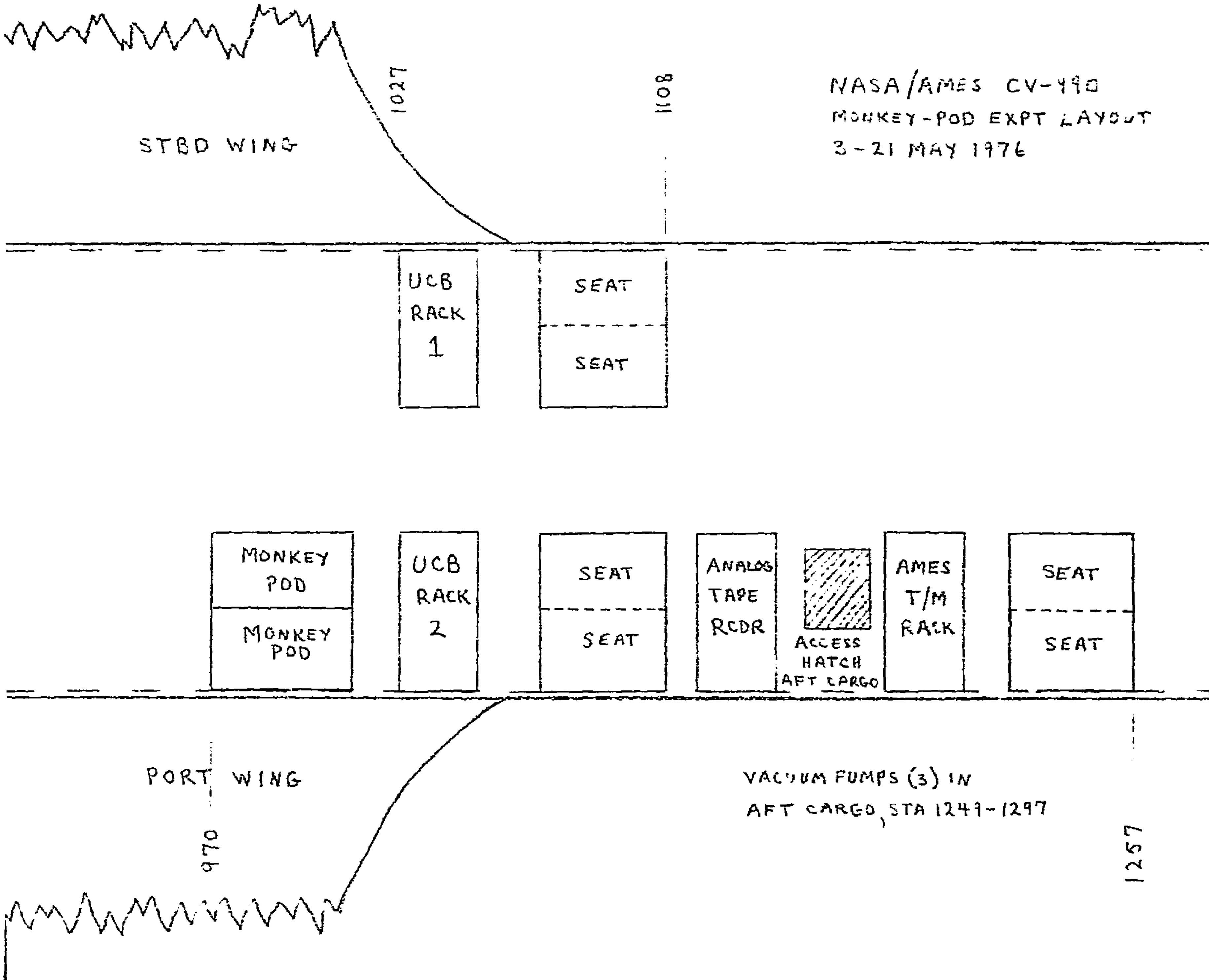

NASA/AMES CV-990
MONKEY-POD EXPT LAYOUT
3-21 MAY 1976
STBD WING
1027
1108
UCB RACK 1
SEAT
SEAT
MONKEY POD
MONKEY POD
UCB RACK 2
SEAT
SEAT
ANALOG TAPE RCDR
ACCESS HATCH AFT CARGO
AMES T/M RACK
SEAT
SEAT
PORT WING
970
VACUUM PUMPS (3) IN
AFT CARGO, STA 1249-1297
1257

Fig. 1

Fig. 2. Drawing CV-990 Monkey Pod Installation,
A-57127602 M009.

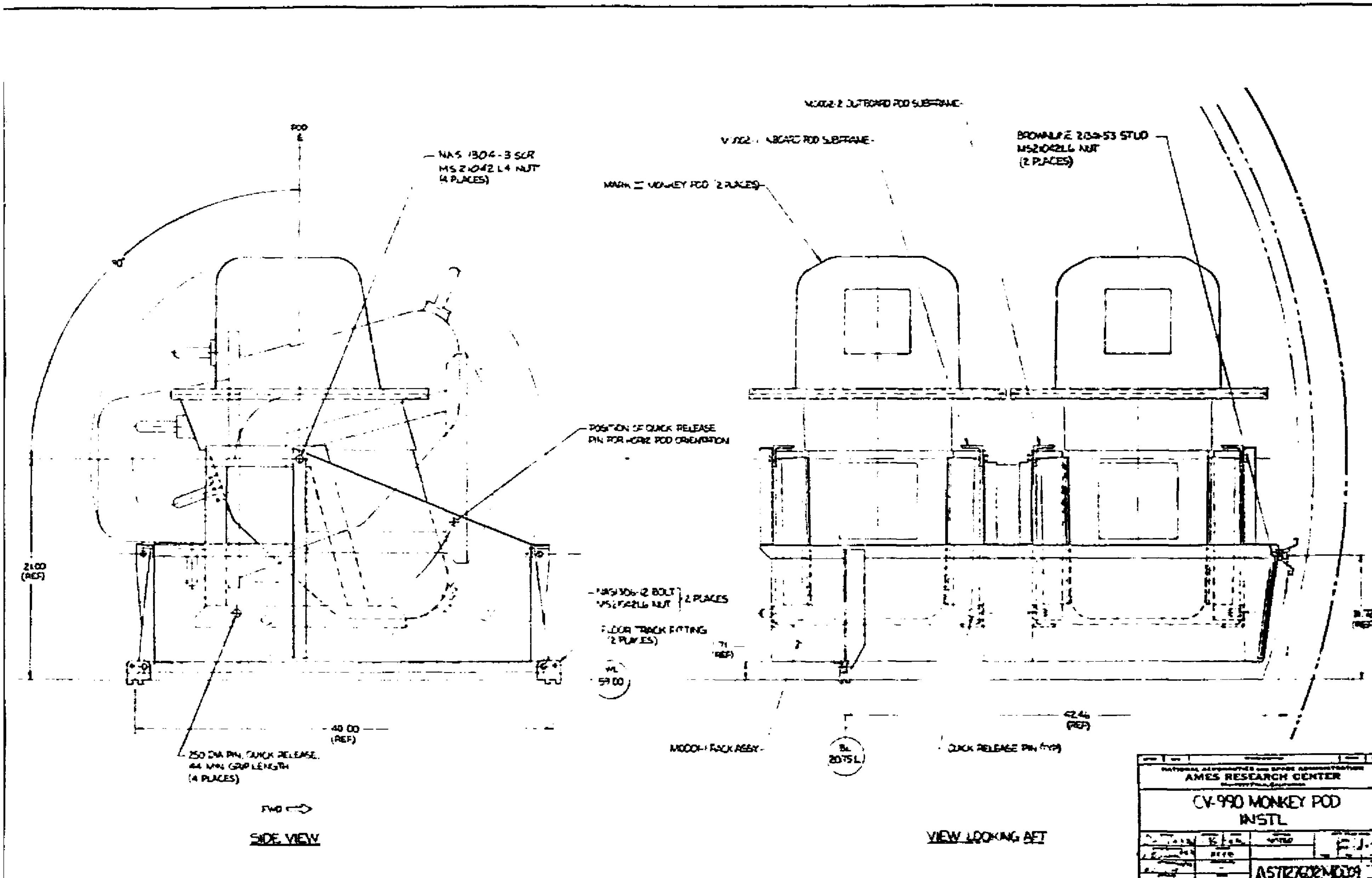

NAS 1304-3 SCR
MS 21042 L4 NUT
(4 PLACES)
POSITION OF QUICK RELEASE
PIN FOR HORIZ POD ORIENTATION
21.00
(REF)
40.00
(REF)
.250 DIA PIN, QUICK RELEASE,
.44 MIN GRIP LENGTH
(4 PLACES)
FWD
SIDE VIEW
MARK II MONKEY POD (2 PLACES)
BROWNLINE 2034-53 STUD
MS21042L6 NUT
(2 PLACES)
FLOOR TRACK FITTING
(2 PLACES)
WL
59.00
42.46
(REF)
QUICK RELEASE PIN (TYP)
BL
20.75 L
VIEW LOOKING AFT
AMES RESEARCH CENTER
CV-990 MONKEY POD
INSTL

Fig. 2

Fig. 3. Monkey-pod experiment system in NASA CV-990 aircraft.

a. Looking aft in CV-990. Pod base and back of support instrumentation rack. Rack contains mass spectrometer assembly, LBNP controls, and physiological data signal conditioners.

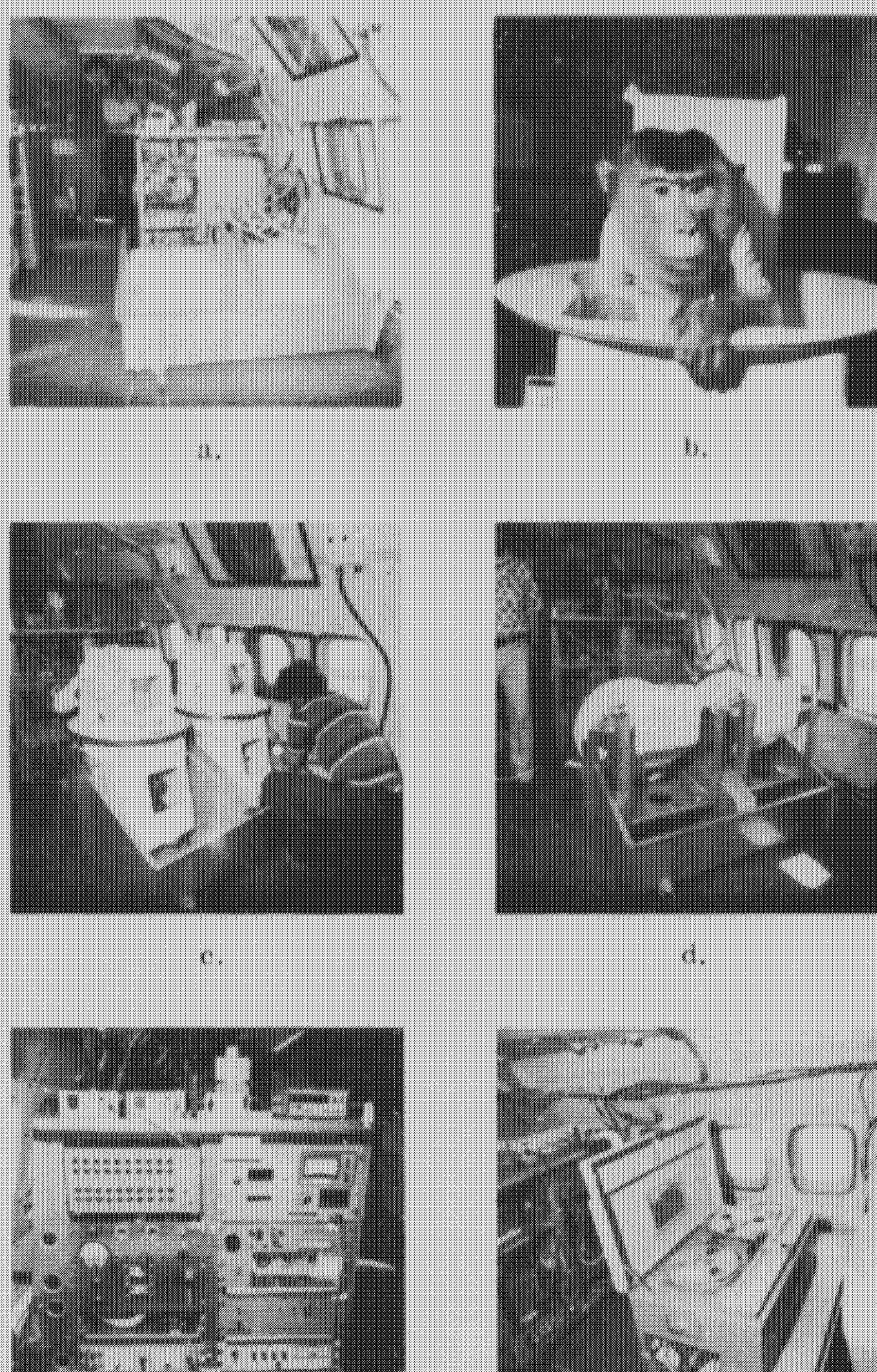
b. *Macaca nemestrina* #174, Exeter. This pig-tailed monkey served as the non-instrumented control animal during the CV-990 flights. Heart rate was measured continuously with skin ECG leads, and respiratory gas exchange measurements were also measured continuously.

c. Two pods with monkeys installed in CV-990.

d. Two pods in horizontal tilt position for LBNP tests.

e. Front of support instrumentation rack. Physiological transducer pre-amplifiers are at upper left, LBNP controls are at lower left, pod temperature and air-flow instrumentation are at upper right, and mass spectrometer controls are at lower right.

f. Ampex Model CP-100 analog data tape recorder used for continuous in-flight recording of physiological data is at right, and NASA/ARC cardiovascular biotelemetry electronics rack is at left.



a. b. c. d. e. f.

Fig. 3, Monkey-pod experiment system in NASA CV-990 aircraft.

Fig. 4. Monkey oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide production ($\dot{V}_{CO_2}$) and respiratory quotient (RQ), and cabin air pressure (P_B) during CV-990 flight of 13 May 1976. Monkey #176 and monkey #337 data are shown during alternate 15 min periods.

Fig. 4

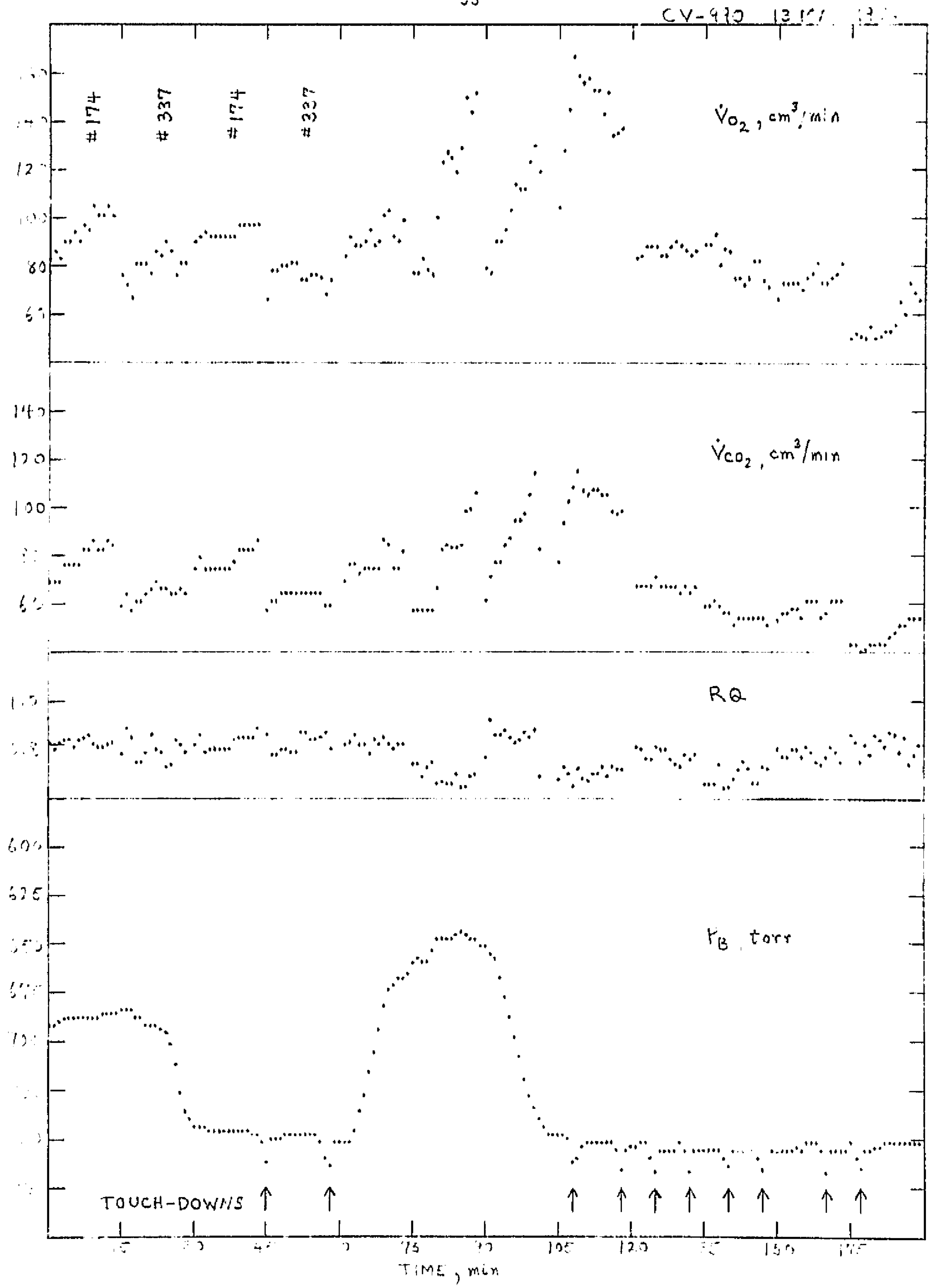

CV-990
#174
#337
#174
#337
$\dot{V}_{O_2}$, cm³/min
$\dot{V}_{CO_2}$, cm³/min
RQ
P_B, torr
TOUCH-DOWNS
TIME, min

Fig. 5. Monkey oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide production ($\dot{V}_{CO_2}$) and respiratory quotient (RQ), and cabin air pressure (P_B) during CV-990 flight of 17 May 1976. Monkey #176 and monkey #337 data are shown during alternate 15 min periods.

Fig. 5

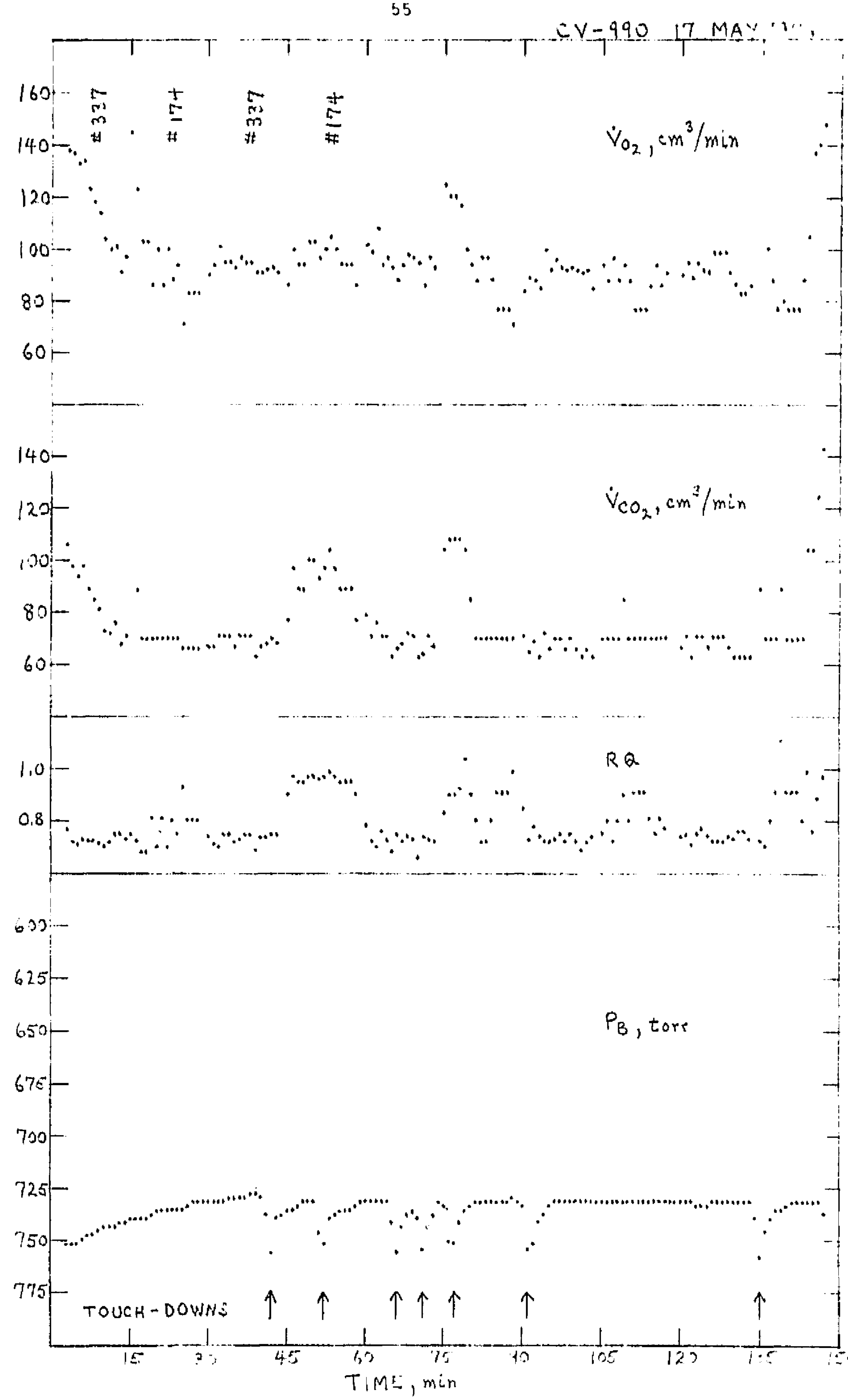

CV-990 17 MAY '7'
#337
#174
#337
#174
$\dot{V}_{O_2}$, cm³/min
$\dot{V}_{CO_2}$, cm³/min
RQ
P_B, torr
TOUCH-DOWNS
TIME, min

Fig. 6. Monkey oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide production ($\dot{V}_{CO_2}$) and respiratory quotient (RQ), and cabin air pressure (P_B) during CV-990 flight of 19 May 1976. Monkey #176 and monkey #337 data are shown during alternate 15 min periods.

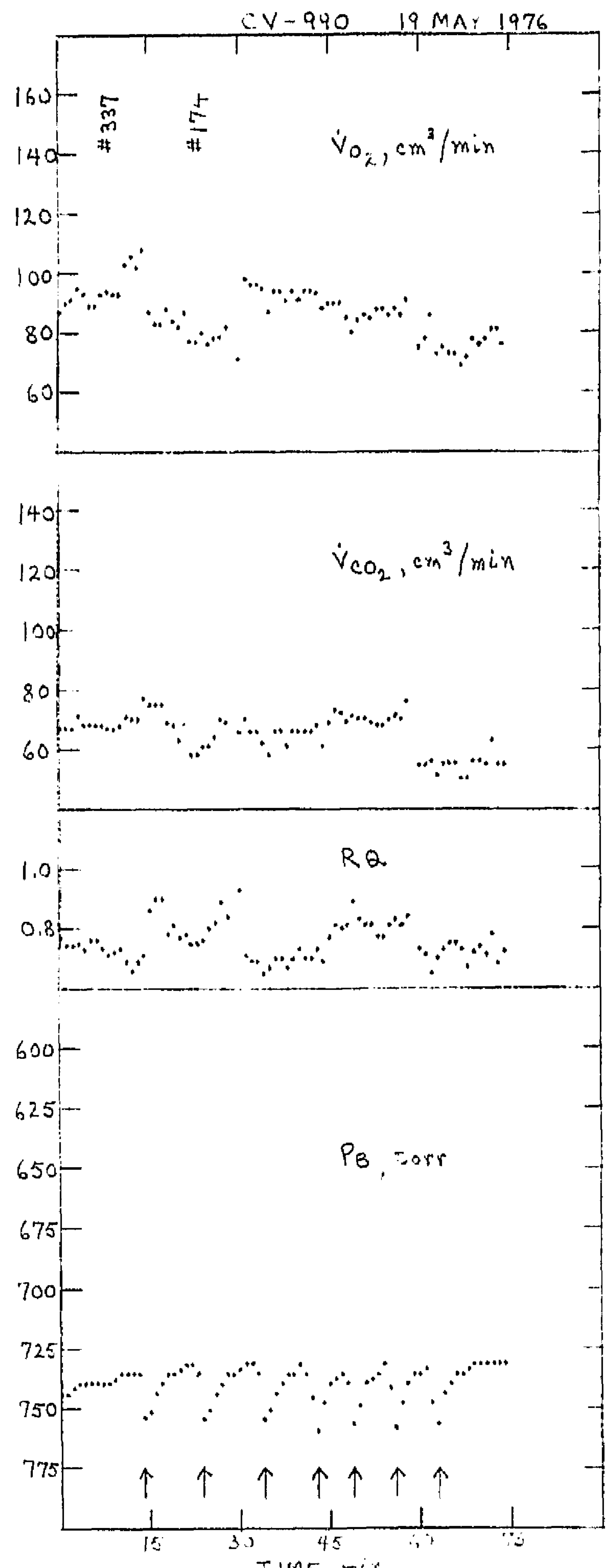

CV-990 19 MAY 1976
#337
#174
$\dot{V}_{O_2}$, cm³/min
160
140
120
100
80
60
$\dot{V}_{CO_2}$, cm³/min
140
120
100
80
60
RQ
1.0
0.8
P_B, torr
600
625
650
675
700
725
750
775
15
30
45
60
75
TIME, min

Fig. 7. Monkey oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide production ($\dot{V}_{CO_2}$) and respiratory quotient (RQ), and cabin air pressure (P_B) during CV-990 flight of 21 May 1976. Monkey #176 and monkey #337 data are shown during alternate 15 min periods.

Fig. 7

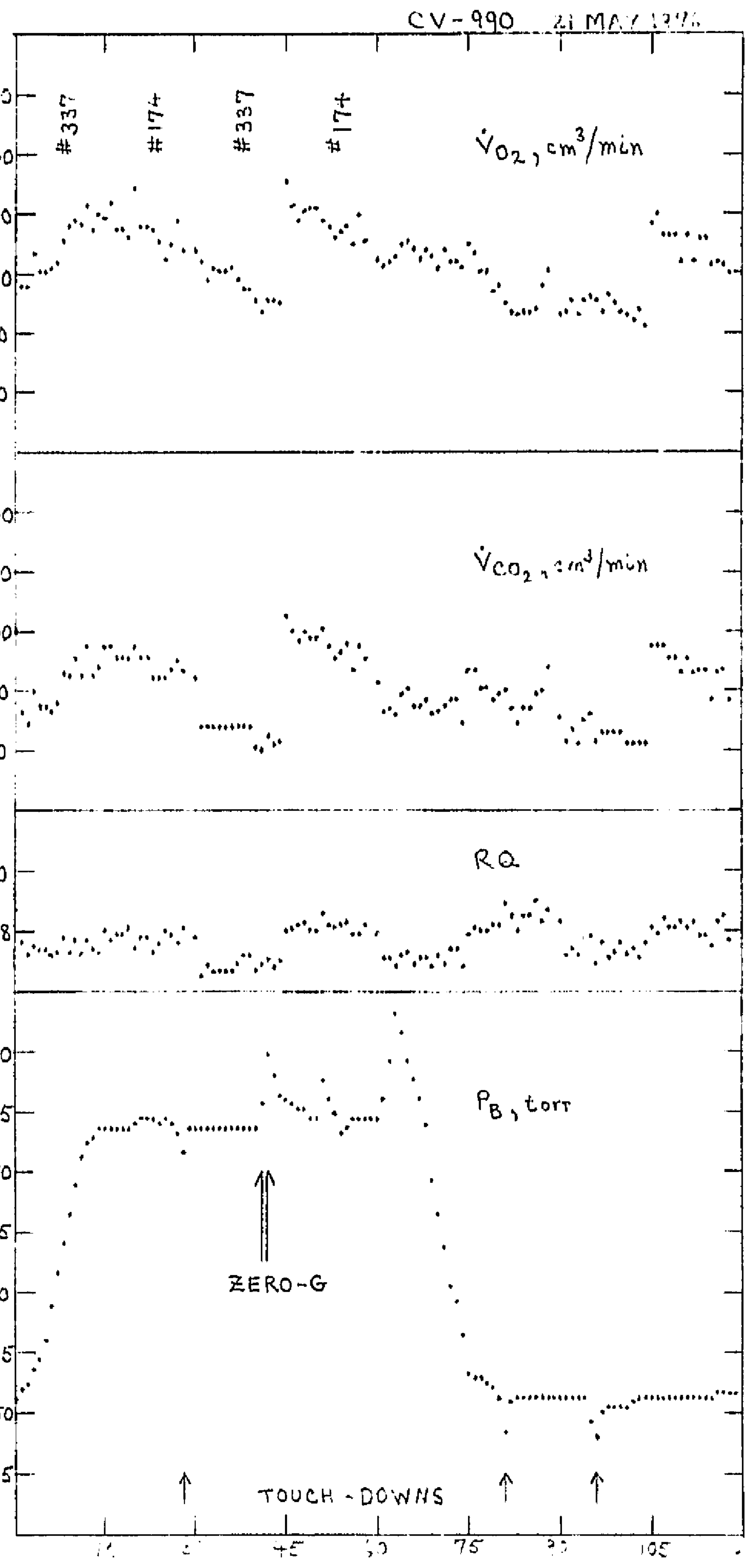

CV-990 21 MAY 1976
#337
#174
#337
#174
$\dot{V}_{O_2}$, cm³/min
$\dot{V}_{CO_2}$, cm³/min
RQ
P_B, torr
ZERO-G
TOUCH-DOWNS
TIME, min

Fig. 8. Vertical acceleration of CV-990 aircraft during the portion of the flight of 21 May 1976 when "zero-*g*" was achieved for several seconds.

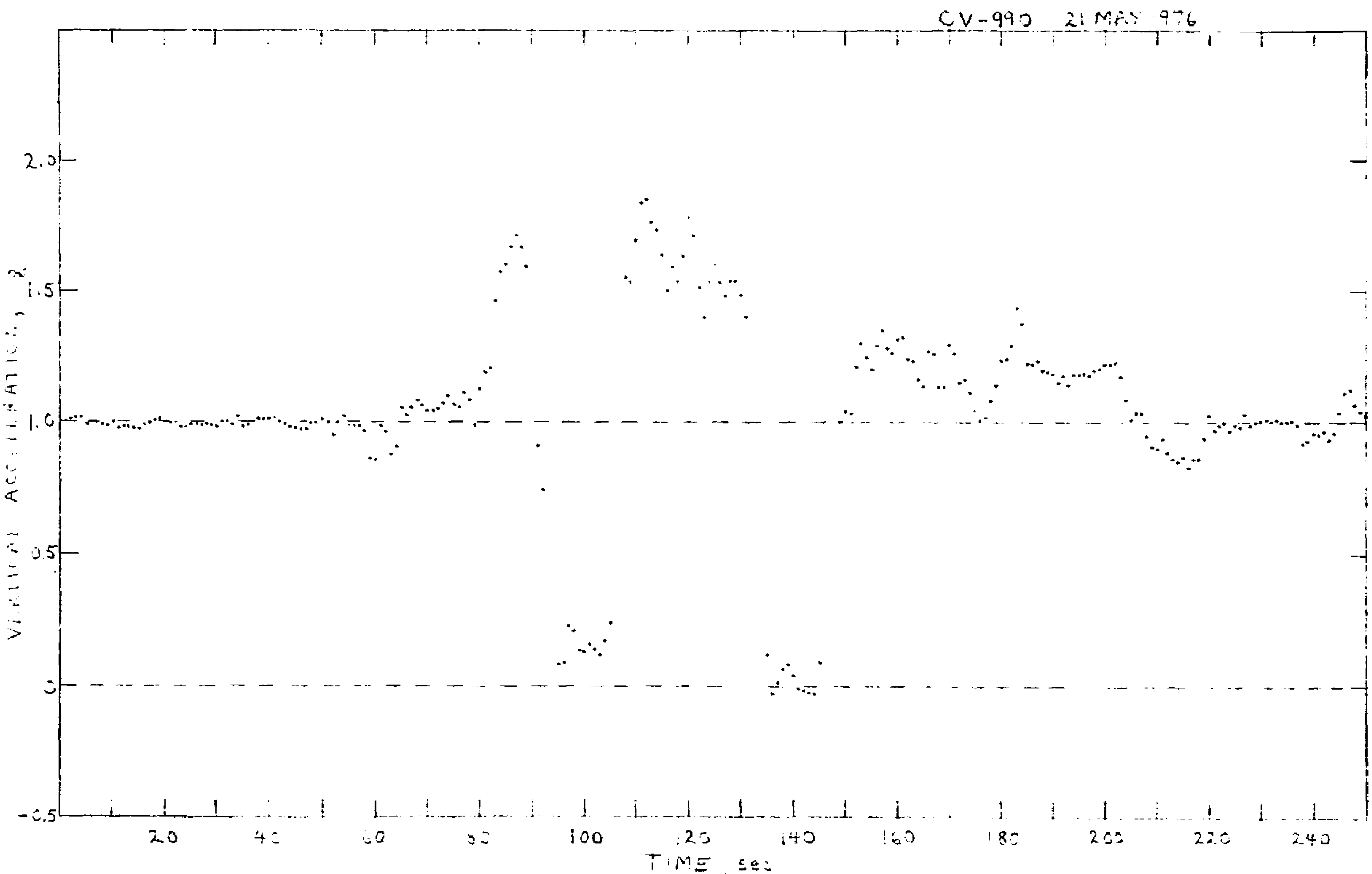
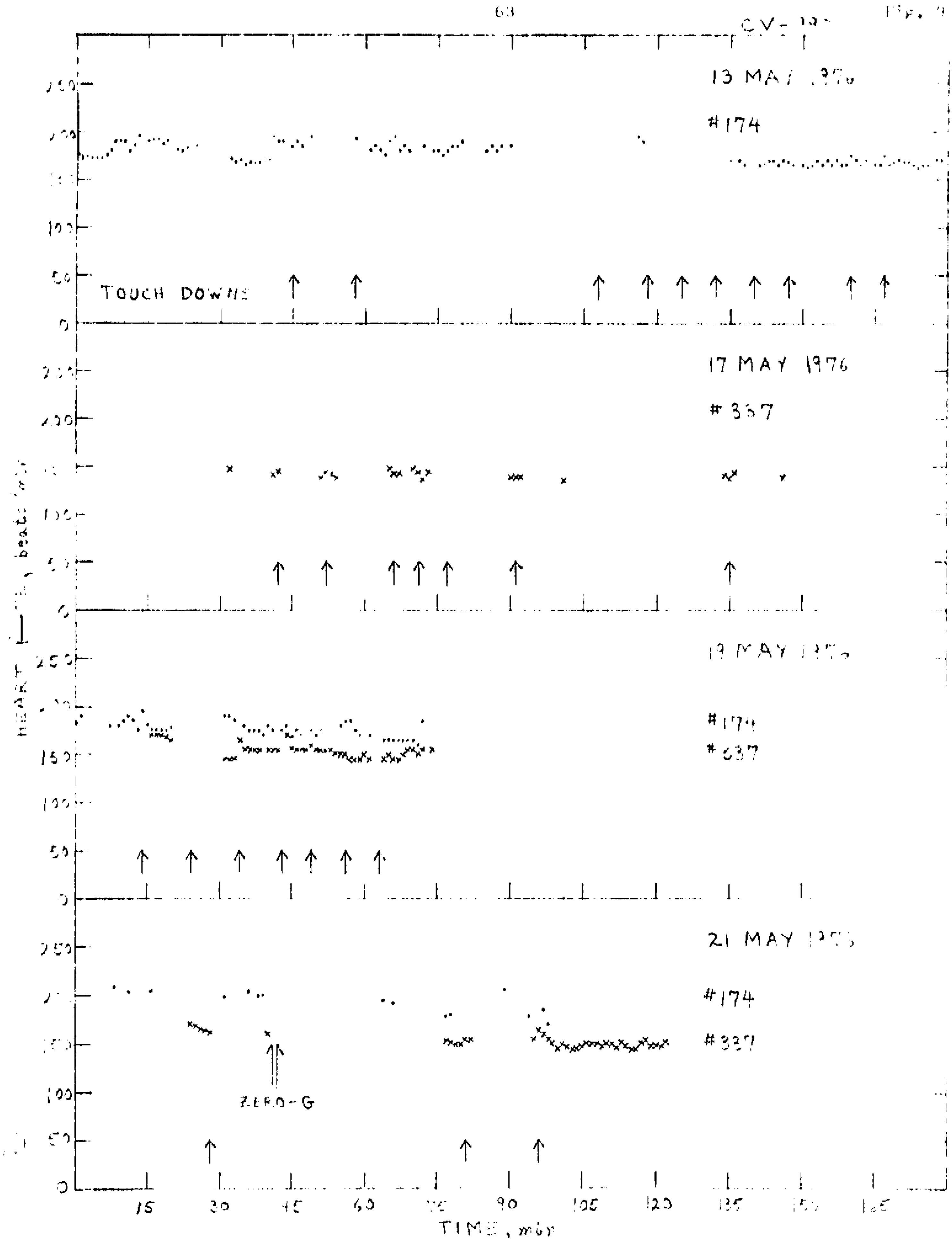

CV-990 21 MAY 1976
VERTICAL ACCELERATION, g
2.0
1.5
1.0
0.5
0
-0.5
20
40
60
80
100
120
140
160
180
200
220
240
TIME, sec

Fig. 4

Fig. 9. Heart rates of monkey #174 (skin electrodes) and monkey #337 (implanted biotelemetry) during CV-990 flights of 13-21 May 1976.


13 MAY 1976
#174
TOUCH DOWNS
17 MAY 1976
#337
19 MAY 1976
#174
#337
21 MAY 1976
#174
#337
ZERO-G
TIME, min

TABLES

Tables

Table 1. Data recording requirements for monkey pod flights on NASA/Ames CV-990

Parameter	#1 Pod Record Interval	#1 Pod Sample Duration	#1 Pod Printout Rate	#1 Pod Sample Rate	#2 Pod Record Interval	#2 Pod Sample Duration	#2 Pod Printout Rate	#2 Pod Sample Rate	Tape Channel	Brush Channel
1. M/S FO_2	15m/30m	30 sec	1/min	1/sec	15m/30m	30 sec	1/min	1/sec	#1	#1
2. M/S FCO_2	15m/30m	10 sec	1/min	1/sec	15m/30m	10 sec	1/min	1/sec		
3. M/S FH_2O	15m/30m	10 sec	1/min	1/sec	15m/30m	10 sec	1/min	1/sec		
4. M/S FN_2	15m/30m	10 sec	1/min	1/sec	15m/30m	10 sec	1/min	1/sec		
5. Mass Flow	15m/30m	C		1/sec	15m/30m	C		1/sec	#2	#2
6. M/S Inlet P	15m/30m	C		1/sec	15m/30m	C		1/sec	#3	
7. Upper Pod P	15m/30m	C		1/sec	15m/30m	C		1/sec	#4	#3
8. Lower Pod P	15m/30m	C		1/sec	15m/30m	C		1/sec	#5	
9. M/S Inlet T	15m/30m	20 sec	1/min	1/sec	15m/30m	20 sec		1/sec	#6	#4
10. #1 Up Pod T	C	10 sec	1/min	1/sec						
11. #1 Low Pod T	C	10 sec	1/min	1/sec						
12. #2 Up Pod T					C	10 sec	1/min	1/sec		
13. #2 Low Pod T					C	10 sec	1/min	1/sec		
14. #1 Pod Water	C	C		10/sec					#7	
15. #2 Pod Water					C	C	1/min	10/sec	#8	
16. #1 Pod HR	C	C		1/sec					#9	
17. #2 Pod HR					C T/M	C			#10	#5
18. #2 Pod AP					C T/M	C	1/min	250/sec	#11	#6
19. #2 Pod LVP					C T/M	C	1/min	250/sec	#12	#7
20. #2 Pod BT					C T/M	C			#13	#8
21. #2 Pod ECG					C T/M	C	1/min	250/sec	#14	

Table 2. Mechanical fabrication drawings list for pod stands and rack

		Identification No.
1.	CV-990 Monkey Pod Rack Assembly	A 57127602 M0001
2.	CV-990 Monkey Pod - Pod Subframe Assembly	A 57127602 M0002
3.	CV-990 Monkey Pod - Top and Bottom Views	A 57127602 M0003
4.	CV-990 Monkey Pod - Rack End Frame Details	A 57127602 M0004
5.	CV-990 Monkey Pod - Rack Center Frame Details	A 57127602 M0005
6.	CV-990 Monkey Pod - Rack Details	A 57127602 M0006
7.	CV-990 Monkey Pod - Rack Details	A 57[illegible] M[illegible]07
8.	CV-990 Monkey Pod - Rack Details	A 57127602 M0008
9.	CV-990 Monkey Pod - Installation	A 57127602 M0009

Table 3. Dimensions of modular components contained in the CV-990 EPL/UCB Bioinstrumentation Rack (Standard Highboy)

	INSTRUMENT	WIDTH cm	DEPTH cm	HEIGHT cm	WEIGHT kg
INBOARD BAY	Mass Spectrometer	48	63	50	12.3
	Thermo Switch Box	48	18	13	1.4
	4-Way Valve Assembly	48	42	28	5.0
	Flow-meter, Thermometer Digital Voltmeter	48	21	27	7.3
	Mass Spectrometer Controls	48	27	19	2.3
	[illegible] Plumbing	--	--	--	3.[illegible]
	Ratio Network	48	28	16	5.5
	Baratron - MKS Instruments	48	61	16	7.3
	Sub-Total				44.3
OUTBOARD BAY	Signal Conditioner - L & M Electronics	48	25	24	18.6
	Harrison Labs. Model 6267A Power Supply	48	40	15	25.0
	LBNP Controls & Plumbing	48	--	--	10.5
	LBNP pumps	48	25	35	11.5
	Sub-Total				65.6
	Top-mounted plate containing 2 water reservoirs 2 power supply boxes 2 waterer pressure sensor and switch boxes	75	61	25 (max. at ht. of water reservoir)	11.0
	Total Weight (including top-mounted plate)				120.9

Table 4. Data parameters to be signal conditioned for monkey-pod flights on NASA/ARC CV-990

1. Mass spectrometer oxygen fraction M/S F O_2
2. Mass spectrometer carbon dioxide fraction F CO_2
3. Mass spectrometer water vapor fraction F H_2O
4. Mass spectrometer nitrogen fraction F N_2
5. Mass flow
6. Mass spectrometer inlet pressure
7. Upper pod pressure
8. Lower pod pressure
9. Mass spectrometer inlet temperatur
10. No. 1 pod upper temperature
11. No. 1 pod lower temperature
12. No. 2 pod upper temperature
13. No. 2 pod lower temperature
14. No. 1 pod water and feed
15. No. 2 pod water and feed
16. No. 1 pod heart rate
17. No. 2 pod heart rate (derived from 21)
18. No. 2 pod aortic pressure (telemetered)
19. No. 2 pod left-ventricular pressure (telemetered)
20. No. 2 pod body temperature (telemetered)
21. No. 2 pod ECG (telemetered)
22. Left-ventricular change in pressure, dP/dt (derived from 19)
23. Left-ventricular end diastolic pressure (derived from 19)
24. Voice (on command)
25. Pod identification
26. Time code

Table 5. Data distribution for monkey-pod flights on NASA/ARC CV-990

PARAMETER	ADDAS CHANNELS	SAMPLES/SEC	TAPE CHANNELS	BRUSH #1 CHANNELS	BRUSH #2 CHANNELS
1	1	1	1	1	
2	2	1	1	1	
3	3	1	1	1	
4	4	1	1	1	
5	5	1	2	2	
6	6	1	-	3	
7	7	1	3	4	
8	8	1	-	6	
9-13	9	1	4	5	
14	10	10	5	-	
15	11	10	6	-	
16	12	1	7	7	
17	13	1	-	8	1
18	14	250	8		2
19	15	250	9		3
20	16	1	10		4
21	17	250	11		5
22	-		-		6
23	-		-		7
24	18		12		-
25	19	1	13		-
26	20	1	14		8

Table 6. Dimensions of modular components contained in the CV-990 EPL/UCB Data Acquisition Rack

INSTRUMENT	WIDTH cm	DEPTH cm	HEIGHT cm	WEIGHT kg
Tektronix R-4010-1 Console	42.5	50	28	7.3
Tektronix Signal Conditioner	48	51	22	13.6
Gould Brush Recorder #481	40	36	42	47.7
Gould Brush DC Preamplifier	44	29	14	4.5
3 Gould Brush Couplers (2 Cardiotachometers and 1 Transducer)	20	48	15	8.0
Gould Power Supply	12	48.5	8	6.8
Clevite Power Supply	12	48	8	5.9
Total Weight				93.8

Table 7. Dimensions of modular components contained in the CV-990 Biotelemetry (T/M) Data Acquisition Rack

INSTRUMENT	WIDTH cm	DEPTH cm	HEIGHT cm	WEIGHT kg
Gould Brush Recorder	40	36	42	47.7
Gould Brush DC Preamplifier	44	29	14	4.5
Astro Comm. Lab. Telemetry Receiver Type TR-104	44	39		4.5
Konigsberg Model D7-M Demodulator	43	44.5	13.5	4.5
Hewlett Packard 1702A Oscilloscope	28	40	19.5	13.0
Data Precision Model 134 Digital Multimeter	22.5	18	9	1.5
Hewlett Packard 721A Power Supply	18	15	10.5	2.5
Storage Locker	43.5	30	26.5	5.0
Total Weight				83.2

Table 8. T/M implanted monkeys: summary as of 13 April 1976

No.	Time in Colony (age)	Weight kg		Date of Surgery	Unit No.	Last Date Checked	Status/Comments
Flight Animals - Pig-tail *(M. nemestrina)*							
603 EPL #337, Simple		Pre Post	16.0 14.25	24 Mar 76	T21B-1 #116	13 Apr 76	Satisfactory; LVP = ? some trapping
604 EPL #422, Bushy		Pre Post	11.80 10.5	6 Apr 76	T21B-3 #120	13 Apr 76	Best signals, all excellent
Test Animal - Pig-tail							
EPL #396 Lovel		Pre Post	13.5 14.0	26 Feb 75	T21B #101	13 Apr 76	Signals present, but low level, very poor quality (could get AR)
Test Animals - Rhesus							
A 109	7-66	Pre Post	15.75 14.5	12 Feb 76	T21B-3 #113	13 Apr 76	Difficult to acquire (coil high in chest, under armpit) LVP signal distorted, other OK.
X 6	7-66	Pre Post	11.25 11.5	29 Feb 76	T21B-3 #115	13 Apr 76	Difficult to acquire, no ECG, pressures OK

Table 9. Summary of monkey pod experiment NASA CV-990 flights

Date		Experiment Elements on Board	Monkey Pod Experiment Related Personnel on Board		Remarks (Hrs = Duration from Takeoff to Return
30 Apr 76	Fri	Checkout T/M electronics for A/C RFI or EMI problems	R. Miranda G. Hoggess	ARC ARC	No electronic interference Moffett - StK - Moffett - 2 hrs
4 May 76	Tu	Performance of pods w/o monkeys	S. Kurasaki D. F. Rahlmann	ARC UCB	Pods secured in vertical and supine positions during flight Moffett - StK - Sac - Moffett - 3 hrs
6 May 76	Th	#337, Simple T/M monkey inboard pod	G. Hoggess R. Miranda D. F. Rahlmann	ARC ARC UCB	Cardiovascular measurements, strip chart recording. Monkey supine and vertical. Moffett - EAFB - Moffett - 4 hrs
7 May 76	Fri	#337, Simple T/M monkey inboard pod	G. Hoggess D. F. Rahlmann	ARC UCB	Cardiovascular measurements; strip chart recording. Moffett - EAFB - StK - Moffett - 4 hrs
11 May 76	Tu	#174 Exeter - control,outb pod #337 Simple - T/M, inbd pod All instrumentation rack operational	A. M. Kodama R. C. Mains D. F. Rahlmann R. W. Johnson G. Hoggess R. Miranda N. Donnelly	UCB UCB UCB ARC ARC ARC Northrop	Commutated 2 pod RGE and cardiovascular measurement T/M and hardware. Strip chart recorder. Moffett - EAFB - Moffett - 10 hrs
13 May 76	Thu	2 Monkey Pods as above 11 May + CP100 Tape Recorder	N. Pace R. C. Mains D. F. Rahlmann B. D. Newsom R. W. Johnson G. Hoggess J. Connally N. Donnelly	UCB UCB UCB ARC ARC ARC ARC Northrop	Full up systems 1st test int[illegible]face computer Moffett - L[illegible] - StK - Moffett - 3 hrs

(continued)

Table 9 (continued)

Date		Experiment Elements on Board	Monkey Pod Experiment Related Personnel on Board		Remarks (Hrs - Duration from Takeoff to Return)
17 May 76	Mon	2 Monkey Pods as above 13 May	B. W. Grunbaum	UCB	All systems activated
			H. Hoffman	UCB	Moffett - StK - San Jose - SF - Moffett
			A. M. Kodama	UCB	3 hrs
			R. C. Mains	UCB	
			D. F. Rahlmann	UCB	
			B. D. Newsom	ARC	
			G. Hoggess	ARC	
			R. W. Johnson	ARC	
			2 Co. Representatives	McD-D	
			2 Co. Representatives	Lockheed	
19 May 76	Wed	2 Monkey Pods as above 17 May	R. C. Mains	UCB	All systems activated
			D. F. Rahlmann	UCB	Moffett - StK - Moffett - 2 hrs
			J. Connally	ARC	
			G. Hoggess	ARC	
			N. Donnolly	Northrop	
21 May 76	Fri	2 Monkey Pods as above 19 May + PCM module	R. C. Mains	UCB	2 periods of zero-*g* in flight
			D. F. Rahlmann	UCB	All systems activated
			J. Connally	ARC	Moffett - StK - Reno - Moffett - 3 hrs
			E. McCutcheon	ARC	+ post-flight LBNP in A/C on ground
			B. D. Newsom	ARC	after return to Moffett
			G. Hoggess	ARC	
			N. Donnolly	Northrop	

Hrs Total Takeoff to Return

Monkey Hours	Simple	Exeter	
	29	21	50 Monkey Hours

Table 10. Summary of respiratory gas exchange measurements on 2 pig-tailed monkeys during CV-990 flight of 13 May 1976.

		Exeter (#174)	Simple (#337)
O_2 Consumption (cm^3/min, STP)	Mean	90.1	91.3
	Range	59-130	50-167
	S.D.	12.3	32.1
	n	81	85
CO_2 Production (cm^3/min, STP)	Mean	73.5	67.4
	Range	53-114	38-115
	S.D.	11.5	19.7
	n	81	85
Respiratory Quotient	Mean	0.815	0.754
	Range	0.689-1.034	0.644-0.889
	S.D.	0.046	0.071
	n	81	85

Table 11. Summary of respiratory gas exchange measurements on 2 pig-tailed monkeys during CV-990 flight of 17 May 1976.

		Exeter (#174)	Simple (#337)
O_2 Consumption (cm^3/min, STP)	Mean	95.6	97.0
	Range	71-148	83-138
	S.D.	17.2	12.1
	n	68	68
CO_2 Production (cm^3/min, STP)	Mean	81.7	71.0
	Range	66-143	63-106
	S.D.	16.6	8.7
	n	68	68
Respiratory Quotient	Mean	0.857	0.733
	Range	0.680-1.040	0.663-0.845
	S.D.	0.100	0.026
	n	68	68

Table 12. Summary of respiratory gas exchange measurements on 2 pig-tailed monkeys during CV-990 flight of 19 May 1976.

		Exeter (#174)	Simple (#337)
O_2 Consumption (cm^3/min, STP)	Mean	84.3	87.7
	Range	76-91	69-108
	S.D.	4.4	10.1
	n	28	45
CO_2 Production (cm^3/min, STP)	Mean	68.6	62.9
	Range	58-76	50-77
	S.D.	4.8	6.7
	n	28	45
Respiratory Quotient	Mean	0.814	0.719
	Range	0.753-0.904	0.651-0.830
	S.D.	0.044	0.044
	n	28	45

Table 13. Summary of respiratory gas exchange measurements on 2 pig-tailed monkeys during CV-990 flight of 21 May 1976.

		Exeter (#174)	Simple (#337)
O_2 Consumption (cm^3/min, STP)	Mean	109.6	102.2
	Range	86-155	82-132
	S.D.	14.3	12.3
	n	75	73
CO_2 Production (cm^3/min, STP)	Mean	91.0	75.2
	Range	74-135	62-120
	S.D.	12.6	11.9
	n	75	73
Respiratory Quotient	Mean	0.831	0.732
	Range	0.730-1.011	0.654-0.909
	S.D.	0.054	0.045
	n	75	73

Table 14. Comparison of values* for some selected respiratory gas exchange parameters derived from (a) a direct strip chart recording and (b) a strip chart transcription or replay of an analog tape recording obtained during CV-990 flight of 21 May 1976.

G.M.T.	Monkey No.	Exhaust Air F_{O_2} (a)	Exhaust Air F_{O_2} (b)	Exhaust Air F_{CO_2} (a)	Exhaust Air F_{CO_2} (b)	Mass Flow (cm^3/min) (a)	Mass Flow (cm^3/min) (b)	Upper Pod Pressure (torr) (a)	Upper Pod Pressure (torr) (b)	M/S Inlet Temperature (°C) (a)	M/S Inlet Temperature (°C) (b)
19:47	Simple (#337	0.1878	0.1881	0.0110	0.0114	7000	7000	632	631	26.0	26.2
:48		0.1878	0.1876	0.0110	0.0114	7000	7000	632	631	25.8	26.0
:49		0.1884	0.1881	0.0110	0.0109	7000	7000	632	631	25.8	26.0
:50		0.1889	0.1887	0.0110	0.0109	7000	7000	632	631	25.6	26.0
:51		0.1889	0.1887	0.0110	0.0109	7000	7000	632	631	25.6	26.0
:52		0.1894	0.1892	0.0099	0.0103	7000	7000	632	631	25.6	26.0
:53		0.1900	0.1897	0.0099	0.0098	6900	7000	622	621	25.6	26.0
:54		0.1889	0.1887	0.0110	0.0109	6700	6700	601	604	25.6	26.0
:55		0.1889	0.1887	0.0104	0.0109	6800	6700	610	612	25.6	26.0
:56		0.1894	0.1892	0.0104	0.0109	6900	6800	618	618	25.8	26.2
:57	Exeter (#174)	0.1836	0.1840	0.0163	0.0162	7100	7100	620	622	26.0	26.4
:58		0.1847	0.1845	0.0157	0.0156	7100	7100	622	622	25.3	26.0
:59		0.1857	0.1855	0.0152	0.0151	7100	7100	624	624	25.1	25.6
20:00		0.1852	0.1851	0.0157	0.0156	7100	7100	624	624	24.7	25.3
:01		0.1852	0.1851	0.0152	0.0151	7200	7100	628	628	24.3	25.1
:02		0.1852	0.1851	0.0152	0.0151	7200	7100	628	628	24.2	24.9
:03		0.1852	0.1851	0.0163	0.0162	6900	6900	612	613	24.2	24.9
:04		0.1857	0.1855	0.0152	0.0151	7000	7000	620	622	24.0	24.7
:05		0.1868	0.1871	0.0141	0.0140	7200	7100	626	627	23.8	24.7
:06		0.1873	0.1871	0.0141	0.0140	7400	7300	634	632	24.0	24.7
Mean		0.1872	0.1870	0.0130	0.0130	7030	7005	624	624	25.1	25.6

* Results normalized with respect to amplification c strip chart recorder.

Table 15. Comparison of O_2 CONSUMPTION RATES (cm^3/min, STP) of 2 pig-tailed monkeys during CV-990 flight of 21 May 1976, computed (a) from post-flight analysis of strip chart records and (b) by ADDAS on a real-time basis in flight.

		(A)	(B)
Exeter (#174)	Mean	109.6	106.3
	Range	86-155	86-132
	S.D.	14.3	11.6
	n	75	71
Simple (#337)	Mean	102.2	100.2
	Range	82-132	82-124
	S.D.	12.3	10.5
	n	73	70

Comparison of CO_2 PRODUCTION RATES (cm^3/min, STP) of 2 pig-tailed monkeys during CV-990 flight of 21 May 1976, computed (a) from post-flight analysis of strip chart records and (b) by ADDAS on a real-time basis in flight.

		(A)	(B)
Exeter (#174)	Mean	91.0	81.4
	Range	74-135	65-119
	S.D.	12.6	11.5
	n	75	71
Simple (#337)	Mean	75.2	65.3
	Range	62-120	53-91
	S.D.	11.9	9.9
	n	73	70

Table 16. Comparison of 1 min average heart rates (beats/min) from sample ADDAS and Brush strip chart records during the 21 May 1976 CV-990 flight.

	Greenwich Mean Time (hours:min)		ADDAS Computation	Strip Chart Estimate	ADDAS Strip Chart
Pod #1	18:44		216	220	- 4
	18:45		212	214	- 2
	18:46		215	214	+ 1
	18:47		208	210	- 2
	18:48		214	217	- 3
	18:45		214	217	- 3
	18:50		211	215	- 4
	18:51		206	213	- 7
	18:52		201	205	- 4
	18:53		202	200	+ 2
		Mean	210	213	- 3
Pod #2	18:52		186	190	- 4
	18:53		181	187	- 6
	18:54		180	185	- 5
	18:55		178	180	- 2
	20:57		146	149	- 3
	20:58		150	152	- 2
	20:59		150	152	- 2
	21:00		147	150	- 3
	21:01		146	148	- 2
	21:02		15[illegible]	152	- 1
		Mean	162	165	- 3

Table 17. Biotelemetric cardiovascular data from the pig-tailed monkey #337, Simple, during level flight with the pod in the upright position.

Date		Heart Rate (beats/min)	Peak Left Ventricular Pressure (torr)	Aortic Diastolic (torr)	Pressures Pulse (torr)
11 May 76	Mean (6)*	154	147	108	39
	Range	(150-156)	(133-156)	(94-118)	(37-42)
17 May 76	Mean (4)*	136	136	93	38
	Range	(129-144)	(133-141)	(95-100)	(36-41)
19 May 76	Mean (4)*	137	127	87	39
	Range	(126-144)	(123-131)	(81-93)	(35-42)
21 May 76	Mean (9)*	132	122	88	34
	Range	(129-138)	(118-130)	(84-96)	(32-34)

( )* Number of observations included in the mean.

Table 18. Biotelemetric cardiovascular data from the pig-tailed monkey #337, Simple during delayed flap maneuvers of the CV-990.

		Heart Rate (beats/min)	Peak Left Ventricular Pressure (torr)	Aortic Pressures Diastolic (torr)	Pulse (torr)
Descent	Mean (10)*	143	141	103	38
	Range	138-156	126-165	92-127	34-42
Landing (10 sec period before and after touchdown)	Mean	144	140	101	38
	Range	135-159	122-151	88-113	34-42
Ascent	Mean (10)*	144	139	100	39
	Range	135-159	122-151	88-113	34-44

( )* = number of observations included in the mean

2 on 11 May 76
6 on 17 May 76
1 on 19 May 76
1 on 21 May 76

10 Total

Table 19. Monkey body weights at insertion into and removal from the pods during the periods in which CV-990 flights were made.

Monkey	Date	Action	Body Weight (kg)	Body Weight Change (kg)	(%)
#337, Simple	5 May 76	Insertion	14.45		
	7 May 76	Removal	13.85	- 0.60	- 4.2
#337, Simple	10 May 76	Insertion	13.95		
	14 May 76	Removal	13.15	- 0.80	- 5.7
#174, Exeter	10 May 76	Insertion	11.50		
	14 May 76	Removal	10.72	- 0.78	- 6.8
#337, Simple	17 May 76	Insertion	13.30		
	21 May 76	Removal	13.20	- 0.10	- 0.8
#174, Exeter	17 May 76	Insertion	10.70		
	21 May 76	Removal	10.60	- 0.10	- 1.0

Table 20. Breaking strength of 3 types of monkey food pellets as measured by the Pfizer Tablet Hardness Tester.

	Purina 5040 Pellets (kg)	NASA Stanlab Pellets (kg)	"Brand X" Pellets (kg)
	3.15	11.00	2.55
	3.05	12.05	2.40
	3.20	13.80	2.20
	2.95	11.40	2.25
	2.80	12.35	2.30
	3.05	10.85	2.30
	2.80	12.05	2.30
	3.45	12.20	2.15
	3.00	12.05	2.50
	3.25	12.80	2.40
n	10	10	10
Mean	3.07	12.06	2.33
S.D.	0.20	0.86	0.13
S.E.	0.06	0.27	0.04
CV	6.5%	7.1%	5.6%

Table 21. Food and water intake summary.

Inclusive Days in Pod	Duration of Pod Restraint (hrs)	Monkey	Food Pellets Consumed (no.)	Water Consumed (ml)
5-7 May	48	#337, Simple	35	1,050
10-14 May	92	#337, Simple	155	1,650
17-21 May	104	#337, Simple	172	1,650
10-14 May	92	#174, Exeter	220	2,100
17-21 May	104	#174, Exeter	534	2,050

Table 22. Effect of supine LBNP on heart rate in 2 monkeys during ground-based tests during the CV-990 flight experiment.

Date	Monkey	Heart Rate (beats/min)*				
			LBNP (torr)			
		Control	40	50	60	Recovery
1[illegible] May **						
	#337	162	168	162	216	156
	#174	185	195	195	195	140
21 May***						
	#337	175	--	--	225	178
	#174	175	--	--	225	180

* All data obtained during last minute of control, LBNP and recovery periods.

** LBNP tests on this day consisted of 5 min at each of three pressures.

*** LBNP tests on this day consisted of 2 min at 60 torr only. Data for subject #337 is mean of 4 tests.

Table 23. Timed urine collections from monkey pods during CV-990 experiment activities.

Date	Time	#337, Simple Urine Volume (ml)	#337, Simple Elapsed Time (hr)	#337, Simple Excretion Rate (ml/hr)	#174, Exeter Urine Volume (ml)	#174, Exeter Elapsed Time (hr)	#174, Exeter Excretion Rate (ml/hr)
10 May 76	2200	--	0	--	--	0	--
12 May 76	0800	325	34	10	655	34	19
13 May 76	0800	220	24	9	255	24	11
14 May 76	0800	435	24	18	375	24	16
	Total	980	82	12	1285	82	16
17 May 76	0800	--	0	--	--	0	--
18 May 76	0800	115	24	5	325	24	14
19 May 76	0800	115	24	5	220	24	9
20 May 76	0800	265	24	11	100	24	4
21 May 76	0800	275	24	11	435	24	18
	Total	770	96	8	1080	96	11

APPENDICES

A. Daily Schedule

B. Protocol for Monkey Insertion, Inflight, Post-Flight and Removal from Pod.

C. Pre-flight calibration procedures for Respiratory Gas Exchange and Cardiovascular Measurements.

D. Respiratory Gas Exchange Instrumentation Ground to Aircraft Power Transition, In-Flight Data Collection, and Shut-Down Procedures.

E. Starting Operations on the Respiratory Gas Exchange Instrumentation.

F. Calibration of Respiratory Gas Exchange Instrumentation and Integration with Strip Chart Recorders, Tape Recorders and the ADDAS Computer.

G. Monkey Pod Telemetry System.

H. On-line Data Reduction of Respiratory Gas Exchange Measurements using the ADDAS and Computer System of the CV-990.

I. On-line Computation of Mass Spectrometer Inlet Pressure and Upper Pod Pressure.

J. On-line Computation of Lower Pod Pressure.

K. On-line Computation of Mass Spectrometer Inlet Temperature, No. 1 Upper Pod Temperature, No. 1 Lower Pod Temperature, No. 2 Upper Pod Temperature, and No. 2 Lower Pod Temperature.

L. On-line Computation of Heart Rate.

M. Food and Water Data Information Requested from Computer Printout.

N. CV-990 Flight Plan Delayed Flap Program.

O. CV-990 ADDAS Computer Output from Monkey Pod Experiment.

P. Sample Computation of respiratory gas exchange for ADDAS.

Q. LBNP Calibration and Operations Procedures for the CV-990 Monkey Pod Flights.

APPENDIX A

DAILY SCHEDULE

EPL/UCB and NASA/ARC

Monkey Pods Experiments - CV-990

Date ______________________________

Estimated Take Off Time ____________

Time	Activity	Action
TBD	Monkey Insertions in Pod	Monday - each week Transport from Bldgs. 236 to 211 Refer to Schedule A where applicable.
0800-0930	Pre-flight Bioinstrumentation calibration	
0830	Standup preflight meeting	
0915	Monkey Pods - Aircraft Installation	
0930	Final All Systems Check Removal of proximal off-board equipment Aircraft doors shut Hold to take off	
1000 = T	Take off	
T to T+180 min	Flight Experiment Procedures	Refer to operational protocol where applicable.
T + 180 min = L	Landing Post-flight calibrations Off load - monkey pods	
TBD	Final ground observational checks: bioinstrumentation and monkey pods	
TBD	Monkey removal from pods	Fridays each week Transport from Bldg. 211 to 236 - Refer to Schedule A where applicable.
	When pertinent, entries in experiment log made throughout each day.	

APPENDIX B

EPL/UCB and NASA/ARC Monkey-Pod Experiment on CV-990 - General Protocol - Monkey Insertion, Inflight, Post-flight, and Removal from Pod. (T = takeoff time for aircraft.)

Time	Event
T minus 120 min	Pod preparation prior to monkey insertion at Bldg. 236. Check cleanliness of lower and upper pod sections. Feeder secured in place and capable of being operated manually in upper pod. Remove blotting paper or other excreta absorbent material from plastic bag and insert in lower pod.
	Selection of 2 test subjects in individual colony squeeze cage on basis of physical condition, feeding and watering pattern and previous performance in pod configuration. #1 (instrumented with T/M implant) and #2 (control without T/M implant).
	Test subjects secured in squeeze cage. Single intramuscular (IM) injection of Ketamine Hydrochloride (4 to 6 mg/kg of body wt) and Atropine Sulfate (0.04 mg/kg of body wt).
	The following operations for #1 and #2 monkeys can be accomplished in parallel or tandem, depending on available trained personnel. Times as[illegible]d here are for both monkeys in parallel.
	Monkeys #1 and #2 removed from cage when tranquilizer effective, examined and weighed to nearest 10 grams. Weight recorded. Monkey placed on prep. table.

Time	Event

Monkey #1 checked for proper positioning of external energizing coil for reception of appropriate T/M signal output.

Monkey #2 prepared for application of silver-silver chloride ECG electrodes by shaving thorax, scrubbing skin with gauze sponges and surgical soap followed by 70% alcohol wipe. Electrodes filled with paste, applied with double-stick washers and covered with a foam adhesive disc.

Minimum of 2 people required for following operations on each monkey:

(1) Silicone divider seal passed over legs and positioned at iliac crest level.

(2) Elastic waistband applied to central sleeve of divider seal.

(3) Restraint jacket passed over head, velcro closure mad and sewn with nylon cord. #1, apply exterior energizing coil and pass leads dorsally. #2, pass ECG leads dorsally.

(4) Lower Body Negative Pressure (LBNP) waist template assembled around waist with rubber gasket on edge of central hole.

(5) LBNP waist template support plate passed over legs and positioned at iliac crest level of monkey.

(6) Monkey placed in lower half of pod couch (sitting on table) and parts listed in steps 5, (oiled spacer bar "O" rings), 1, and 3 (in that order) passed over spacer bars of couch.

(7) Upper half of pod couch joined to lower half, and restraint jacket hammock secured to upper half of couch.

(8) Upper and lower leg restraint bars positioned and secured.

Time	Event
	(9) Entire couch/pod divider/monkey assembly passed into the lower pod by one person holding onto the upper couch, while second person directs the positioning through the window on lower pod.
	(10) Waist template support plate pressed into position, compressing the silicone "O" ring seal.
	(11) Divider seal and jacket skirt edges slid into the groove in the edge of the pod divider shelf and compression ring and retainer ring placed on the jacket skirt perimeter and secured with screws.
	(12) Press rubber "O" rings into beveled seat on support plate.
	(13) Upper/lower pod "O" ring placed in groove of the lower pod and the upper pod set in place. #1, place receiving antenna and exteriorize leads of energizing coil through upper pod. #2, exteriorize ECG leads through upper pod.
	(14) Barrel or Marmon clamp placed over the edges of the upper and lower pod and the clamp tightened with bolt.
	Transport of monkey/pods from Bldg. 236 to Bldg. 211 in government furnished transport vehicle. If this step delayed, provision should be made for air flow through upper and lower pod.
	The following procedures are to be considered if flight is scheduled on day of monkey insertions into pods.
T - 30 min	On board loading of monkey pods. Connecting of interfacing electronic, gas, waterer, and food reservoir lines. Add known quantities of food and water to reservoirs.
T - 5 min	Final ground check out of total experiment package.

Time	Event
T to L (landing)	Following takeoff and throughout flight, data parameters will be recorded as shown in Table 1.
TBD	The initiation and sequencing of lower body negative pressure trials will be determined in relationship to the actual flight pattern schedule of the aircraft (TBD).

LBNP trials to be performed as follows:

(1) Throughout test monkey should ideally not be exposed to noise (other than background) of human, other organism, or equipment origin. Monkey should not be able to observe human or other organisms through upper pod window.

(2) Control Period:

Record heart rate and make notes of any monkey behavior which can be discerned, e.g. shaking pod.

(3) LBNP period:

Same as in (2), then the following, in order.

(a) To initiate LBNP -- shut off lower pod air flow switch.

(b) Shut off air inlet valve to lower pod.

(c) Turn air outlet, lower pod valve to LBNP.

(d) LBNP switch to ON

(e) Increase voltage on LBNP control knob to give 15 mm Hg neg. press. as read from transducer channel on Brush recorder. Gradually increase voltage over period of about 15 seconds.

(f) Maintain pressure for 15 min.

(g) Decrease voltage on LBNP control knob to zero.

(h) LBNP switch to OFF.

(i) Turn air outlet, lower pod valve to Ventilation.

Time	Event
	(j) Open air inlet valve to lower pod.
	(k) Turn on lower pod air flow switch.
	(4) Recovery period:
	Same as.in (2).
L	Procedure to follow on return to base from each day's flight.
L + 10 min	Final checkout of bioinstrumentation and data acquisition system collection of flight strip chart recordings for analysis.
L + 15 min	Disconnect interfacing lines to pods and prepare for unloading and record amount of food and water consumed.
L + 20 min	Move pods to ground based positions designated area in Bldg. 211.
L + 30 min	Attach air lines (intake and exhaust) for ventilation of upper and lower pod sections.
L + 120 min	Observational notations made on monkey behavior and performance from L + 30. Corrective action taken if needed before lights out period.

The above procedures will be carried out on Monday of each week of the tentative flight schedule. Removal (R)/or recovery of the monkey from the pod will be carried out on Fridays as follows.

Time	Event
L + 20 min (of last flight during weekly series)	Move pods from aircraft to transport vehicle. Transport to Bldg. 236.
L + 30 min = R	Count all food tablets remaining in feeder.
	Remove upper pod.
	Tranquilize monkeys.
	Remove debris and record number of uneaten food tablets which may be present.
	Disassemble divider parts in reverse order of insertion procedure.
	While removing couched monkeys:
	Cleanse lower couch with distilled H_2O and clean spatula, allowing washings to be added to lower pod contents.
	Remove monkeys from couch.
	Wash lower couch with distilled H_2O and spatula - washings to lower pod contents.
	Wash lower portion of monkey body with distilled H_2O - washings to lower pod contents.
	Determine body weight of test monkey and return to cage.
	Remove lower pod contents and place in container for subsequent chemical analysis.
	Wash lower pod interior with distilled H_2O and spatula - add washings to container.
	Store container at -15°C.
R + 90 min	Observational notations on cage behavior.
	Wash and store pod parts in appropriate order for assembly and monkey insertion when scheduled for weekly series of subsequent flight trials or ground laboratory base line studies.

APPENDIX C

EPL/UCB Protocol for Bioinstrumentation Procedures for
Monkey-Pod Experiment on CV-990 Flights.

(Pre-flight calibrations to be carried out each day)

(T = aircraft takeoff)

Time	Event
T - 120 mins	Pre-set calibration gas flows from onboard cylinders or ground base cylinder on dollies to insure out-board leak in calibration gas line, and leave "zero" cylinder flow ON.

Enter experiment area aboard CV990 aircraft to record EPL/WMRS/UCB data and carry out following:

Record in-line barometric pressure sensor.

Mass spectrometer (MS) operations.

(a) Place MS Output/DVM Switch to Voltage position and record MS inlet pressure transducer voltage on DVM.

(b) Adjust Sample Outlet Valve as needed to set above voltage between 3.490 and 3.510 volts.

(c) Place MS Output/DVM Switch to Current position and record MS ion pump current (measured as a negative voltage) on DVM. The nominal reading is between -20 and -10 millivolts.

(d) Place MS Output/DVM Switch to the CO_2, O_2, N_2, and H_2O positions and record MS signal outputs on [illegible] for CO_2, O_2, N_2, and H_2O respectively for pod air.

During normal running mode, the MS sampling system will be set with the Sample Valve in the Pod position, and the Calibration Valve in the Cabin Air position.

(e) Turn Sample Valve to Calibration position (activating Calibration Valve).

MS should now be sampling cabin air.

Time	Event
	(f) Place MS Output/DVM Switch to Voltage position and adjust Sample Outlet Valve as needed to set voltage between 3.490 and 3.510 volts.
	(g) Allow 5 minutes for stabilization of readings, then place MS Output/DVM Switch to the CO_2, O_2, N_2, and H_2O positions and record MS signal outputs on DVM for CO_2, O_2, N_2, and H_2O respectively for cabin air.
	(h) Turn Calibration Valve to Cylinder position. MS should now be sampling from the "zero" calibration gas cylinder.
	(i) Place MS Output/DVM Switch to Voltage position and adjust Sample Outlet Valve as needed to set voltage between 3.490 and 3.510 volts.
	Adjust recorder base lines as needed with the "zero" calibration gas. CO_2 5 div from left of chart O_2 5 div from right of chart N_2 Mid-scale (25 div) H_2O 5 div from left of chart
	Run calibration curves by connecting calibration gas line, in turn, to cylinders 1, 2, and 3. Allow about 5 minutes for each cylinder. Re-connect calibration gas line to "zero" cylinder.
	Disconnect calibration gas line at cylinders and allow MS to sample aircraft cabin air.

Time	Event
	Shut off main valves on calibration gas cylinders.
	In the event of power failure in test facility or accidental loss of power to mass spectrometer during a trial, close MS Sample Inlet Valve (blue handle) fully clockwise and snug as soon as possible.
	The mass spectrometer is protected against application of power out of normal sequence and will not return to operation upon restoration of power.
	Procedures r quired to restore operation of mass spectrometer will depend on duration of power outage and time before closure of valve.
T - 60	The calibration of the pressure transducer and gauge should be done before the monkey pod is connect to and after it is disconnected from the console inside the aircraft. The calibration of the Biotachometer is to be done at least twice -- at the beginning and conclusion of flight.
	Turn PRESSURE INPUT VALVE to CAL.
	On transducer pre-amplifier set SENSITIVITY to OFF and adjust pen POSITION to convenient base line (one large division to left of right margin of paper).
	Increase SENSITIVITY in steps and move pen back to base line with BALANCE CONTROL. Set SENSITIVITY to 10/DIV.
	Attach manometer system to PRESSURE CAL. PORT.
	Close leak on rubber pressure bulb and apply 20 in. water pressure.

Time	Event
	Set pen at eight large divisions to left of base line by adjusting GAIN control.
	Reduce pressure to 10 in. water momentarily and then drop to 0 in. water by opening leak valve on bulb.
	If base line unchanged, proceed to next step; if changed, set pen POSITION to base line and repeat.
	Write pressure values of 20, 10 and 0 in. water on strip chart on appropriate line.
	Remove manometer system from PRESSURE CAL. PORT and turn PRESSURE INPUT VALVE to POD.
T - 40	Calibration of biotachmeter with ECG simulator.
	Turn SENSITIVITY to OFF and RESPONSE to BEAT.
	Set pen position on recorder right edge of chart with ZERO control.
	Turn SENSITIVITY to CAL. and set pen position on left edge of chart with 50 DIV. control.
	Turn SENSITIVITY to 5 BEATS/MIN/DIV. and RESPONSE to AVE.
	If THRESHOLD light is not flashing in regular rhythm and it is expected that the subject's heart beat should be steady, then turn THRESHOLD to limit in counterclockwise direction and then gradually in clockwise direction until light flashes in regular rhythm.
	The ECG can be obtained by turning the SENSITIVITY to ECG.
	Disconnect ECG simulator.

Time	Event
T - 30	On-board loading of 2 monkey pods. Connect interfacing lines (gas, electronic, etc.) to bioinstrumentation racks.
	Initiate T/M system checkout.
	Record upper pod air flow rate and temperature from panel meters.
	Check biotachometers with actual ECG and heart rates from monkey subjects.
	Through all of foregoing calibration procedures, the integration of signal flow from pod to signal conditioners to ADDAS channels and to tape recorders should be carefully maintained.
T to L	For flight experiment operations, refer to schedule protocol for experimental pod monkeys - Appendix B.
	Continuous measurements all parameters. LBNP time TBD in respect to flight pattern.

APPENDIX D

GROUND TO AIRCRAFT POWER TRANSITION, IN-FLIGHT DATA COLLECTION, AND SHUT-DOWN PROCEDURES.

A) Following pre-flight calibration procedures, leave respiratory gas exchange instrumentation ON except mass spectrometer, which should be put in standby mode.

Note: The standby mode is assumed as a safeguard against MS venting, inasmuch as power interruption will necessarily occur during transition from ground to aircraft power.

1) Turn Loop Mode Switch to OPEN.

2) Close Sample Inlet (black handle) Valve (vertical).

3) Open Sample Outlet (micrometer handle) Valve (fully CCW).

Note: The reading on DVM in VOLTAGE position should decrease to 0 volt.

4) Close MS-Sample Inlet (blue handle) Valve (fully CW and snug).

5) Turn Filament Selector Switch to FILAMENT 1 MANUAL.

6) Turn MS Electronics Switch OFF.

B) As soon as possible after transition from ground to aircraft power, start up mass spectrometer as in Step K of "Starting Operations on Respiratory Gas Exchange Console ...."

C) Leave shelf mounted Sample Valve in CAL position and Calibration Valve in CABIN position so that MS is sampling cabin air during its "warm-up" prior to take-off.

D) Just before take-off, or after 15 minutes of "warm-up", whichever comes first, switch Sample Valve to POD position.

Adjust Sample Outlet (micrometer handle) Valve until instrument panel DVM on VOLTAGE position reads 3.500 ± 0.010 volts.

System is now in a "hands-off" and "running" mode -- sit back and monitor data outputs for duration of flight.

E) In the event of an unscheduled power interruption during flight, close MS-Sample Inlet (blue handle) Valve (fully CW and snug) AS SOON AS POSSIBLE, then complete rest of "Operate to Standby" routine as in Step A.

Upon restoration of power, start up mass spectrometer as in Step K of "Starting Operations on Respiratory Gas Exchange Console...."

F) After final landing or on "Experiments-power-off" instructions from mission manager before final landing, put MS in standby mode as in Step A, and power off all other instrumentation.

APPENDIX E

STARTING OPERATIONS ON RESPIRATORY GAS EXCHANGE INSTRUMENTATION

(IN-BOARD BAY OF UCB INSTRUMENTATION HIGH-BOY)

A) Digital Thermometer Power Switch ON.

Verify Probe Selector Switch in position A.

B) Mass Flowmeter Power Switch ON.

C) No. 1 Upper Pod Vent. Power Switch ON.

<u>Note</u>: Although certain switches and ports on the instrumentation rack are labeled Pod 1 or Pod 2 to facilitate integration with the pods, the two air flows in the system are better characterized by function -- an analyze and ventilate line and a ventilation only line. Each pod is alternately "on-line" for analyses and ventilation or just ventilation.

D) No. 2 Upper Pod Vent. Power Switch ON.

E) M/S Vac. Pump Power Switch ON.

F) DC Power Supply Switch ON (may already be on).

Verify 25 VDC output on panel meter.

G) 4-Way Valve Power Switch ON.

H) 4-Way Valve Timer Switch ON.

At next switching step of valve; i.e., from "No. 1 Pod On-Line" to "No. 2 Pod On-Line", or vice versa, turn Timer OFF.

At the next quarter-hour (clock time) turn Timer back ON.

The alternation between Pod 1 and Pod 2 for respiratory gas exchange measurements at 15-minute intervals should now occur at approximately each quarter-hour.

I) Baratron Power Switch ON.

J) Plug in heating tapes on High-Boy/Pods Interface Panel.

K) Mass Spectrometer operations.

Ref.: Operation of NASA/Skylab Mass Spectrometer Instructions dated February 1975.

In standby mode during CV990 operations, switches on the MS Control Unit and MS Sample Valves should be in the following positions:

1) Main Power ON.
2) Ion Pump Switch ON.
3) MS Electronics Switch OFF.
4) Filament Selector Switch on FILAMENT 1 MANUAL.
5) Loop Mode Switch on OPEN.
6) Sample Inlet (black handle) Valve CLOSED (vertical).
7) Sample Outlet (micrometer handle) Valve OPEN (fully CCW).
8) MS-Sample Inlet (blue handle) Valve CLOSED (fully CW).

To operate,

1) Place instrument panel DVM Switch in CURRENT position.

DVM should read between -100 and -10 millivolts.

If not, high vacuum compartment of MS may have vented, requiring the "cryopump" procedure.

Caution: DO NOT proceed until a safe vacuum condition is established.

If aircraft power has been off, the MS is considered to be in a "shut-down" mode. Hence, allow about 30 minutes for nominal voltage to be obtained.

If cryopumping becomes necessary, the MS will be removed from the high-boy at the end of the flight and the procedure carried out at EPL/WMRS/UCB.

For disconnect and cryopump procedures, see Operation of Mass Spectrometer Instructions dated 18 June 1974. (Note: Cables J1 and J3 will have to accompany the MS for use with the Systems Test Unit at EPL).

2) Turn MS Electronics Switch on MS Control Unit ON.

3) Press and release Power Reset Button.

4) Switch DVM to voltage position.

5) Close Sample Outlet (micrometer handle) Valve (CW) 4-1/2 turns.

6) Open Sample Inlet (black handle) Valve (CCW) until DVM reads approx. 3.5 volts.

7) Adjust Sample Outlet (micrometer handle) Valve until DVM reads 3.500 $\pm$ 0.010 volts.

8) Open MS-Sample Inlet (blue handle) Valve (CCW) 2 turns.

9) Turn Filament Selector Switch to FILAMENT 2 MANUAL.

10) Turn Loop Mode Switch to CLOSED.

Mass Spectrometer is now in operation.

L) Allow 15 minutes to stabilize all instrumentation before proceeding with calibrations.

APPENDIX F

CALIBRATION OF RESPIRATORY GAS EXCHANGE INSTRUMENTATION and INTEGRATION WITH STRIP-CHART RECORDERS, TAPE RECORDER, AND THE ADDAS COMPUTER.

A) Digital Thermometer (Parameters 9-13).

1) Switch Temperature Multiplexer to AUTO (ON) and depress CAL Button.

   Place Reference Temperature Switch to 20°C position for zero cal. value.

   Record voltage corresponding to °C from ADDAS video display on Cal. Factors Work Sheet.

   Set analog tape recorder Channel 4 to zero.

   Set strip chart recorder Channel 5 to zero.

2) Place Reference Temperature Switch to 40°C position for full-scale cal. value.

   Record voltage corresponding to °C from ADDAS video display on Cal. Factors Work Sheet.

   Set analog tape recorder Channel 4 to full-scale.

   Set strip chart recorder Channel 5 to full-scale.

3) Leave Reference Temperature Switch at 40°C and retract CAL Button.

B) Mass Flowmeter (Parameter 5)

1) Set mass flow at 8,000 cm^3/minute using panel meter and flow control valve for zero cal. value.

   Record voltage corresponding to 8000 cm^3/minute from ADDAS video display on Cal. Factors Work Sheet.

   Set analog tape recorder Channel 2 to zero.

   Set strip chart recorder Channel 2 to zero.

2) Set mass flow at 10,000 cm^3/minute using panel meter and flow control valve for full-scale cal. value.

Record voltage corresponding to 10,000 cm^3/minute from ADDAS video display on Cal. Factors Work Sheet.

Set analog tape recorder Channel 2 to full-scale.

Set strip chart recorder Channel 2 to full-scale.

3) Return mass flow to nominal 9,000 cm^3/minute.

4) Verify volume flow of approx. 9 liters/minute on rotameter in ventilation only line.

C) MS Inlet Pressure Meter (Parameter 6).

1) Place instrument panel DVM to VOLTAGE position.

Set MS Inlet Pressure at 190 torr (2.6 volts on DVM) using MS Sample Outlet (micrometer handle) Valve for zero cal. value.

Record voltage corresponding to 190 torr from ADDAS video display on Cal. Factors Work Sheet.

No analog tape recorder channel.

Set strip chart recorder Channel 3 to zero.

2) Set MS Inlet Pressure at 260 torr (3.6 volts on DVM) using MS Sample Outlet (micrometer handle) Valve for full-scale cal. value.

Record voltage corresponding to 260 torr from video display on Cal. Factors Work Sheet.

No analog tape recorder channel.

Set strip chart recorder Channel 3 to full-scale.

3) Return MS Inlet Pressure to nominal 253 torr (3.5 on DVM).

D) Baratron (Parameter 7).

1) Set Baratron signal equivalent to 580 torr by (a) placing Offset Voltage Switch to READ and (b) using 4-Decade Offset Voltage Controls to obtain a panel meter reading of 58 for zero cal. value.

Record voltage corresponding to 580 torr from ADDAS video display on Cal. Factors Work Sheet.

Set analog tape recorder Channel 3 to zero.

Set strip chart recorder Channel 4 to zero.

2) Set Baratron signal equivalent to 780 torr by (a) placing Offset Voltage Switch to NEG and (b) using 4-Decade Offset Voltage Controls to obtain a panel meter reading of 78 for full-scale cal. value.

Record voltage corresponding to 780 torr from ADDAS video display on Cal. Factors Work Sheet.

Set analog tape recorder Channel 3 to full-scale.

Set strip chart recorder Channel 4 to full-scale.

3) Return Baratron to normal operation by (a) placing Offset Voltage Switch to OUT and (b) zeroing all 4-Decade Offset Voltage Controls.

E) Mass Spectrometer (Parameters 1-4).

1) Pre-set cal. gas cylinder flows to insure out-board leak in Calibration gas line and to prevent over-pressurizing MS sample line.

Note: A mid-column position of float in Leak Indicator (mounted on LBNP panel of out-board bay of UCB Instrumentation High-Boy) satisfies above conditions.

2) Place instrument panel DVM to VOLTAGE position and adjust Sample Outlet (micrometer handle) Valve as needed to set voltage between 3.490 and 3.510 volts.

E,2) Directly in front of the panel mounted MS sample valves are two shelf mounted valves labeled SAMPLE and CALIBRATION. The Sample Valve has two positions labeled POD and CAL. The Calibration Valve has two positions labeled GASES and CABIN.

During MS shut-down or standby modes, the shelf mounted valves will normally be set with the Sample Valve in the CAL position and the Calibration Valve in the CABIN position.

3) Attach cal. gas line to Cal. Cyl. #1.

4) Turn Calibration Valve to GASES position and check to see that the Leak Indicator shows correct gas flow.

5) Adjust Sample Outlet (micrometer handle) Valve as needed to set VOLTAGE on instrument panel DVM to between 3.490 and 3.510 volts.

6) Allow 5-10 minutes for Cal. Gas #1 to flush sampling system and provide stable readings of gas fractions for F_{O_2}, F_{CO_2}, F_{H_2O}, and F_{N_2} zero cal. values.

Record voltages corresponding to F_{O_2} of 0.2089, F_{CO_2} of 0.0003, F_{H_2O} of 0.0 and F_{N_2} of 0.7908 from ADDAS video display on Cal. Factors Work Sheet.

Set analog tape recorder Channel 1 to zero for multiplexed signal of gas fractions.

Set strip chart recorder Channel 1 to zero at mid-scale for multiplexed signal of gas fractions.

7) Move cal. gas line to Cal. Cyl. #2.

8) Allow 5-10 minutes for Cal. Gas #2 to flush sampling system and provide stable readings for F_{O_2} and F_{CO_2} full-scale cal. values.

E,8) Record voltages corresponding to F_{O_2} of 0.1910 and F_{CO_2} of 0.0184 from ADDAS video display on Cal. Factors Work Sheet.

Set analog tape recorder Channel 1 to 80% full-scale for F_{O_2} and F_{CO_2}.

Set strip chart recorder Channel 1 to 80% full-scale for F_{O_2} and F_{CO_2}.

9) Move cal. gas line to Cal. Cyl. #3.

10) Allow 5-10 minutes for Cal. Gas #3 to flush sampling system and provide a stable reading for F_{N_2} full-scale cal. value.

Record voltage corresponding to F_{N_2} of 0.7476 from ADDAS video display on Cal. Factors Work Sheet.

Set analog tape recorder Channel 1 to 80% full-scale for F_{N_2}.

Set strip chart recorder Channel 1 to 80% full-scale for F_{N_2}.

11) Shut off cal. gas cylinders (3) and turn shelf mounted Calibration Valve to CABIN position.

12) To use Cal. Cyl. #4 (small, internal MS cylinder for F_{H_2O} standard), close Sample Inlet (black handle) Valve to vertical.

13) Open Sample Outlet (micrometer handle) Valve fully CCW.

Note: The reading of instrument panel DVM in VOLTAGE position should decrease to 0 volt.

14) Place toggle switch of Cal. Gas Control to Cal. II position (down).

15) Partially close Sample Outlet (micrometer handle) Valve CW until a reading of approximately 3.5 volts is obtained on the instrument panel DVM.

16) Place F_{H_2O} Signal Divider (4:1) Switch (on Ratio Network panel on fore side of in-board bay in UCB Instrumentation High-Boy) to 1/4 position.

17) Allow 1 minute for Cal. Gas #4 flush sampling system and provide a stable reading for F_{H_2O} full-scale cal. value.

Record voltage corresponding to F_{H_2O} of 0.0516 from ADDAS video display on Cal. Factors Work Sheet.

Set analog tape recorder Channel 1 to 80% full-scale for F_{H_2O}.

Set strip chart recorder Channel 1 to full-scale for F_{H_2O}.

18) Place toggle switch of Cal. Gas Control to OFF position (horizontal).

19) Place F_{H_2O} Signal Divider (4:1) Switch to DIRECT position.

20) Open Sample Outlet (micrometer handle) Valve fully CCW.

Note: The reading of instrument panel DVM in VOLTAGE position should decrease to 0 volt.

21) Close Sample Outlet (micrometer handle) Valve (CW) 4-1/2 turns.

22) Open Sample Inlet (black handle) Valve (CCW) until DVM reads approx. 3.5 volts.

23) Adjust Sample Outlet (micrometer handle) Valve until DVM reads 3.500 $\pm$ 0.010 volts.

24) MS should now be sampling cabin air.

F) On-line Computer.

1) Take Cal. Factors Work Sheet and compute cal. factor <u>m</u> for all the parameters.

2) Enter <u>m</u> and <u>b</u> values for each parameter at the ADDAS terminal for storage and on-line computations.

3) Computer should then be instructed via terminal to assume mode which will permit determination of cabin air composition.

4) Enter cabin air data at terminal for storage and on-line computation of $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$.

   Note: If appropriate programming is available, items 3 and 4 may be accomplished in a single operation.

5) Instruct computer via terminal that calibrations are complete and to assume "RUN" mode.

6) Set analog tape and strip chart recorders in "RUN" mode.

APPENDIX G

MONKEY POD TELEMETRY SYSTEM

The multichannel telemetry system for the monkey pod experiment is designed to recover the coded information from a given channel multiplexed telemetry signal. The demodulator provides analog "high level" signals suitable to drive standard recording instruments.

Channels are assigned in the following way:

Channel 1	Reference D.C. voltage
Synch pulse	Synchronizes Demodulation
Channel 2	Subcommutated channel
	2a: -4 volts
	2b: unregulated power
	2e: Temperature
	2g: Zero
	2H: +4 volts
Channel 3	Left Ventricular Pressure
Channel 4	Aortic Pressure
Channel 5	ECG
Channel 6&7	not used

Equipment Operation and Set Up

1. Connect the 240 khz power oscillator to the monkey's jacket coil which is found in the left pocket.

2. Bring the power cord from the power supply to the power oscillator.

3. Locate the receiver antenna into position. (i.e., outside the monkey pod, in the immediate vicinity of the animal)

4. Turn the telemetry system "ON." (receiver, demodulator, oscilloscope, D.V.M., and Power Supply)

5. Verify that carrier signal from the transmitter is being received, that is:

(a) Receiver is tuned to the transmitter frequency (10 khz signal can be heard)

(b) signal strength meter reads highest signal

(c) tuning is approximately near "0"

(d) I.F. Bandwith is set at 300 khz

(e) Deviation is set at the "250" scale

(f) video output is reading POSITIVE in the VU meter and the "VIDEO GAIN" setting is set at approximately "8"

(g) RF Gain is "AGC" and "M": 2nd "LO" is set at "VFO": 1st "LO" is set "VFO-AFC"

6. Verify that the "zero/CAl" switch is in the center or neutral position in the demodulator.

7. Verify that proper PWM signal is being received in scope display

8. Adjust the VIDEO OUTPUT again until the PWM signal at the input monitor from the demodulator (scope display) is approximately 4 to 6 volts peak to peak.

9. Observe polarity of PWM signal and adjust demodulator accordingly by checking the polarity switch (i.e., if normal-polarity switch positive: if inverted-polarity switch negative (see last page of this appendix).

10. Measure voltage output from channel #1 of the telemetered signal and note.

11. Switch to zero (0) mode @ demodulator. (observe that calibrator signal is "normal" i.e., polarity switch positive)

12. Adjust frequency potentiometer(screw) in front panel of demodulator until voltage of channel #7 of demodulator equals that of channel #1 in the implanted unit.

13. Adjust the calibration of "potentiometers" (3-5) to read zero volts.

14. Record 10 seconds of zero (0) mode signal.

15. Change "zero/CAl" switch to CAl mode and record ten seconds of signal.

16. Switch to the neutral position in the "zero/CAl" switch. Observe polarity of PWM signal and record physiological data.

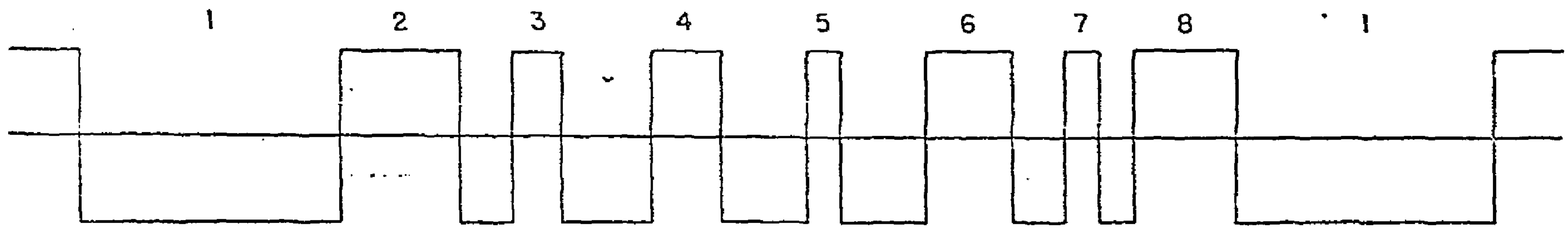
17. Temperature measurement:

(a) Measure voltage output from channel #2G and adjust potentiometer 2 to read ZERO VOLTS.

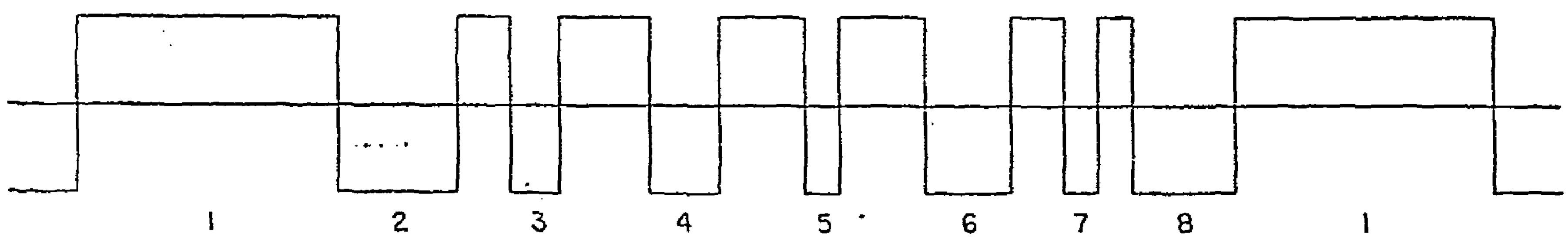
(b) switch to channel 2E and record voltage output-This will be the temperature reading in volts.

18. END OF STUDY. Turn equipment off and disconnect power oscillator from animal.

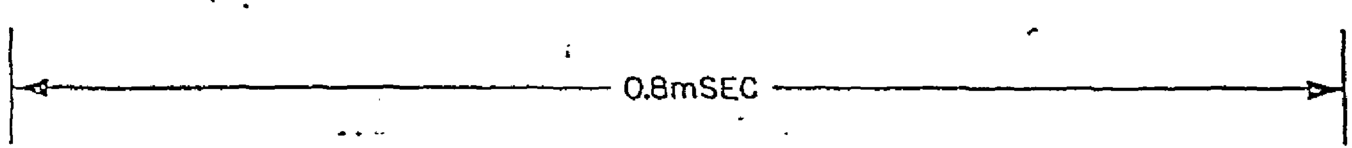
DIRECT PWM OUTPUT FROM F.M. RECEIVER



(Shown in the Normal-Positive Direction)



(Shown in the Inverted-Negative Direction)



SCOPE DISPLAY

APPENDIX H

ON-LINE DATA REDUCTION OF RESPIRATORY GAS EXCHANGE MEASUREMENTS USING THE ADDAS AND COMPUTER SYSTEM OF THE CV990.

Objective: To analyze and reduce continuous signal outputs from respiratory gas exchange instrumentation to obtain the oxygen consumption rate, carbon dioxide production rate, and respiratory quotient on a "real time" basis for two monkey subjects during a series of CV990 flights.

Method: The composition of exhaust air and the mass flow of air through the hood (upper pod) sections of two monkey pods will be alternately monitored 15 minutes at a time for the duration of the CV990 flights.

The data channels to be analyzed by the on-board computer are the mass spectrometer (M/S) signal outputs for F_{O_2}, F_{CO_2}, F_{H_2O}, and F_{N_2}, and the flowmeter signal output for mass flow; i.e., parameters 1, 2, 3, 4, and 5 on UCB data table dated 12 February 1976.

Oxygen consumption rate ($\dot{V}_{O_2}$) in cm^3/minute, will be computed by, $\dot{V}_{O_2} = \dot{V}(F_{I_{O_2}} - F_{E_{O_2}})$, and carbon dioxide production rate ($\dot{V}_{CO_2}$) in cm^3/minute by, $\dot{V}_{CO_2} = \dot{V}(F_{E_{CO_2}} - F_{I_{CO_2}})$, where $\dot{V}$ is the mass flow of air ventilating the subject (upper pod air flow) in cm^3/minute, $F_{I_{O_2}}$ and $F_{I_{CO_2}}$ are the fractional O_2 and CO_2 content of the inlet air, and $F_{E_{O_2}}$ and $F_{E_{CO_2}}$ are the fractional O_2 and CO_2 content of the exhaust air. Respiratory quotient will be computed as the ratio, $(\dot{V}_{CO_2})/(\dot{V}_{O_2})$.

Calibration factors (computational constants) will be generated by daily calibration procedures which will be carried out during an approximately one hour period before take-off.

It is understood that power will be made available for instrument warm-up and calibration before each flight.

In the statement below of the operations required for the in-flight computations of respiratory gas exchange, it is also assumed that the ADDAS and computer system will be available and on-line during the pre-flight calibration period.

Required characteristics and operations of computer system:

The system should operate in four different modes, depending on instructions entered at a terminal.

Modes 1, 2, and 3 will be required during calibration periods before each flight to compute and store data concerned with mode 4 computations during the flight.

The four modes should operate as described below:

MODE 1 (Gas Calibration).

On signal, readings Mass Spectrometer Zero(1), MSZ(2), MSZ(3), MSZ(4) are obtained for each channel of the mass spectrometer.

The notations 1, 2, 3, and 4 represent oxygen, carbon dioxide, water vapor, and nitrogen respectively.

On a second signal, a second set of readings Mass Spectrometer Span(1), MSS(2), MSS(3), MSS(4) are obtained.

Using specified constants Zero(1), Z(2), Z(3), Z(4) and Span(1) S(2), S(3), S(4), the values M(I) for slope and B(I) for intercept are calculated as follows:

$$M(I) = \frac{Z(I) - S(I)}{MSZ(I) - MSS(I)}$$

$$B(I) = Z(I) - M(I) * MSZ(I)$$

The eight values M(1), M(2), M(3), M(4) and B(1), B(2), B(3), B(4) are stored until the next Mode 1 operation when they are replaced by a new set of values.

MODE 2 (Flow Calibration).

On signal, a reading FMZ, for Flow Meter Zero, is taken from the flow meter.

On a second signal, a second reading FMS, for Flow Meter Span, is obtained.

From specified constants Z(5) and S(5) for Zero and Span, the slope M(5) and intercept B(5) are calculated as follows:

$$M(5) = \frac{Z(5) - S(5)}{FMZ - FMS}$$

$$B(5) = Z(5) - M(5) * FMZ$$

The values M(5) and B(5) are stored until the next mode 2 operation when they are replaced by a new set of values.

MODE 3 (Measurement of Inlet Air).

On signal, readings Mass Spectrometer Inlet Air(1), MSIA(2), MSIA(3), MSIA(4) are made for each channel of the mass spectrometer.

Using the stored values M(1), M(2), M(3), M(4) and B(1), B(2), B(3), B(4), the following are calculated:

FIA(1) = M(1) * MSIA(1) + B(1), for Fraction Inlet Air

FIA(2) = M(2) * MSIA(2) + B(2)

FIA(3) = M(3) * MSIA(3) + B(3)

FIA(4) = M(4) * MSIA(4) + B(4)

TOTAL = FIA(1) + FIA(2) + FIA(3) + FIA(4)

$$\text{DIØ} = \frac{\text{FIA(1)}}{\text{TOTAL} - \text{FIA(3)}}$$, for Dry Inlet Oxygen

$$\text{DICD} = \frac{\text{FIA(2)}}{\text{TOTAL} - \text{FIA(3)}}$$, for Dry Inlet Carbon Dioxide

The values DIØ and DICD are stored until the next Mode 3 operation when they are replaced by a new set of values.

The values FIA(1), FIA(2), FIA(3), and FIA(4) are printed.

MODE 4 (Measurement of Exhaust Air)

Following modes 1, 2, and 3 operations, the instrumentation will be switched to monitor the exhaust air from the two upper pods.

In the "run" mode, readings of Mass Spectrometer Exhaust Air(1) MSEA(2), MSEA(3), MSEA(4), and FLEA, for FLow Exhaust Air will be sampled 1/sec, and averaged for one-minute periods (the average reading may be based on 10 to 60 samples; i.e., every 6th sample to all samples).

Using the stored values M(1), M(2), M(3), M(4), M(5) and B(1), B(2), B(3), B(4), B(5), the following calculations are made:

FEA(1) = M(1) * MSEA(1) + B(1), for Fraction Exhaust Air

FEA(2) = M(2) * MSEA(2) + B(2)

FEA(3) = M(3) * MSEA(3) + B(3)

FEA(4) = M(4) * MSEA(4) + B(4)

ALL = FEA(1) + FEA(2) + FEA(3) + FEA(4)

$$\text{DEØ} = \frac{\text{FEA(1)}}{\text{ALL} - \text{FEA(3)}}$$, for Dry Exhaust Oxygen

$$\text{DECD} = \frac{\text{FEA(2)}}{\text{ALL} - \text{FEA(3)}}$$, for Dry Exhaust Carbon Dioxide

FLØW = 0.932 * [M(5) * FLEA + B(5)]

The values FEA(1), FEA(2), FEA(3), FEA(4), and FLØW, together with time code and pod identification are printed and displayed on video 1/min.

Using the stored values DIØ and DICD, the following are calculated:

ØCR = FLØW (DIØ - DEØ), for Oxygen Consumption Rate

CDPR = FLØW (DECD - DICD), for Carbon Dioxide Production Rate

$RQ = \frac{CDPR}{ØCR}$, for Respiratory Quotient

The values ØCR, CDPR, and RQ, together with time code and pod identification are printed and displayed on video 1/min.

APPENDIX I

ON-LINE COMPUTATION OF MASS SPECTROMETER INLET PRESSURE AND UPPER POD PRESSURE (Parameters 6 and 7).

During the pre-flight calibration period, zero and full-scale values of pressure will be presented to each of the two sensors.

Voltages corresponding to the zero and full-scale values of each parameter will be recorded by the computer, and calibration curves of the form, $y = mx + b$, computed and stored.

Alternatively, voltages corresponding to zero and full-scale values of each parameter can be obtained by the experimenter, either as a print-out from the computer or on a DVM, the calibration curves computed on a hand calculator, and the calibration factors m and b entered at a terminal and stored.

In the "run" mode, readings from the pressure sensors will be sampled 1/sec, and averaged for one-minute periods (the computed average may be based on 10 to 60 samples; i.e., every 6th sample to all samples).

Using the stored calibration data, MASS SPECTROMETER INLET PRESSURE and UPPER POD PRESSURE will be computed, and printed and displayed on video 1/min.

APPENDIX J

ON-LINE COMPUTATION OF LOWER POD PRESSURE (Parameter 8).

During the pre-flight calibration period, zero and full-scale values of differential pressure will be simulated by a calibration device.

Voltages corresponding to the zero and full-scale values of the parameter will be recorded by the computer, and a calibration curve of the form, y = mx, computed and stored.

Alternatively, voltages corresponding to zero and full-scale values of the parameter can be obtained by the experimenter, either as a print-out from the computer or on a DVM, the calibration curve computed on a hand calculator, and the calibration factor m entered at a terminal and stored.

In the "run" mode, readings from the pressure sensor will be sampled 1/sec, and averaged for one-minute periods (the computed average may be based on 10 to 60 samples; i.e., every 6th sample to all samples).

Using the stored calibration data, LOWER POD PRESSURE will be computed, and printed and displayed on video 1/min.

APPENDIX K

ON-LINE COMPUTATION OF MASS SPECTROMETER INLET TEMPERATURE, NO. 1 UPPER POD TEMPERATURE, NO. 1 LOWER POD TEMPERATURE, NO. 2 UPPER POD TEMPERATURE, AND NO. 2 LOWER POD TEMPERATURE (Parameters 9 - 13).

During the pre-flight calibration period, zero and full-scale values of temperature will be simulated by a calibration device.

Voltages corresponding to the zero and full-scale values of the parameters will be recorded by the computer, and a calibration curve of the form, $y = mx$, computed and stored.

Alternatively, voltages corresponding to zero and full-scale values of the parameters can be obtained by the experimenter, either as a print-out from the computer or on a DVM, the calibration curve computed on a hand calculator, and the calibration factor m entered at a terminal and stored.

In the "run" mode, multiplexed readings from the five temperature sensors and reference will be sampled 1/sec.

The "dwell" time on each sensor and reference will be 10 secs. The readings from each sensor will be averaged for 10-second periods (the computed average may be based on 5 to 10 samples; i.e., every other sample to all samples).

Using the stored calibration data, MASS SPECTROMETER INLET TEMPERATURE, NO. 1 UPPER POD TEMPERATURE, NO. 1 LOWER POD TEMPERATURE, NO. 2 UPPER POD TEMPERATURE, and NO. 2 LOWER POD TEMPERATURE will be computed, and printed and displayed on video 1/min.

APPENDIX L

ON-LINE COMPUTATION OF HEART RATE (Parameters 16 and 17)

Parameter 16: No. 1 Pod Heart Rate

Parameter 17: No. 2 Pod Heart Rate (derived from Parameter 21)

During the pre-flight calibration period, zero and full-scale values of heart rate will be simulated by a calibration device. The voltages corresponding to these values for both parameters will be obtained by the experimenter, either as a print-out from the computer or on a DVM, the calibration factor computed on a hand calculator and the cal. factor (beats/min/volt) entered at a terminal and stored. Also, high and low heart rate limit values will be chosen by the experimenter and entered at a terminal and stored.

In the "run" mode, heart rate readings will be sampled 1/sec and averaged for one-minute periods (the computed average may be based on 10 to 60 samples; i.e., every 6th sample to all samples). If a sample is between the designated heart rate limits it will be included in the average; if not, it will be left out.

Using the stored calibration factor data, No. 1 Pod Heart Rate and No. 2 Pod Heart Rate will be computed and, along with the number of samples used (n) in the computation, printed and displayed on video 1/min.

APPENDIX M

ON-LINE COMPUTATION OF FOOD AND WATER CONSUMPTION

Parameter 14: No. 1 Pod Food and Water

Parameter 15: No. 2 Pod Food and Water

Water and food consumption will be sampled at a rate of 10/sec, and displayed as a total of events during a one-minute period. In addition, a running total will be obtained during the flight. If additional computer capability is available, the percentage of the total time spent in these activities will be estimated, printed and displayed.

CV-990 FLIGHT PLAN
DELAYED FLAP PROGRAM

FLIGHT NUMBER	8	PILOT	F. Drinkwater
DATE	5/21/76	COPILOT	C. Mattraw
PRE-FLIGHT BRIEF	1000	RESEARCH PILOTS	
DOOR CLOSING	1030		
TAKEOFF	1100		
FLIGHT TIME	3 hr	TEST CONDUCTOR	J. Bull
DEBRIEF	Pilots Conf Rm After Flight	TEST COORDINATOR	D. Endrud

TEST OBJECTIVES

1. Compare fuel consumption for fuel opt profile and 3° glide path from 30,000 ft into Stockton.
2. Evaluate Descent G and N into new airports Reno, Sonoma (RNO,STS,SJC,NUQ)
3. Evaluate Delayed Flap at 200 kt initial airspeed.

GENERAL FLIGHT TEST PLAN

1. Takeoff, proceed to Stockton, conduct Descent into SCK 29R from 30,000'
2. Depart, proceed to Reno, conduct Descent/Approach into RNO 16.
3. Depart, proceed to Stockton, conduct Descent into SCK 29R from 30,000'.
4. Depart, proceed to Sacramento, Sonoma County, Oakland, and San Jose.
5. Return to Moffett.

SPECIAL AIRCRAFT REQUIREMENTS

1. None

SPECIAL INSTRUMENTATION REQUIREMENTS

1. ADLAS to run continuously from taxi out to taxi in.

SPECIAL NOTES

1. None

Date 5/21/76

CV-990 FLIGHT PLAN
DELAYED FLAP PROGRAM

RUN NO.	Taxi out time ____ Taxi in time ____ TEST	PILOT	STRIP CHART
1.	Enter Ramp Aircraft Gross Weight ______	Drink water	
2.	Takeoff and climbout for Stockton Metropolitan. (Conduct two zero "G" monkey maneuvers)		
3.	Conduct the following experimental Descents/Approaches. HMIN = 500. Slow to 200 kts by Glide Slope Capture.		

CRUISE WINDS		DESCENT INITIAL CONDITIONS HDG/DIST	ALT	TAN PT/RAD	APPROACH CONDITIONS WGT	VREF	FUEL USED	WINDS
#3 SCK 29R	1.	Use E/D and Pitch Wheel Fuel Optimal Profile	30000	8.0/2.5				
#8 RNO 16	2.			8.0/2.5				
#3 SCK 29R	3.	V = 250 kts	30000	8.0/2.5				
#5 SAC 16	4.			8.0/2.5				
" STS 32	5.			8.0/2.5				
#6 OAK 29	6.	Follow BAY APP	At least 6000	8.0/2.5				
#1 SJC 30L	7.			8.0/2.5				
#9 NUQ 32R	8.	Uncouple at RWY centerline		6.0/2.5				

Initial Letdown Point into Stockton Metropolitan.

Altitude	Vortac	Latitude	Longitude
20,000	062/62	38° 0.0'N	119° 53.0'W
25,000	062/78	38° 3.0'N	119° 41.0'W
30,000	062/94	38° 6.1'N	119° 29.0'W

Fuel Optimal Profile:

Altitude	Airspeed
30,000	233 kts
25,000	233 kts
20,000	233 kts
15,000	245 kts
13,000	250 kts
[illegible]	[illegible] kts
11,000	260 kts
10,000	250 kts

TIME 142 13 04.01	POD ID = 5	# OF SAMPLES
FEA OXYGEN	.1962	60
FEA CARBON DIOXIDE	.0077	60
FEA WATER VAPOR	.0237	60
FEA NITROGEN	.7710	60
MASS FLOW	8137.9	60
OXYGEN CONSUMPTION	65.2	
CARBON DIOXIDE PRODUCTION	53.9	
RESPIRATORY QUOTIENT	.826	
M/S INLET PRESSURE	257.9	60
UPPER POD PRESSURE	739.4	60
LOWER POD PRESSURE	.1	60
M/S INLET TEMPERATURE	23.0	0
#1 UPPER POD TEMPERATURE	23.0	0
#1 LOWER POD TEMPERATURE	23.0	0
#2 UPPER POD TEMPERATURE	23.0	0
#2 LOWER POD TEMPERATURE	23.9	0
#1 POD HEART RATE	150.3	60
#2 POD HEART RATE	179.9	9
#1 POD WATER EVENTS	0	
RUNNING TOTAL	0	
#2 POD WATER EVENTS	0	
RUNNING TOTAL	0	
#1 POD FOOD EVENTS	0	
RUNNING TOTAL	0	
#2 POD FOOD EVENTS	0	
RUNNING TOTAL	0	

SAMPLE

CV-990 ADDAS COMPUTER OUTPUT FROM MONKEY POD EXPERIMENT ON 21 MAY 1976.

APPENDIX P

Sample computation of respiratory gas exchange for ADDAS.*

	Volts	Calibration Factors	Fractions
FIA OXYGEN	-0.391	F = 0.00256(volts) + 0.2089	0.2079
FIA CARBON DIOXIDE	0.000	F = 0.00259(volts) + 0.0003	0.0003
FIA WATER VAPOR	0.678	F = 0.00737(volts) + 0.0000	0.0050
FIA NITROGEN	-0.648	F = 0.00617(volts) + 0.7908	0.7868
TOTAL			1.0000
DIØ			2.2089
DICD			0.0003
FEA OXYGEN	-6.680	F = 0.00256(volts) + 0.2089	0.1918
FEA CARBON DIOXIDE	4.170	F = 0.00259(volts) + 0.0003	0.0111
FEA WATER VAPOR	3.392	F = 0.00737(volts) + 0.0000	0.0250
FEA NITROGEN	-3.031	F = 0.00617(volts) + 0.7908	0.7721
ALL			1.0000
DEØ			0.1967
DECD			0.0114

FLØW = 0.932 (1111.1 cm^3/min/volt x 8.691 volts) = 9,000 cm^3/min, STP.

O_2 CONSUMPTION RATE = 9,000 cm^3/min (0.2089 - 0.1967) = 109.8 cm^3/min, STP.

CO_2 PRODUCTION RATE = 9,000 cm^3/min (0.0114 - 0.0003) = 99.9 cm^3/min, STP.

RESPIRATORY QUOTIENT = (99.9 cm^3/min) / (109.8 cm^3/min) = 0.909

* Refer to Appendix H for notations and description of operations.

APPENDIX Q

LBNP Calibration and Operation Procedures for the CV-990 Monkey Pod Flights

A. Calibration of Differential Pressure Transducer and Gauge

The transducer and gauge are mounted on the LBNP control panel (part of UCB Bioinstrumentation Rack) and are connected in parallel to monitor the upper/lower pod differential pressure. The gauge provides a meter reading of pressure which is used to set the appropriate LBNP pump voltage. The transducer provides an electrical output proportional to pressure which is recorded and indicates both the time course and pressure level of the LBNP test.

To complete an electrical calibration of the pressure transducer

1) Activate the CAL. switch on the transducer pre-amplifier (part of UCB Data Acquisition Rack) to place the calibrating resistor, equivalent to 100 torr, in the circuit.
2) To pre-set the above adjustable calibrating resistor or to provide a physical pressure calibration to the transducer and gauge, set the PRESSURE INPUT VALVE to CAL. and apply 100 torr to CAL. PORT with the mercury manometer system.

B. Calibration of Biotachometers

The biotachometers are mounted in the UCB Data Acquisition Rack. Each unit has had the standard calibration signal of 500 beats/min changed to 250 beats/min in order to provide the optimum full-scale calibration signal for the ADDAS system. This calibration signal is provided as output by turning the SENSITIVITY dial to CAL. In the rate mode the SENSITIVITY dial should be turned to 5 beats/min/div.

C. LBNP Test Operations

A two-pod LBNP test protocol was devised for the CV-990 flights which provided the sequential application of negative pressure to each subject with the maximum possible overlap of separate 75 min test procedures. This resulted in a two-pod total test duration of 100 min. This protocol is shown below.

Elapsed Time (min)	Event
0	Tilt both pods to supine position
30	Pod #1, begin Control
45	Pod #1, begin LBNP
50	Pod #2, begin Control
60	Pod #1, begin Recovery
65	Pod #2, begin LBNP
75	Pod #1, end Recovery
80	Pod #2, begin Recovery
95	Pod #2, end Recovery
100	Tilt both pods to upright position

Throughout the test environmental disturbances to the monkey subjects should be minimized so as to avoid behavioral influences on the data collected. During the CV-990 flights it was difficult to meet these conditions. The major attempt made was to cover the upper pod windows so that visual contact between humans and monkeys was prevented.

During the control and recovery periods for each subject pertinent observations of monkey behavior and environmental disturbances were noted on the strip chart record so as to assist in the interpretation of the data.

The initiation of the LBNP period for Pod #1 was accomplished by following the sequence noted below. The same sequence was followed for Pod #2. All controls are located on the LBNP control panel.

1) Set PRESSURE INPUT VALVE to PODS

2) Set UPPER and LOWER POD PRESSURE SELECTOR VALVES to POD #1

3) Set POD #1 LOWER POD PUMP SELECTOR VALVE to LBNP

4) Close POD #1 LOWER POD AIR INLET PORT

5) Turn on LBNP PUMP POWER switch

6) Turn LBNP CONTROL knob until desired pressure (40, 50 or 60 torr) is reached on pressure gauge.