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70-DD-02

BIOMEDICAL EVALUATION OF THE APOLLO 8 MISSION

MANNED SPACECRAFT CENTER

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BIOMEDICAL EVALUATION OF THE APOLLO 8 MISSION

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Physiological Data - E. C. Moseley, Ph. D. and F. A. Michelli, B.S.

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TABLES

FIGURES

ACRONYMS

ac	alternating current
ACTH	adrenocorticotrophic hormone
ASAP	as soon as possible
BMDADS	Biomedical Data Analysis and Display Subsystem
CAAD	Computation and Analysis Division
Cap Comm	capsule communicator
CCATS	Communications Command and Telemetry Systems
CDR	Commander
CM	Command Module
CMP	Command Module Pilot
CPK	creatine phosphokinase
CSM	Command and Service Module
CWP	cold water port
dc	direct current
DNA	deoxyribonucleic acid
dpm	disintegrations per minute
DWG	dring water gun
D/TV	digital television
e.d.t.	eastern daylight time
EKG	electrocardiogram
ENT	ear, nose, and throat
ESSA	Environmental Sciences Service Administration
FEV	forced expired volume

F - 0 (1, 2, .., n)	days before launch
g	acceleration of gravity
g.e.t.	ground elapsed time
GMK	Green Monkey kidney
G.m.t.	Greenwich mean time
GSE	ground support equipment
HEK	human embryonic kidney
HWP	hot water port
IVA	intravehicular activity
KSC	Kennedy Space Center
LBNP	lower-body negative pressure
LDH	lactic acid dehydrogenase
LHEB	left hand equipment bay
LMP	Lunar Module Pilot
MCA	multiple channel analyzer
MCC	Mission Control Center
MOCR	Mission Operations Control Room
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
NPDS	Nuclear Particle Detection System
P	general probability distribution function
PCM	pulse code modulation
PEFR	peak expiratory flow rate
PHA	phytohemagglutinin

P/N	part number
PRD	personal radiation dosimeter
pH	hydrogen ion concentratoon
PVC	premature ventricular contraction
R + 0 (1, 2, .., n)	days after recovery
RBE	relative biological effectiveness
RNA	ribonucleic acid
RSM	radiation survey meter
RTCC	Real-Time Computer Complex
SEC	space environment console
S/N	serial number
SMEC	summary message enable keyboard
SPAN	Solar Particle Alert Network
SPS	service propulsion system
SSR	staff support room
STPD	standard temperature and pressure, dry
T - 0 (1, 2, .., n)	hours until lift-off
TEI	transearth injection
TLD	thermoluminescent dosimeter
T-M	throat-mouth
TM S/W	telemetry switch
USB	unified S-band
VABD	Van Allen Belt dosimeter
ZPN	impedance pneumogram

BIOMEDICAL EVALUATION OF APOLLO 8 MISSION

1.0 INTRODUCTION

During the 6.1-day lunar orbital flight of Apollo 8, three astronauts accumulated 441 man-hours of space flight experience. For the first time in the U.S. space program, the astronauts reported symptoms of motion sickness during the adaptation phase of the intravehicular activity.

As in Apollo 7, the inflight real-time operational medical support was limited to biomedical monitoring on a time-shared basis; but, the Apollo 8 crew did participate in a series of special preflight and postflight medical studies designed to assess the changes incident to space flight.

Analysis of the Apollo 8 biomedical data confirms the Apollo 7 finding that the Apollo Command Module does provide a habitable environment. The physiological changes observed postflight were generally consistent with those noted and reported in earlier manned space flights.

The inflight and postflight chronology of Apollo 8 medical events is included in the Appendix.

2.0 INFLIGHT BIOMEDICAL EVALUATION

2.1 BIOINSTRUMENTATION PERFORMANCE

The Apollo 8 bioinstrumentation harnesses were modified extensively following the difficulties experienced during the Apollo 7 flight. The changes involved materials as well as design:

a. The pin connectors were eliminated altogether.

b. A silicone rubber strain-relief cuff was attached to the signal conditioner input connector.

c. Polyvinyl-chloride-coated lead wire of larger gage replaced the smaller gage Teflon-coated wire used in Apollo 7.

d. The input connector to the signal conditioner was redesigned to allow easier application.

The Apollo 8 bioharnesses used by the CDR and the CMP performed flawlessly throughout the duration of the flight.

The LMP's sternal electrocardiogram (EKG) signal was suddenly degraded in quality at 115-1/2 hours into the mission. The EKG baseline shifted frequently and the EKG signal conditioner output was intermittently blocked out. The impedance pneumogram (ZPN) signal, however, remained excellent in quality. A loose sternal biosensor was suspected as causing the problem; however, the LMP's attempt to troubleshoot the system failed to identify any obvious anomalies in the biosensors or lead connectors. He was asked to switch the input leads of the EKG and ZPN signal conditioners, that is, reconfigure the sternal EKG to an axillary EKG. An excellent, noise-free axillary electrocardiogram resulted. Interestingly, the ZPN from the sternal sensors provided a usable and noise-free impedance signal. Since a good ZPN signal was received from the sternal sensors; a loose connection, either a biosensor or input lead connector, was assumed to be responsible for the Lunar Module Pilot's degraded sternal EKG signal.

Postflight examination of the Apollo 8 bioharnesses demonstrated no failures or anomalies. Temperature sensitive indicator tape was attached to each dc-dc converter to measure any overheating of the dc-dc converter (see Apollo 7 report). The maximum temperature reached by the dc-dc converters was approximately 120° F. This value was within design specifications.

In summary, performance of the Apollo 8 bioinstrumentation system was good and the modifications made subsequent to the Apollo 7 flight were proven adequate and effective.

2.2 PHYSIOLOGICAL DATA

In contrast with the Apollo 7, where only 10 hours of usable physiological data were collected during the entire 11-day mission, the Apollo 8 inflight results are based on approximately 24 hours of sampled data for each crewman. In general, the quality of the data during Apollo 8 was very good. Descriptive statistics describing the heart and respiration rates calculated for each mission phase, and by mission days, are given in table 2-I. The Command Module Pilot's heart rate was lower and less variable than the heart rates of the other two crewmen. The Commander's heart rate ranged from 60 to 130 beats per minute, the Command Module Pilot's from 51 to 88, and the Lunar Module Pilot's from 63 to 101 beats per minute. These data reflect normal variations; but, as expected, heart rates greater than the typical range occurred during critical phases of the mission. Annotated plots showing cardiac activity, as reflected in heart rates, during such phases are shown in figure 2-1. Attempts to plot heart rate as a function of acceleration were only partially successful because of noise in one or both parameters at any given time. The highest heart rates occurred during the transearth injection (TEI) burn; but a rapid return to normal baseline (expected daily heart rate) occurred characteristically after each of the critical steps of the mission.

Results from attempts to fit the collected heart-rate data with sine waves that would describe the daily physiological variations are given in table 2-II; however, the collected heart-rate data does not include sleep. The results indicate that the Commander, Command Module Pilot, and Lunar Module Pilot operated on a daily circadian cycle of 24.3, 25.4, and 22.3 hours, respectively. Based on this circadian model, the baseline heart rates for the respective crewmen were 81 ± 2, 73 ± 2, and 83 ± 2 beats per minute. A comparison of the baseline figures for the same crewmen in the Gemini VII and Apollo 8 flights show their heart rates were significantly ($P < 0.001$) lower during the Gemini flight suggesting that perhaps the Apollo 8 mission was more strenuous and demanding than the Gemini VII flight.

The changes in baseline heart rate and periodicity given in table 2-II are most readily attributed to sampling problems and to lengthened activity periods associated with the lunar orbital mission phase. These results, as well as those given in table 2-I, suggest that human circadian variations in heart rate are not influenced by gravity or lighting variations, such as associated with earth orbital flights. The results also indicate that about 10 percent of the variations seen in heart rate for these crewmen were a function of the time of day they were monitored. Such percentages compare favorably with earlier estimates.

In general, the ground systems for handling biomedical information worked well during Apollo 8. Daily off-line processing frequently resulted in spuriously high variability estimates thought to be caused by erroneous cardiotachometer outputs during signal lock-on and loss. Efforts are being made to correct this with analog and/or digital filters.

2.3 MEDICAL OBSERVATIONS

2.3.1 Lift-off and Powered Flight

The physical sensation of lift-off was perceptible to the crew, and instrument cues served to confirm the sensation. The maximum g-loading experienced by the crew during powered flight was 4.0. The Commander's prelaunch baseline heart rate was approximately 72 beats per minute. During powered flight, his heart rate ranged from 95 to 130 with an average of 118 beats per minute. No vertigo or disorientation was experienced by the crew. This phase of flight was completely normal.

2.3.2 Adaptation to Weightlessness and Intravehicular Activity

Following orbital insertion, each crewmember experienced the characteristic feeling of fullness of the head that is well-documented in previous manned space flight reports. The Commander noted in his postflight debriefing that he was aware of this sensation for about 4 hours, while the Lunar Module Pilot experienced this phenomenon for approximately 24 hours after orbital insertion.

Apollo 8 was the first manned space flight in which the astronauts experienced inflight symptoms of mild motion sickness. In the postflight medical debriefing, the crew characterized their symptoms as identical with those of incipient "mild seasickness." They related that they experienced nausea shortly after leaving their couches and beginning intravehicular activity (moving about unrestrained in the weightless environment of the spacecraft). The nausea was precipitated by rapid body movements and could be controlled or ameliorated by reducing the number and rapidity of these movements. At no time were any abnormal eye movements (nystagmus) noted by the crew, nor did they experience any disorientation. The duration of symptoms varied between 2 and 24 hours depending on the crewman; however, none of the crewmembers felt that the symptoms interfered in any way with their operational effectiveness.

The Command Module Pilot and the Lunar Module Pilot each took one Lomotil tablet prophylactically when the exact nature of their medical problem was still unclear to them. The Lunar Module Pilot also took one Marezine tablet with good results. His symptoms completely subsided and no additional medication was used or required for control of these mild symptoms of motion sickness.

Following subsidence of symptoms and adaptation to movement within the zero-g environment, each crewman was then able to perform rapid head movements and tilting without difficulty or recurrence of symptomatology.

2.3.3 Inflight Illness

After the Commander's symptoms of motion sickness (par. 2.3.2) dissipated, he experienced the additional symptomatology described below. This inflight illness is believed to be unrelated to motion sickness.

When the Commander was unable to fall asleep 2 hours into his initial rest period scheduled to begin at 11 hours ground elapsed time (g.e.t.) he took a 100-mg Seconal capsule. This induced approximately 5 hours of sleep which was described by the Commander as "fitful." Upon awakening, the Commander felt nauseated and had a moderate occipital headache. He took two 5-grain aspirin tablets and then went from the sleep station to his couch to rest. The nausea, however, became progressively worse. Finally retching occurred and the Commander vomited twice. After termination of his first sleep period, the Commander also became aware of some increased gastrointestinal distress and was concerned that diarrhea might occur.

During the mission, the Flight Surgeons had the clinical impression that the Commander was experiencing an acute viral gastroenteritis. This tentative diagnosis was based upon a voice tape dump report by the crew that the Commander had a headache, a sore throat, loose bowels, and had vomited twice. A private air-to-ground conversation between the Flight Surgeon and the Commander verified that the previous report was correct, but that the Commander was feeling much better. The Commander also stated that he had not taken any medication for his illness which he described as "24-hour intestinal flu." (Prior to the Apollo 8 launch, an epidemic of acute viral gastroenteritis lasting 24 hours was present in the Cape Kennedy community.) The Commander's temperature was 97.5° F on two occasions subsequent to his nausea and vomiting. The Flight Surgeon advised the Commander to take one Lomotil tablet and to use Marezine, if the nausea should return. The Commander's inflight illness, however, soon remitted completely and no further treatment was required. In the postflight medical debriefing the Commander suspected that his symptoms may have been a side effect of Seconal. He related that during his preflight trial of Seconal, he had experienced a mild drug "hangover" and an uncomfortable feeling bordering on nausea which he attributed to a viral gastrointestinal upset. When he used Seconal on two occasions during the flight, he experienced the identical symptoms, headache and nausea, as in the preflight drug trial. Additional postflight drug testing with Seconal has been scheduled for the Commander; however, until the results of these tests become available, a final diagnosis cannot be made.

The Commander furthermore related during debriefing that his vomitus was essentially liquid in character and easily contained in two fecal bags. He also reported no problems associated with vomiting in weightlessness, particularly, no difficulty with aspiration of vomitus.

2.3.4 Work and Sleep Cycles

The very busy schedule of the flight activity precluded simultaneous sleep periods for the crew. As in the Apollo 7 flight, large departures from the crew's normal circadian periodicity caused fatigue during the mission. The wide dispersions of the work-sleep cycles are given in figure 2-2. A "practical shift" of 3 hours before or 8 hours after the start of the Command Module and Lunar Module Pilot's usual Cape Kennedy sleep period is shown. The Commander experienced a "practical shift" of 11 hours before to 2-1/2 hours later than his assumed Cape Kennedy sleep time. The planned sleep periods versus the actual periods and amount of sleep obtained are compared in figure 2-3. It should be noted that real-time changes in the flight plan work-and-sleep cycles were required because of crew fatigue, particularly following the TEI burn. The exact amount of sleep each crewman obtained was indeterminable. On the basis of their flight experience, the crew recommended simultaneous sleep periods for subsequent lunar missions, particularly during the translunar coast and transearth coast phases of flight.

2.3.5 Crew-Status Reporting Procedures

The crew-status reporting procedures were a detailed test objective for the Apollo 8 flight. Food, water, exercise, and sleep were to be logged for purposes of enhancing medical knowledge of space flight requirements for future lunar missions as well as providing data critical to the analysis and interpretation of the special postflight medical studies. A significant amount of water and exercise data, however, was not recovered.

2.3.6 Inflight Exercise

A calibrated inflight exercise protocol was not planned for the Apollo 8 flight. The inflight exercise performed during the flight was solely for crew relaxation and not a medical exercise program. The crew estimated that they exercised approximately 10 minutes per crewman per day. The Apollo 8 crew generally demonstrated more cardiovascular deconditioning in their postflight lower body negative pressure (LBNP) and ergometry tests than the Apollo 7 crew, despite a shorter mission duration (6.1 days versus 10.8 days). The fact that the Apollo 7 crew exercised 4-1/2 times (45 minutes per crewman per day) as much as the Apollo 8 crew appears to account for the observed difference between these crews.

2.3.7 Apollo Medical Kit

As a result of the experience gained during treatment of the Apollo 7 inflight illness, the type and quantity of available drugs in the medical kit were changed. A second medical kit was required to contain some of the additional new items. The contents of the primary Apollo medical kit is documented in the Apollo 7 Mission Report. The modifications in drug type and quantity made for the Apollo 8 mission are given in table 2-III. During the flight, seven items were used from these kits; table 2-IV lists the type and quantity of medications used by each crewman.

2.3.8 Waste Management

The Apollo 8 crewmembers did not report any problems with micturition in weightlessness. They did, however, recommend that the Apollo urine system be changed to a chemical toilet for the Apollo Applications Program.

During the Apollo 8 flight, neither the Command Module Pilot nor the Lunar Module Pilot had any bowel movements. The Commander had a total of three, one every other day. It is interesting to note that only the Lunar Module Pilot went on a preflight low-residue diet. The crew also recommended in their postflight medical debriefing that the fecal disposal system should be improved for future space flight programs.

Postflight analysis of the Commander's stools showed that their average wet weight was 157 grams, with a range of 86 to 199 grams. Examination of the fecal bags demonstrated no swelling or leakage.

TABLE 2-I.-APOLLO 8 CREW HEART RATE

Phase	Commander			Command Module Pilot			Lunar Module Pilot		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Prelaunch	80	72	24	76	75	9	75	74	11
Launch	118	113	24	--	--	--	--	--	--
Earth orbit	93	87	20	71	71	8	98	99	12
Translunar coast	80	75	20	69	67	16	83	82	17
Lunar orbit	80	75	22	73	70	16	84	84	13
Transearth coast	81	76	20	67	63	16	78	75	22
Average baseline rate for entire mission	81.6		26.6	69.3		19.4	82.0		22.6
Day									
0	79	74	20	73	71	11	85	85	12
1	94	82	32	68	65	18	78	75	23
2	80	75	20	71	68	15	83	82	17
3	83	73	28	69	66	13	88	83	28
4	77	73	19	69	65	16	84	79	23
5	78	73	21	66	[illegible]	18	[illegible]	72	16

TABLE 2-II.-CIRCADIAN VARIATION IN HEART RATE

	Gemini VII		Apollo 8		
	Command Pilot	Pilot	Commander	Command Module Pilot	Lunar Module Pilot
Sampled data					
No. samples	600	600	239	239	239
Mean, beats/min	73.1	66.3	82.5	72.9	84.4
Standard deviation, beats/min . . .	9.3	10.9	18.1	20.8	17.3
Calculated					
Fitted curve parameters					
Period (biological day), hr . . .	23.5	23.5	24.3	25.4	22.3
Amplitude of variation, beats/min	7.3	8.2	9.3	8.7	7.6
Phase of variation, hr[1]	20.2	19.8	18.9	16.4	22.2
Baseline, beats/min	71.2	64.3	80.8	73.3	83.0
Circadian ratio[2]	0.10	0.13	0.11	0.12	0.09
Standard error					
Period, hr	2.98	3.18	5.5	6.9	5.0
Amplitude, beats/min	0.69	0.85	3.8	4.8	3.7
Phase, hr	0.35	0.40	1.1	1.9	1.7
Baseline, beats/min	0.35	0.44	2.0	2.3	1.9

[1]Referenced to local launch time (Gemini VII - 2:30 p.m. e.s.t.; Apollo 8 - 7:51 a.m. e.s.t.).
[2]Amplitude/baseline, or variation due to circadian effects.

TABLE 2-III.- APOLLO 8 MEDICAL KIT MODIFICATIONS

Item	Dose and Form	Use	Quantity
Cyclizine	50-mg tablets	Motion sickness	12 vice 24
Pseudoephedrine/triprolidine HCl	62.5-mg tablets	Decongestant	60 vice 24
Darvon vice Darvon Cpd-65	32-mg capsules	Pain	18
Polycillin vice tetracycline	250-mg capsules	Bacterial infection	60
Afrin nasal spray	Spray bottles	Decongestant	3
Sodium secobarbital	50-mg capsules 100-mg capsules	Sleep Sleep	12 21
Spare electrodes	--	--	12 vice 4
Sternal EKG assembly	--	--	1
Axillary ZPN assembly	--	--	1

TABLE 2-IV.- APOLLO 8 MEDICATION USE

Drug	Quantity		
	Commander	Command Module Pilot	Lunar Module Pilot
Aspirin	4	2	--
Diphenoxylate HCl/Atropine SO_4	--	1	1
Sodium Secobarbital, 50 mg	1	--	5
100 mg	1	--	1
Cyclizine HCl	--	--	1
Methylcellulose eyedrops	√	√	√
Nasal emollient	√	√	--
Skin cream	--	√	√

√ = Unknown amount used.

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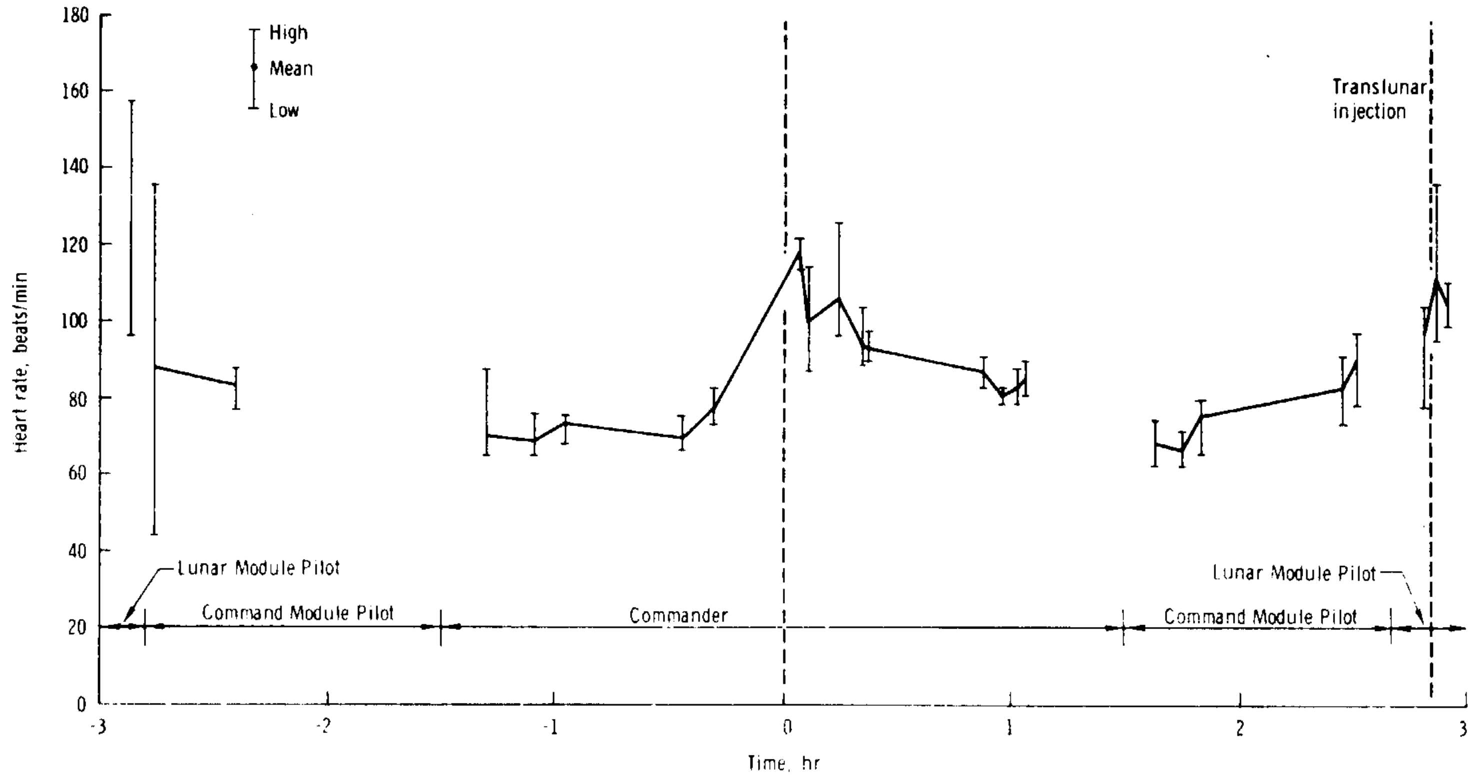
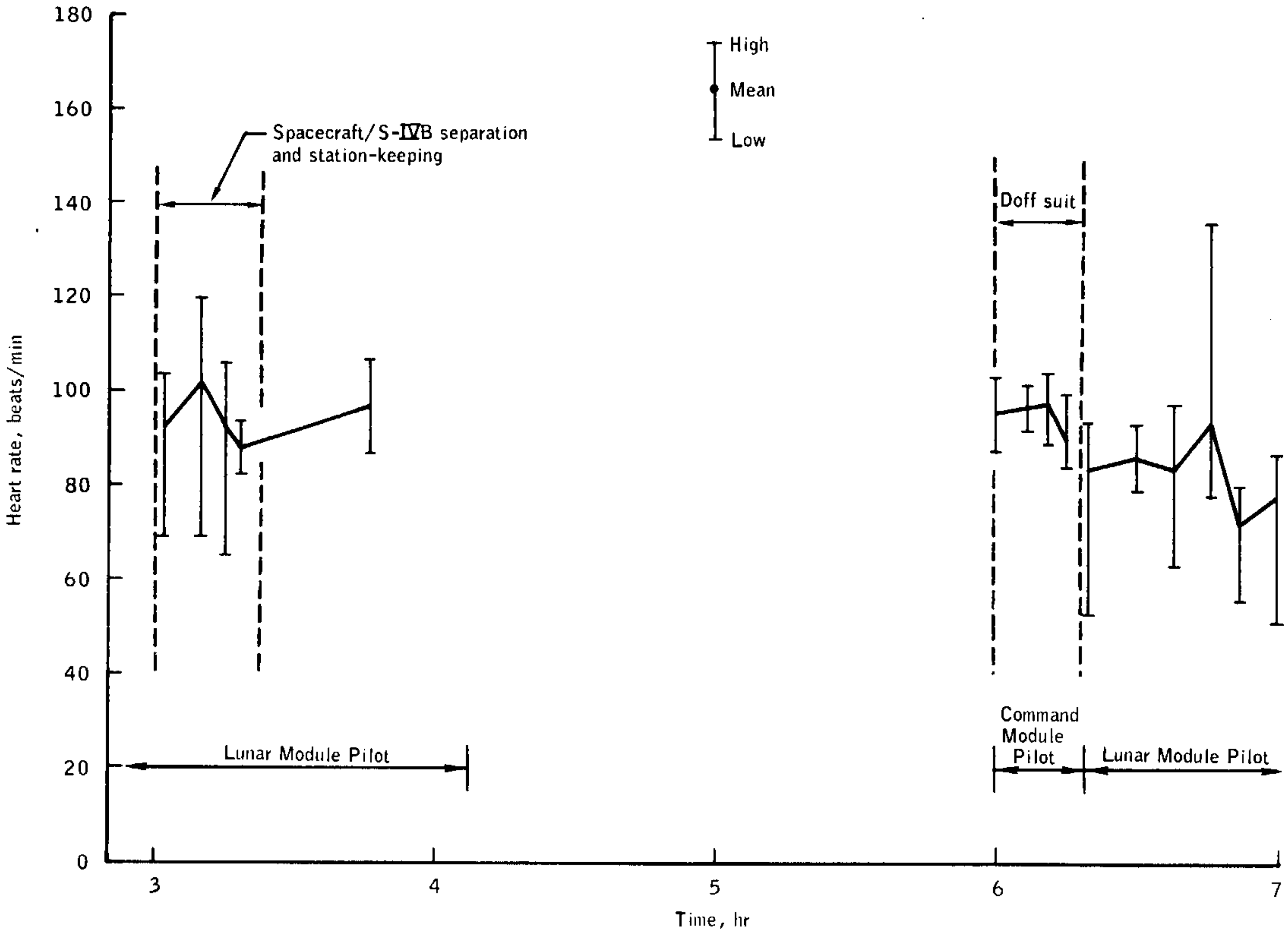


(a) Prelaunch, launch, and translunar injection.

Figure 2-1.- Crew heart rates

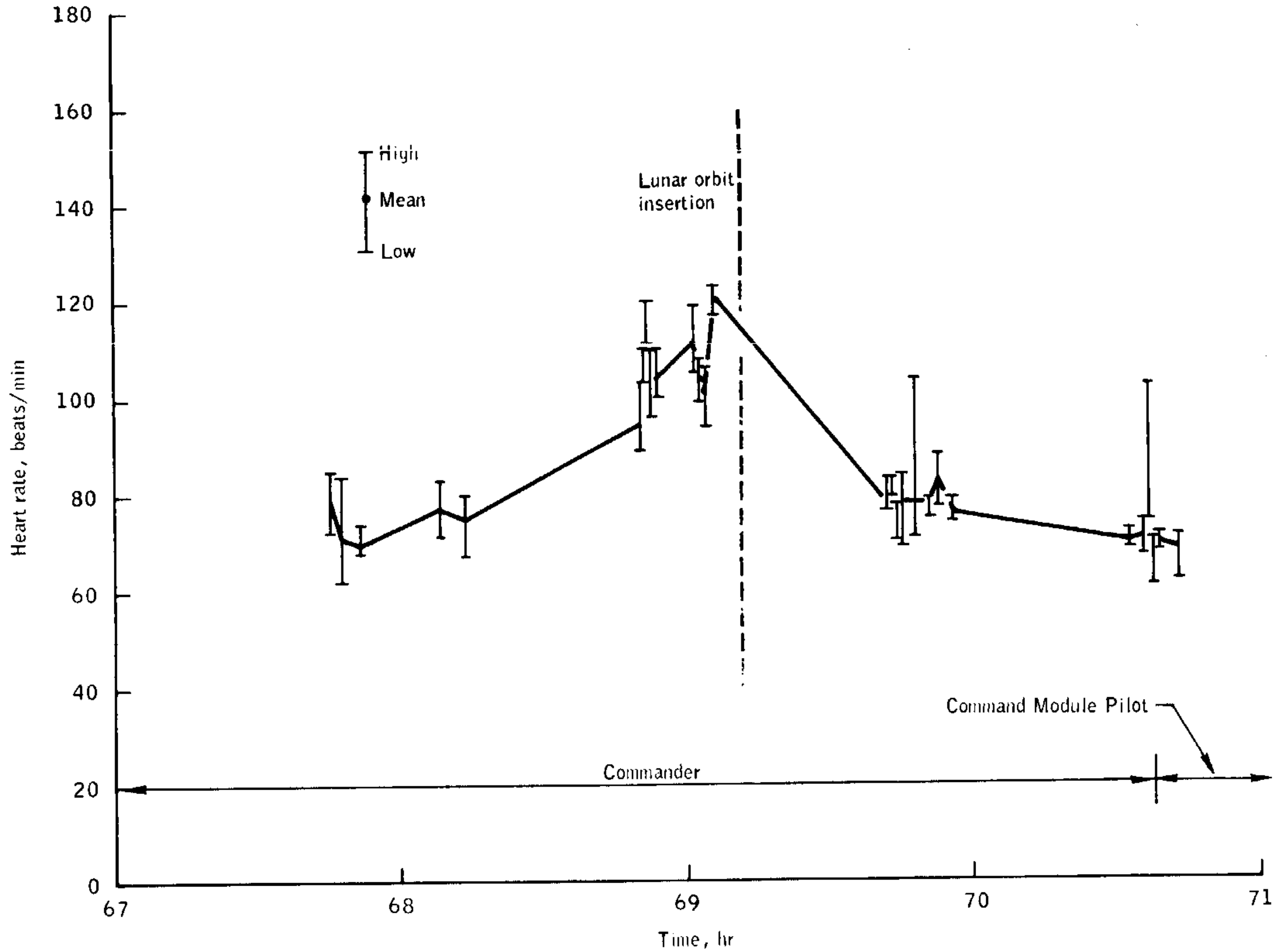
NASA-S-69-696



(b) Translunar coast.

Figure 2-1.- Continued.

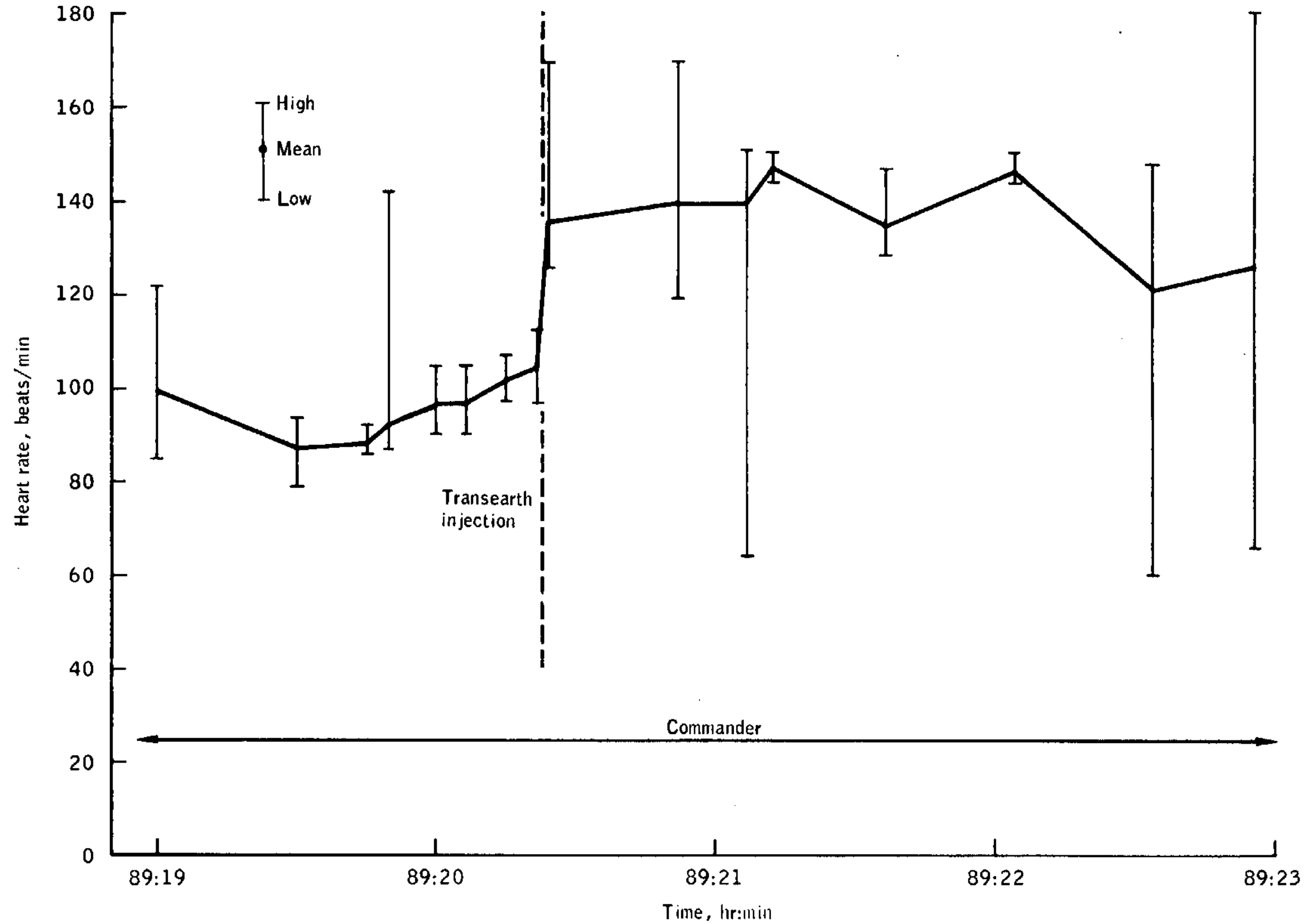
NASA-S-69-697



(c) Lunar orbit insertion.

Figure 2-1.- Continued.

NASA-S-69-698



(d) Transearth injection.

Figure 2-1.- Concluded.

NASA-S-69-699

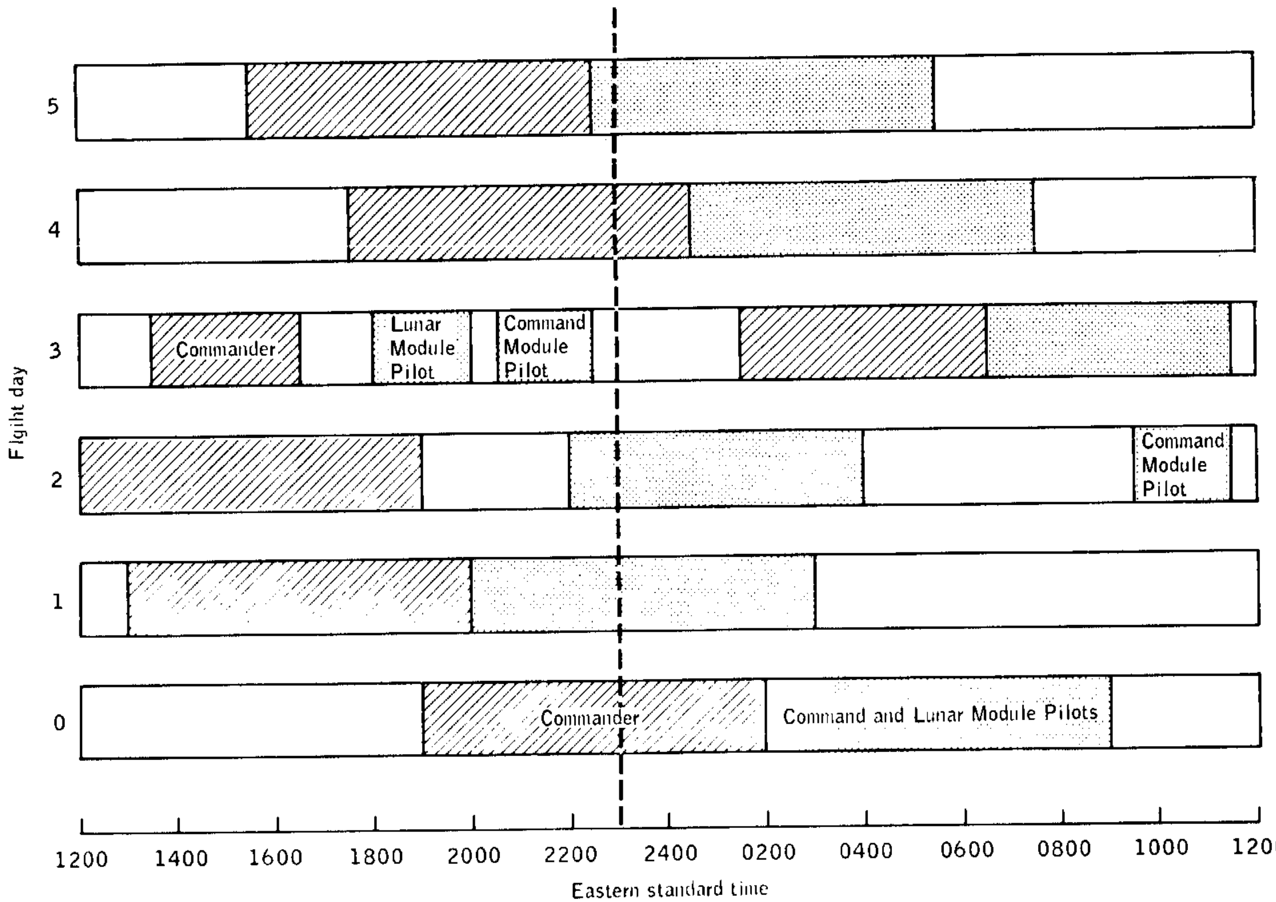


Figure 2-2.- Crew rest cycles.

NASA-S-69-700

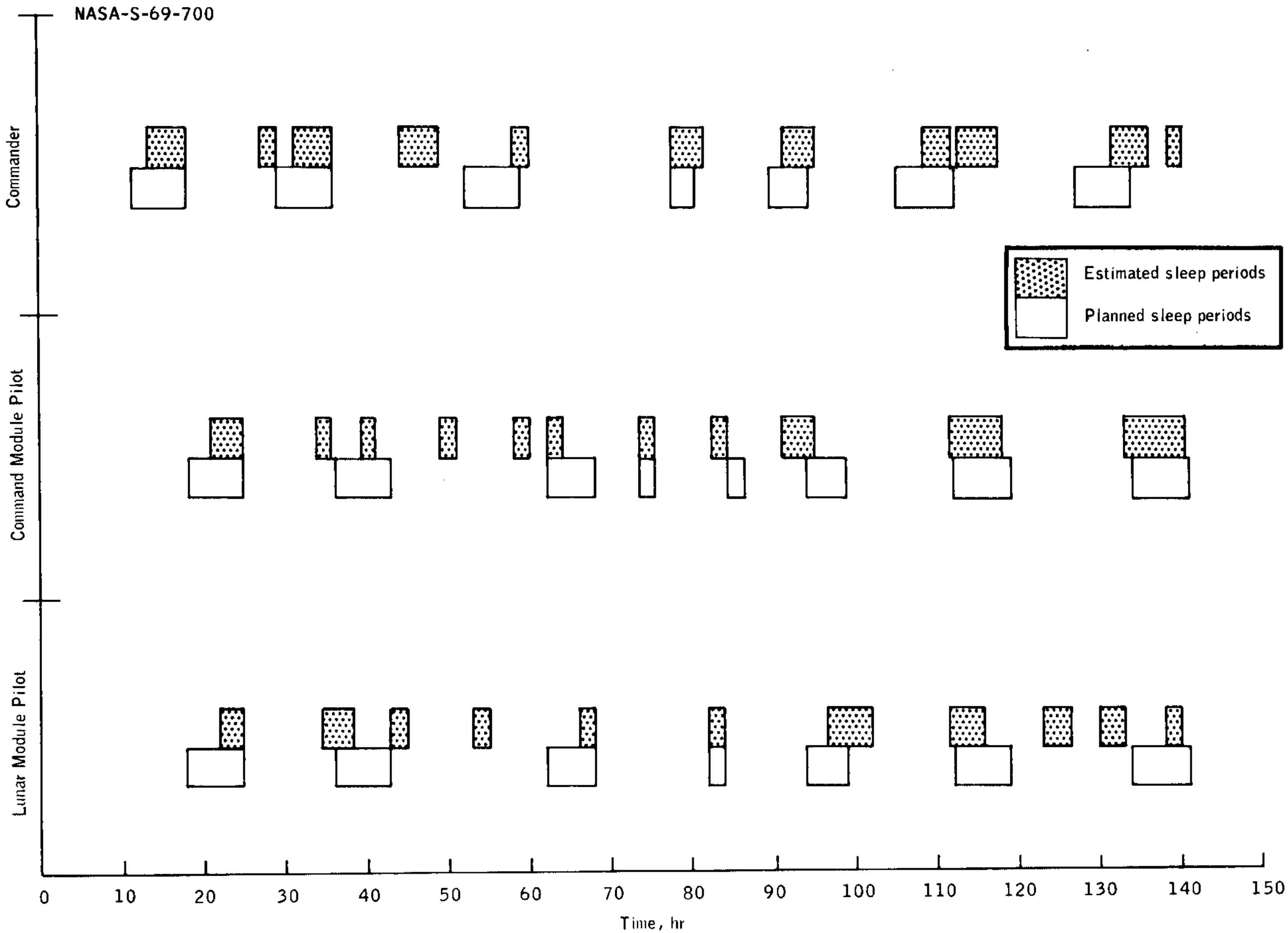


Figure 2-3.- Planned and crew-estimated sleep.

3.0 REENTRY AND READAPTATION TO THE FORCE OF GRAVITY

The maximum deceleration force experienced by the flight crew during reentry of the Apollo 8 spacecraft was 6.9g. The crew had no difficulty performing their duties throughout this period of the mission. The drogue and main parachute deployment produced a lesser opening shock than the Commander and Command Module Pilot experienced on their previous Gemini space flights. The landing impact was probably somewhat greater than that of the Apollo 7 spacecraft although no quantitative data is available.

Following splashdown, the Apollo 8 spacecraft assumed the Stable II attitude (apex down) in the water and was uprighted to the Stable I (apex up) position after 4-1/2 minutes using flotation bags. The post-landing environment was described by the flight crew as very comfortable and cool. No offensive odors were noted. The Commander, however, became seasick and vomited once — no antimotion sickness drugs were taken during the entry phase of the flight and the crew had to wait in the spacecraft approximately 1 hour for sunrise and egress.

During the postflight medical debriefing, the Commander and Command Module Pilot commented about the significant difference between the Gemini VII and the Apollo 8 flights in readapting to the force of gravity. They observed that the weakness in their legs experienced following the Gemini VII flight was completely absent following Apollo 8. The crewmen attributed this difference not only to the difference in mission duration but also to the fact that intravehicular activities and more effective exercise were performed during the Apollo 8 flight. The crewmen did not experience the subjective feeling of heaviness in the extremities reported by the Apollo 7 crewmembers.

4.0 POTABLE WATER

4.1 WATER SERVICING

4.1.1 Preflight

The Ground Support Equipment (GSE) load water was deionized, microbially filtered water which met specification standards. Before the flight, the load water was chlorinated with an aqueous solution of sodium hypochlorite. This chlorinated water (containing 8 mg of chlorine per liter) was injected into the spacecraft water system and the system soaked for a 6-hour period. Then the spacecraft system was drained, flushed, and refilled with nonchlorinated GSE water preparatory to lift-off. The preflight water servicing chronology is given in table 4-I.

To chlorinate the water for flight, one ampoule each of chlorine solution (sodium hypochlorite) and buffer solution (sodium dihydrogen phosphate) was injected into the spacecraft system at T - 2:30 hours using inflight chlorination equipment and procedures. Thirty minutes after chlorination; 1200, 300, and 60 ml of water were flushed through the hot-water food preparation port, the cold-water food preparation port, and the water gun, respectively, to effect a volume exchange of the potable water system.

4.1.2 Inflight

The Apollo 8 crew performed six chlorinations of the potable water system at approximately 24-hour intervals. The schedule of the chlorinations is given below.

Ground Elapsed Time, hour: minute
31:00
50:00
73:23
96:00
121:23
143:59

4.2 INFLIGHT WATER CONSUMPTION

Water consumption during the Apollo 8 flight, shown in Table 4-II, was estimated from the onboard daily water log, not from the water gun count. (The water gun was used to flush the urine collection device; the amount used could not be determined.) Even though the water consumption data are missing for days 5 and 6, serial postflight body weights indicate that the Apollo 8 crew was in a state of negative water balance at the time of landing. The postflight physical examinations also confirmed this finding.

4.3 WATER CHEMICAL AND BACTERIOLOGICAL ANALYSES

Chemical and bacteriological analyses of the spacecraft water were required for the following reasons:

a. To evaluate the preflight water servicing procedure (i.e., spacecraft water system sterilization and disinfection, final load water loading technique, and final load water potability).

b. To determine the potability of the water remaining in the spacecraft water system postflight.

c. To evaluate the inflight chlorination procedure.

d. To evaluate the ability of the system to deliver potable water.

4.3.1 Sampling Procedures

The general sampling times and procedures for the chemical and microbial analyses are shown in table 4-III.

4.3.2 Results

4.3.2.1 Chemical analyses.- Tabulated results of chemical analyses of GSE and spacecraft water are shown in table 4-IV.

The preflight analyses indicated that all ionic species (trace metals) were within specification limits. Analyses conducted December 13 and 15, 1968, on GSE water failed to conform to specifications for surface tension. Other categories of samples were within specified limits.

Postflight analyses of samples taken at splashdown + 14 hours indicated that the concentration of nickel ions present in the hot water port was 2.42 mg/l, and in excess of the specified limit of 0.05 mg/l. The remaining ionic species were within specification limits. The postflight spacecraft water from the hot-water food preparation port and the water gun contained a chlorine residual of 0.1 mg/l and 2.0 mg/l respectively. This residual was obtained 17 hours after the last crew chlorination. Among other categories, the taste and odor for the water gun sample was 5 units, exceeding the specification limits of 3 units. This excess is probably related to the 2.0 mg/l chlorine residual, although some correlation may exist between taste and odor and the relatively high total-solids content of 12.76 mg/l. Specification limit for total solids is 14 mg/l.

4.3.2.2 Microbiological analyses.- Tabulated results of microbial analyses of GSE and spacecraft water are shown in table 4-V. As can be seen in the table, tests for coliform and anaerobic bacteria, and yeasts and molds were negative in both preflight and postflight cultures. However, preflight tests for total bacterial count were generally positive in potable water, both in GSE and spacecraft systems. The positive tests were the result of no chlorine in the spacecraft system water between the time of completion of the flushing operation used to remove the chlorine soak solution and the time of preflight chlorination at T-2:30 hours (i.e., during the 4-day interval from December 16, 1968 to December 20, 1968). Postflight microbial analyses were entirely negative for both use ports in the spacecraft when sampled at splashdown + 14 hours. Water samples from the waste tank were also analyzed; 1.41×10^4 colonies/150 ml were cultured.

4.4 DISCUSSION

4.4.1 Preflight

The fact that organisms were cultured from the spacecraft water system after the chlorine soak is not surprising; the chlorine soak was only used to initially disinfect the system and to condition it for subsequent inflight chlorination, and the microbial results were obtained when the water contained no chlorine. Without a bacteriostatic level of a biocide in water, a sterile condition is very difficult to maintain unless a much more vigorous sterilization technique than the chlorine soak is employed.

However, the positive microbial results are no indication that the chlorine soak does not have merit; the soak does afford a significant and required degree of disinfection (e.g., no organisms were detected in the water gun immediately following the chlorine soak). Moreover, the rate of chlorine degradation can be ascertained during the soak (fig. 4-1). These data are required to project the degradation rate of chlorine which can be anticipated inflight. Furthermore, the biocidal efficiency of the chlorine soak will be increased by the use of a buffer in the chlorinated water.

The rapid multiplication of organisms in the potable water is significant. In the 4-day preflight period, the concentration of organisms increased from an initial count of 2.0×10^3/150 ml to 5.0×10^4/150 ml. Then a subsequent decrease to 5.0×10^3/150 ml (probably attributable to an overgrowth phenomenon) occurred. For example, the water gun count increased dramatically. The initial count was negative; the final count was 1.1×10^5/150 ml.

The microbial content of the preflight water necessitated the preflight chlorine injection. Unfortunately, operational difficulties in collecting spacecraft water samples at the time of countdown prevented verifying the effectiveness of this procedure. However, previous experience indicates that the combination of preflight injection and the flushing procedure would have controlled the microbial content.

Analysis of the chlorine degradation documented during the chlorine soak period showed that the minimum chlorine residual of 0.5 mg/l was maintained in the spacecraft system during the chlorine soak period.

4.4.2 Inflight

The inflight chlorination equipment worked satisfactorily (except for a minor chlorine leak), and the chlorinations were performed throughout the flight. The first inflight chlorination, however, was performed at 31:00 g.e.t., which was 7 hours after the scheduled time. Consequently, 33.5 hours elapsed between chlorination times, thereby precluding the maintenance of a chlorine residual. The remaining inflight chlorinations were performed very nearly on schedule.

4.4.3 Postflight

The postflight water samples were collected 17 hours after the last inflight crew chlorination. The chlorine residuals were 0.1 mg/l and 2.0 mg/l in the hot water and the water gun water, respectively. The lower residual in the hot water was expected. The water gun residual, which is more representative of the system residual, was lower than expected. The theoretical chlorine residual immediately after chlorination is 6.0 mg/l. This theoretical residual in combination with the scheduled 24-hour dose rate and the time and amount of postflight chlorine residual indicated that the level of chlorine would have been maintained throughout the flight. However, this data also indicated that the minimum required level of 0.5 mg/l would not be maintained.

The chemical analysis of the postflight water shows a significant level of nickel in the hot water. This concentration of 2.42 mg/l was categorically higher than the recommended level of 0.05 mg/l and significantly higher than the maximum allowable concentration of 1.0 mg/l. Moreover, toxic effects to man could occur as a result of this nickel ion concentration. Since previous data from other spacecraft systems indicate that higher levels were experienced more often in spacecraft systems which did not contain chlorine, the nickel concentration cannot be directly attributable to the presence of chlorine in the water.

4.5 CONCLUSIONS

The following conclusions were drawn from the water servicing, consumption, and chemical and biological analyses for the Apollo 8 mission:

a. The use of preflight sterilization/disinfection procedures, while not absolute, is not contraindicated or without merit and should continue to be used on future missions.

b. Apollo 8 potable water contained a chlorine residual (0.1 to 2.0 mg/l) throughout the flight. This chlorine residual level, however, did not meet the minimum required level of 0.5 mg/l.

c. Since the lack of complete sterilization resulted in positive preflight microbial tests of the spacecraft potable water, the potable water had to be chlorinated *in situ* a short time before liftoff. Since no significant change in the water servicing procedure is anticipated, the requirement to chlorinate preflight will continue.

d. The health of the crewmen was jeopardized by the high nickel content of the spacecraft hot water.

4.6 RECOMMENDATIONS

Recommendations for future Apollo flights, which are based on Apollo 8 experiences, are as follows:

a. Potable water in subsequent flights should be sampled in a manner similar to that used on Apollo 8.

b. A buffer, sodium dihydrogen phosphate, should be used in the initial chlorine soak to increase the biocidal efficiency of the soak.

c. If the final loaded water does not contain a bactericide, the preflight chlorination with flush at T-3 hours or later should be retained.

d. The nickel contamination problem in the spacecraft hot water should be thoroughly investigated.

e. The chlorine leak that was experienced during one of the inflight chlorinations should be investigated.

TABLE 4-I.- CHRONOLOGY OF SERVICING PREFLIGHT WATER

Hour	Action
Friday, December 13, 1968	
2100	Sodium hypochlorite added to GSE water
2200	Chlorination of GSE completed
Saturday, December 14, 1968	
1430	Chlorinated water injected into spacecraft system
2030	Spacecraft system drained
Sunday, December 15, 1968	
--	Flush of GSE to remove chlorine residual begun
0200	Flush of spacecraft system begun
Monday, December 16, 1968	
--	Flush of spacecraft system completed: final water loaded

TABLE 4-II.- APOLLO 8 CREW DRINKING WATER CONSUMPTION

Water consumption ounces							
Crewman	Flight Day						Total, ounces
	1	2	3	4	5	6	
Commander	57	56	99	100	(a)	(a)	312
Command Module Pilot	57	59	84	86	(a)	(a)	286
Lunar Module Pilot	79	84	86	96	(a)	(a)	335

[a]Data Missing

TABLE 4-III.- SAMPLING PROCEDURES

Time	System	Sample port	Sample number	Sample volume, ml	Sample distribution			
					KSC		MSC	
					Number	Volume, ml	Number	Volume, ml
Immediately prior to final servicing of spacecraft systems (baseline sample)[c]	GSE	GSE final sample point prior to the spacecraft connect point	2	2000	1	1000	1	2000
			1	[a]500	1	500		
			1	[b]10	1	10		
Immediately following final servicing of spacecraft systems	CM/3	Water gun	2	2000	1	2000	1	2000
			1	500	1	500		
			1	10	1	10		
T - 4 days	CM/3	Water Gun	1	1000	1	500	1	1000
			1	500	1	10		
			1	10				
		Hot water port	1	500	1	500	1	1000
			1	10	1	10		
T - 30 to T - 24 hours	CM[d]	Water gun	2	1000	1	1000		
			1	500	1	5000		
			1	10	1	10		
		Hot water port	1	500	1	500		
			1	10	1	10		
Postflight	CM	Water gun	1	[e]2000			1	2000
			1	500			1	500
			1	10			1	10
			1	[f]100				
		Hot water port	1	[e]500			1	500
			1	500			1	10
			1	10				
			1	[f]100				
		Waste water tank	1	[e]1000			1	2000
			1	500			1	500
			1	10			1	10

[a]The 500-ml samples were used for microbiological analyses except where specified "chem" for chemical analysis.

[b]The 10-ml samples listed in the table were taken with a vacutainer for anaerobic analysis.

[c]Total sterility not required at this point.

[d]These samples were taken prior to fuel cell activation.

[e]Used for chemical analysis.

[f]Used for chlorine residual analysis.

TABLE 4-IV.- APOLLO 8 MANNED SPACECRAFT CHEMICAL ANALYSIS OF WATER

Parameter	December 18, 1968			December 20, 1968			December 27, 1968 (Splashdown +14 hours)		
	Hot water port MSC	Water gun MSC	Water gun KSC	Hot water port MSC	Water gun MSC	Water gun KSC	Hot water port	Water gun	Waste tank
pH, units at 25° C	7.41	7.20	6.2	7.79	7.13	6.7	7.55	7.40	6.63
Electrical conductivity, microhms at 25° C	0.42	0.29	-	0.49	0.25	--	1.87	2.13	0.56
Surface tension, dynes/cm at 20° C									
Total solids, mg/l	0.96	0.65	1.6	0.69	0.84	1.8	10.99	12.76	1.38
Nonvolatile solids, mg/l	0.81	0.56	1.6	0.58	0.76	1.8	10.78	12.60	1.31
Total filterable solids, mg/l	0.56	0.26	0.0	0.39	0.44	0.0	10.29	12.26	1.08
Taste and odor, threshold units at 45° C	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	5.0	<3.0
Turbidity, units	0.2	0.2	0.23	0.2	0.3	0.25	0.4	0.4	0.2
Color, units	1.0	1.0	<5.0	1.0	1.0	<5.0	1.0	1.0	1.0
Ionic species, mg/l:									
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Cr	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	<0.05	<0.05
Cu	<0.01	<0.01	<1.0	<0.01	<0.01	<1.0	0.06	0.04	0.04
Fe	0.03	<0.02	<0.3	0.02	<0.02	<0.3	0.04	0.09	0.07
Pb	<0.01	<0.01	<0.05	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01
Mn	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	0.06	0.05
Hg	<0.005	<0.005	<0.013	<0.005	<0.005	<0.013	<0.005	<0.005	<0.005
Ni	0.02	0.02	<0.05	0.03	0.02	<0.05	2.42	0.08	0.35
Ag	<0.01	--	<0.05	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01
Zn	0.02	--	<5.0	0.02	0.03	<5.0	0.06	0.11	0.15
Ca	0.03	--	--	0.03	0.03	--	0.07	0.02	0.13
Na	0.03	--	--	0.03	0.02	--	8.1	10.8	0.47
K	<0.05	--	--	<0.05	<0.05	--	0.12	0.07	0.05
Se	<0.01	--	--	<0.01	<0.01	--	<0.01	<0.01	<0.01
Mg	0.03	--	--	0.03	0.03	--	0.03	0.04	0.02
Al	--	--	--	--	--	--	0.59	0.39	0.28

TABLE 4-IV.- APOLLO 8 MANNED SPACECRAFT CHEMICAL ANALYSIS OF WATER - Concluded.

Parameter	December 13, 1968 KSC GSE-potable water prechlorination	December 15, 1968 GSE before final loading		December 16, 1968 Hot water port MSC	December 16, 1968 Water gun	
		KSC	MSC		MSC	KSC
pH, units at 25° C	6.3	6.3	6.73	7.31	6.32	6.1
Electrical conductivity, microhms at 25° C	0.45	0.17	0.31	0.28	0.40	--
Surface tension, dynes/cm at 20° C	71.4	71.3	--	--	--	--
Total solids, mg/l	.2	.0	.92	.98	.99	0.6
Nonvolatile solids, mg/l	.2	.0	.84	.88	.82	.4
Total filterable solids, mg/l	.0	.0	.42	.48	.59	.0
Taste and odor, threshold units at 45° C	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Turbidity, units	.20	.25	.3	.3	.4	.25
Color, units	<5.0	<5.0	1.0	1.0	1.0	<5.0
Ionic species, mg/l:						
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu	<1.0	<1.0	<0.05	<0.05	<0.05	<1.0
Fe	<0.3	<0.3	.02	.03	.02	<0.3
Pb	<0.05	<0.05	<0.01	<0.01	<0.01	<0.05
Mn	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hg	<0.008	<0.008	<0.005	<0.005	<0.005	<0.008
Ni	<0.05	<0.05	.03	.24	.09	<0.05
Ag	<0.05	<0.05	<0.01	<0.01	<0.01	<0.05
Zn	<5.0	<5.0	.02	<0.01	.02	<5.0
Ca	--	--	.01	--	.02	--
Na	--	--	.02	--	.03	--
K	--	--	<0.05	--	<0.05	--
Se	--	--	<0.01	--	<0.01	--
Mg	--	--	.02	--	.04	--

TABLE 4-V.- APOLLO 8 MANNED SPACEFLIGHT

MICROBIAL ANALYSIS OF WATER

Date	Collection point and time	Total count	Coliform	Anaerobic	Yeast and Mold
12-15-68	Preload GSE (0100)	450 colonies/150 ml *Flavobacterium* sp. IIIa	Negative	Negative	Negative
12-16-68	Postload, preflight T-6 days Hot-water port (0400)	2000 colonies/150 ml *Flavobacterium* sp. IIIa	Negative	Negative	Negative
	Water gun (0400)	Negative	Negative	Negative	Negative
12-18-68	Preflight T-4 days Hot-water port (2400)	75000 colonies/150 ml *Flavobacterium* sp. IIIa	Negative	Negative	Negative
	Water gun (2400)	300 colonies/150 ml *Flavobacterium* sp. IIIa	Negative	Negative	Negative
12-20-68	Preflight T-23 hours Hot-water port (0500)	5000 colonies/150 ml *Flavobacterium* sp. IIIa	Negative	Negative	Negative
	Water gun (0500)	11×10^5 colonies/150 ml *Flavobacterium* sp. IIIa	Negative	Negative	Negative
12-27-68	Splashdown +14 hours Hot-water port Water gun Waste tank	 Negative Negative 14100 colonies/150 ml *Flavobacterium* sp. IIIa	 Negative Negative Negative	 Negative Negative Negative	 Negative Negative Negative

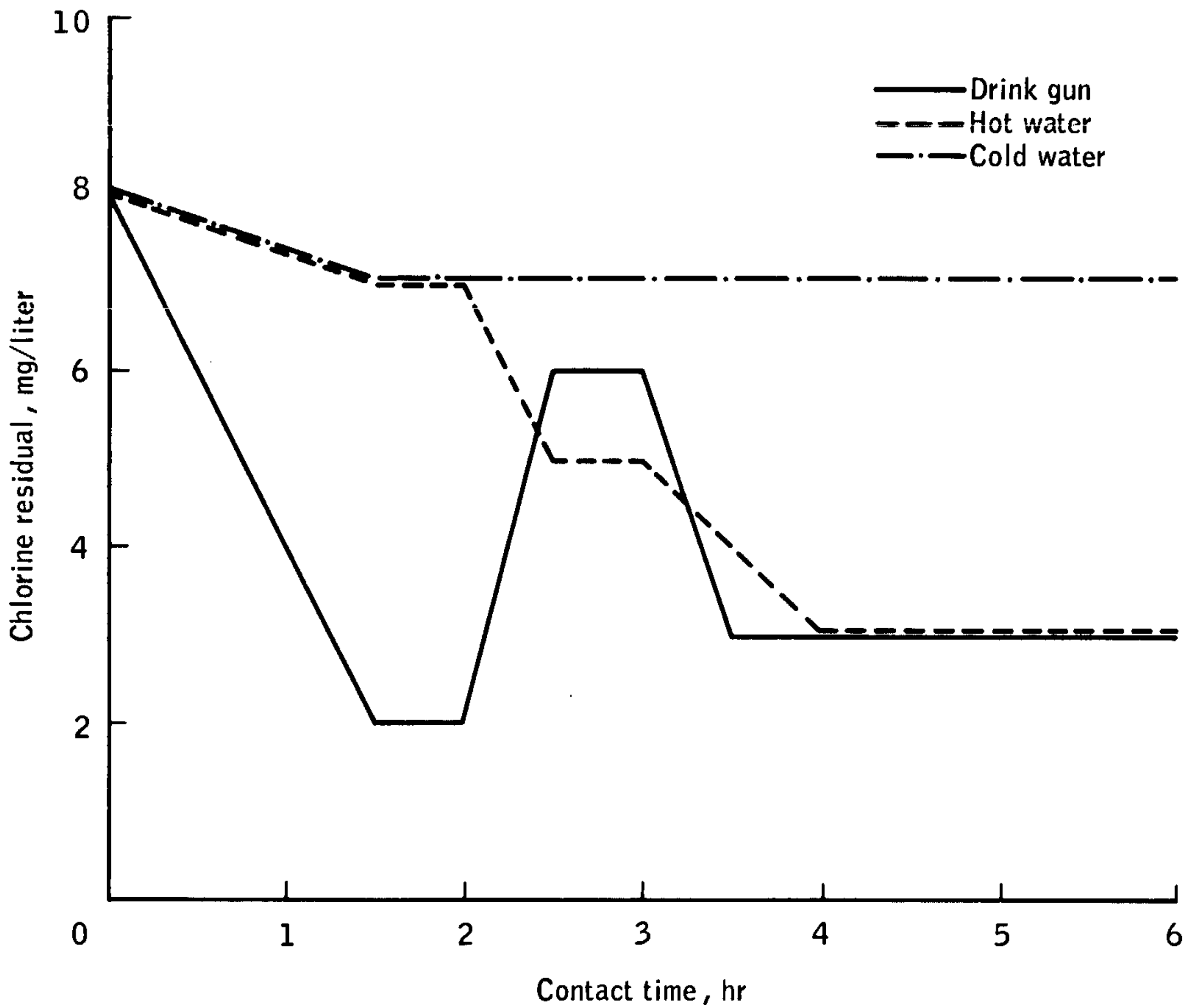


Figure 4-1. - Apollo 8 potable water system presoak chlorine residuals.

5.0 FOOD SYSTEMS

5.1 INTRODUCTION

The Apollo 8 food system provided the necessary nutrients to maintain optimal crew performance throughout the mission. A 4-day menu cycle, containing approximately 2500 calories per man per day, was supplied. Each crewmember was provided a total of 32 meals as described in table 5-I and a special Christmas dinner as described in table 5-II. The quantity of food stowed was adequate for an 11-day mission, although the mission was planned for 6.1 days.

5.2 FOOD SUPPLIES

5.2.1 Rehydratables and Bite-size Food

Ninety-six meals, personal hygiene items (a wet skin-cleaning towel with each meal), oral hygiene items (3 toothbrushes, 1 tube of toothpaste, and 1 spool dental floss), and chewing gum (3 sticks per day stowed in Meal A) were supplied. Forty-one meals (P/N 14-0122/Line 16J) and the oral hygiene items were stowed in the lower equipment bay (LEB) food container and 55 meals (P/N 14-0123/Line 16J) were located in the left hand equipment bay (LHEB) food container. The weights of the food supplies including the spacecraft food containers were 31.52 pounds and 40.70 pounds for the LEB and LHEB respectively. The 96 overwrapped meals contained a total of 463 primary food packages, 309 rehydratable and 154 bite-size food packages.

The crew rest-work cycles and eat periods scheduled in the flight plan determined the types of food located in the LEB and LHEB. Meals were arranged so that breakfast (Meal A) would be available to the crewmember after rest periods.

5.2.2 Wet-Pack Food

The turkey chunks and gravy used for the special Christmas dinners were wet-pack food that did not require rehydration. The meal was eaten with a spoon provided in the meal package. The turkey chunks and gravy was packaged in a flexible aluminum-plastic laminate and stowed with the other Christmas dinner menu items in 4 overwrapped packages (total weight of 2.3 pounds).

5.2.3 Contingency Food

A Contingency Feeding System, consisting of one contingency feeding valve adapter (Pontube) and two restrainer pouches overwrapped in Kel-F-82, was stowed for each crewmember in the LHEB food container.

The Contingency Feeding System would allow a crewmember in a pressurized suit to consume liquid food (fruit drinks and cocoa only) if necessary. One end of the Pontube attaches to the rehydratable food package water valve and the other end passes through the helmet port, allowing the food to be transferred from the food package to the crewman's mouth without depressurizing the suit. A valve on the Pontube is used to slowly equalize the pressure within the food package. The restrainer pouch would minimize the chance of rupturing the food package during liquid food consumption, and if rupture does occur, would contain most of the escaping liquid preventing excessive dispersion throughout the crew compartment. This system will function at pressures of 3.5 and 4.0 psid if the food package heat seals are adequate.

5.3 EVALUATION OF FOOD SYSTEM

5.3.1 Preflight

Each crewmember was provided with a 4-day menu for evaluation before the mission. The meals in this menu contained representative food items available for flight. Some items were deleted at the request of the crew. For the flight menu, an effort was made not to repeat food items during the 4-day cycle and to keep sweet items at a minimum. One extra drink per day per man was provided. The extra drink was placed in the Meal A overwrap for the crew member to consume at anytime during the day.

5.3.2 Inflight

There were no food package failures during the mission. No real-time comments about the food were transmitted by the crew. However, comments on food during postflight crew debriefings indicated that the food was acceptable but could be improved. The crew commented that the bite-size food items were either too dry or too sweet, rehydratable food items required too much time to prepare, and neither were as tasty as the specially prepared turkey. No problems were encountered in eating the turkey with a spoon.

5.3.3 Postflight

The food stowage containers with their contents were removed from the spacecraft and transported to MSC for evaluation. The weights of the LEB and the LHEB food containers as received were 23.25 pounds and 36.76 pounds, respectively. An inventory of the returned meal overwraps and primary food packages revealed some missing items. The missing items included: (1) one white toothbrush, (2) one spool of dental floss with overwrap, (3) six primary overwraps, and (4) 22 bite-size food packages. Inventory of the returned unused foods and waste food packages is a method of determining the quantity of food consumed by each crewmember. An alternate method of determining food intake is for the crewmembers to maintain an onboard log of the foods eaten during the mission. The onboard log was not maintained during this mission and therefore contributed little information for calculation of caloric intake.

An estimate of the daily caloric intake for each crewman is presented in table 5-III. Two values are presented, one calculated from returned empty packages and the other including all mission food (the actual value probably falls somewhere in between). The water required to rehydrate the consumed foods was 580 ounces; 190 ounces for the Commander, 206 ounces for the Command Module Pilot, and 184 ounces for the Lunar Module Pilot.

During the postflight food evaluation, it was noted that the germicide tablet provided with each rehydratable food package to prevent bacterial growth and gas formation was not used on eight packages.

A definite odor was present in packages of meat items in which the germicide tablet was not used.

TABLE 5-I.- APOLLO 8 MENU CYCLE

Meal	Day 1[a], 5, 9	Day 2, 6, 10	Day 3, 7, 11	Day 4, 8, 12
A	Peaches Bacon squares (8) Cinnamon toasted bread cubes (8) Grapefruit drink	Canadian bacon and applesauce Sugar-coated corn flakes Apricot cereal cubes (8) Grapefruit drink Orange drink	Fruit cocktail Bacon squares (8) Cinnamon toasted bread cubes (8) Cocoa Orange drink	Canadian bacon and applesauce Toasted bread cubes (8) Strawberry cereal cubes (6) Cocoa Orange drink
B	Corn chowder Chicken and gravy Toasted bread cubes (6) Sugar cookie cubes (6) Cocoa Orange drink	Tuna salad Chicken and vegetables Cinnamon toasted bread cubes (8) Pineapple fruitcake (4) Pineapple-grapefruit drink	Cream of chicken soup Beef pot roast Toasted bread cubes (8) Butterscotch pudding Grapefruit drink	Pea soup Chicken and gravy Cheese sandwiches (6) Bacon squares (6) Grapefruit drink
C	Beef and gravy Beef sandwiches (4) Cheese-cracker cubes (8) Chocolate pudding Orange-grapefruit drink	Spaghetti and meat sauce Beef bites (6) Bacon squares (6) Banana pudding Grapefruit drink	Potato soup Chicken salad Turkey bites (6) Graham cracker cubes (6) Orange drink	Shrimp cocktail Beef and vegetables Cinnamon toasted bread cubes (8) Date fruitcake Orange-grapefruit drink
Total daily calories, K cal	2485	2537	2522	2441

[a]Day 1 menu consisted of meals B and C only.

TABLE 5-II.- APOLLO 8 SPECIAL CHRISTMAS DINNER

Turkey and gravy
Cranberry-applesauce
Grape punch
Coffee
Stainless steel spoon

TABLE 5-III.- APOLLO 8 TOTAL AND AVERAGE DAILY CALORIC INTAKE

Day	No. of Meals	Daily caloric intake, kcal (a)	Daily caloric intake, kcal (b)
Commander			
1	2	985	985
2	2	881	881
3	3	1984	2155
4	3	1906	2139
5	3 (+ Xmas)	1582	1986
6	3	1368	1600
7	1	147	147
		Total: 8853	Total: 9893
		Average per day[c]: 1475	Average per day[c]: 1649
Command Module Pilot			
1	2	1497	1664
2	2	973	973
3	3	2061	2135
4	3	1366	1825
5	3 (+ Xmas)	1899	2528
6	3	1227	1996
7	0	0	0
		Total: 9023	Total: 11 121
		Average per day[c]: 1503	Average per day[c]: 1853
Lunar Module Pilot			
1	2	1005	1005
2	2	1297	1529
3	3	1610	1834
4	3	1604	2046
5	3 (+ Xmas)	809	994
6	3	1059	1383
7	0	0	0
		Total: 7384	Total: 8791
		Average per day[c]: 1230	Average per day[c]: 1465

[a]Calculated from returned empty packages only.

[b]Includes returned empty packages plus mission food and packages (not returned).

[c]Six days.

6.0 PREFLIGHT AND POSTFLIGHT PHYSICAL EXAMINATIONS

6.1 EXAMINATION ON NOVEMBER 23, 1968 (F - 28 day)

Physical examinations as delineated in the Medical Requirements Document, Apollo Mission C Prime, were performed on November 23, 1968 at the MSC Flight Medicine Dispensary by Lt. Colonel Daniel Spoor, USAF, MC. The Lunar Module Pilot was seen in consultation by Dr. Edward M. Shapiro, Dermatologist.

The Lunar Module Pilot was found to have seborrhea of the face, complicated by a microsporum infection. He also had a small area of ringworm on the left forearm. These lesions were treated with Mycolog ointment to the face and Tinactin to the arm lesion. A small pedunculated nevus in the anterior axillary line, subject to trauma by the pressure garment shoulder seam, was excised during this examination.

No significant findings not already on record from annual physical examinations were noted in the Commander or Command Module Pilot. (Crew weights for this examination and subsequent examinations are shown in table 6-I.)

6.2 EXAMINATION ON DECEMBER 7, 1968 (F - 14 day)

Dr. C. A. Jernigan performed the F - 14 day physical examinations as prescribed in the Medical Requirements Document, Apollo Mission C Prime. The examinations were performed in the MSC Flight Medicine Branch Dispensary on December 7, 1968.

The Commander had a herpetic lesion of the upper lip on which he had been using Blistex ointment. At the time of the examination, the lesion appeared to be resolving.

The Command Module Pilot was noted to have tinea pedis on the left great toe and seborrhea of the scalp. Tinactin was prescribed for the tinea, and Sebutone shampoo daily, 5 days prior to flight, was prescribed for the seborrhea.

The Lunar Module Pilot's tinea corpora was still present with a secondary pustule which appeared to be healing. It was recommended that he continue the Tinactin drops up until the time of the mission.

6.3 EXAMINATION ON DECEMBER 16, 1968 (F - 5 day)

Comprehensive physical examinations as prescribed in the C-Prime Medical Requirements Document were performed on December 16, 1968 in the Medical Suite, Operations and Checkout Building, Kennedy Space Center. The ophthalmology examination was performed by Dr. Jernigan, the ENT examination by Dr. Charles LaPinta, and the remainder of the examination by Colonel Daniel Spoor.

The Command Module Pilot still had moderate seborrhea of the scalp. The Lunar Module Pilot's seborrhea and tinea were both improved, but still detectable.

No other significant physical findings were noted.

6.4 FLIGHT DAY (F - 0) EXAMINATION

Flight day physical examinations were performed at the Operations and Checkout Building, Kennedy Space Center. The Commander was examined by Dr. Alan C. Harter and the other two crewmembers by Dr. Jerry M. Joiner.

The Commander had a slight injection of the nasal mucosa and the right side of the oral pharynx, with minimal lymphoid hyperplasia. He also had a slight amount of abdominal gas. None of these findings were considered significant by the examiner. There were no significant findings in the other two crewmen.

6.5 RECOVERY DAY (R + 0) EXAMINATION

The recovery day physical examinations were performed in the sick bay of the USS Yorktown. The ophthalmology and the ENT portions were performed by Dr. Charles LaPinta; the remainder of the examination was performed by Lt. Colonel Daniel Spoor.

6.5.1 Commander

Small aphthous ulcers were noted on the hard palate, the right buccal mandibular gingiva, and the inside of the upper lip.

There were healing pinpoint lacerations of the skin 2 centimeters below the hairline of either side of the forehead, which the Commander believes to have been caused by headset pressure.

6.5.2 Command Module Pilot

The conjunctivae were very mildly injected. Seborrheic dermatitis of the left malar region, left eyebrow, and scalp were rather prominent. There was a 1-centimeter healing laceration of the tip of the tongue in the midline, the etiology was unknown to the Command Module Pilot.

6.5.3 Lunar Module Pilot

There was moderately severe chapping of the lips, worse on the lower lip. The dermatophytosis of the left forearm was again apparent but had not enlarged, and was not inflamed. Moderate congestive prostatitis was noted after it became symptomatic following evacuation of a large hard stool. This condition responded well to massage and to two doses of Pyridium plus rehydration.

Two small pustules and a moderate amount of surrounding maceration were present under the superior sternal biomedical sensor. The sensor was still firmly in place.

The recovery day medical procedures required approximately 30 minutes longer than prescribed in the Medical Requirements Document. This was caused by several delays in the protocol resulting from radio-telephone messages for the crewmembers. An emergency appendectomy performed on a USS Yorktown crewmember during the period of the physical examinations did not in any way interfere with the postflight medical protocol (or vice versa).

6.6 POSTFLIGHT EXAMINATIONS

The Lunar Module Pilot developed a mild pharyngitis on January 2, 1969. This evolved into a "common cold" syndrome with coryza and a nonproductive cough. He received symptomatic therapy and was almost fully recovered when seen on January 8, 1969.

The Commander reported similar symptoms beginning on January 8, 1969 shortly before departing on his public relations tour.

TABLE 6-I.- APOLLO 8 FLIGHT CREW WEIGHT

Crewmember	Weight, lb						
	F - 28	F - 14	F - 5	F - 0	R + 0	R + 1	R + 2
Commander	168.00	168.50	170.00	169.25	160.50	163.25	165.50
Command Module Pilot	168.50	171.00	168.50	171.80	164.00	164.75	165.75
Lunar Module Pilot	145.50	148.00	145.50	142.00	138.00	138.50	-

7.0 TOXICOLOGICAL EVALUATION

7.1 INTRODUCTION

The toxicological analysis of the environment within the Apollo Command Module (CM) was necessary to adequately evaluate human physiological performance and reaction to spacecraft environment. The analysis was performed to verify that no deleterious materials were introduced into the spacecraft environment as a result of alteration and repairs which may have occurred after altitude chamber tests at KSC.

7.2 PROCEDURE

Atmospheric sampling of the Apollo 8 CM was performed on September 16, 1968 during the unmanned altitude chamber test at KSC. The off-gassing test consisted of 8 hours of continuous sampling. The cabin was maintained at 5-psia O_2 with a mean temperature of 70° F. The first grab sample was taken immediately following the initial decompression, and hourly samples were taken thereafter.

Cryogenically trapped samples were obtained over the test period providing integrated values for that period. A sampling rate of 500 standard milliliters per minute through the cryotraps was used.

7.3 RESULTS

The analytical results of the toxicological evaluation are given in tables 7-I and 7-II. Freon-12, -22, -113, and -114 are combined and reported as "Freons." The identity of ethanol and isopropanol was established, but silicone eluted at the same point in the gas chromatograph as ethanol and isopropanol preventing accurate quantitation of these compounds.

The contaminants observed resembled those found in the Apollo 7 CM; however, total contaminant levels were higher in the early phases of the Apollo 8 CM offgassing than in the Apollo 7 CM.

Although isoprene was found the Apollo 7 CM, it was not found in the Apollo 8 CM. The Freon levels found in the Apollo 8 CM indicated the continuous liberal use of Freon-113 as a cleaning agent in and around the spacecraft. Although the quantity of Freon-113 allowed in the spacecraft at any one time is limited, replenishment of that quantity is not limited.

Styrene was found in the Apollo 8 CM and had reached a level of 1.5 ppm. The identity of this compound was verified by mass spectroscopy and a combination of mass spectroscopy and gas chromatography. Although the level found was not at the irritant level, the presence of styrene required a review of all possible sources, since styrene is a normal component of polystyrene and butyl rubber, neither of which should be in the spacecraft.

The results of the toxicological evaluation of the Apollo 8 CM indicated a satisfactory atmosphere for human habitation.

The LiOH-charcoal canisters were recovered postflight for elution and analysis. The data are still being analyzed; however, the anticipated high Freon levels were found in the first canisters examined.

TABLE 7-I.- APOLLO 8 COMMAND MODULE ATMOSPHERE

EVALUATION, GRAB SAMPLE ANALYSIS

Compound	Quantity, ppm, for sample number (taken during unmanned run, Sept. 16, 1968)								
	1	2	3	4	5	6	7	8	9
Freons	11.21	5.91	3.50	5.15	8.77	8.41	5.72	8.41	8.55
n-hexane	-	-	-	-	-	.06	.005	.007	.01
n-heptane	.02	.01	.01	.02	.02	.02	.01	.009	.01
Benzene	.01	.02	.06	.04	.05	.02	.006	.007	.005
Cyclohexane	.001	.004	.001	.01	.003	.001	.006	.003	.006
Toluene	.16	.11	.09	.18	.18	.15	.17	.23	.16
n-octane	.04	.005	.01	.03	.01	.02	.01	.02	.04
Xylenes	.05	.076	.07	.12	.07	.15	.056	.024	.09
Ethyl benzene	.02	.01	.01	.03	.01	.04	.01	.005	.01
Styrene	.5	.5	.32	.28	.64	1.5	.3	.32	.64
Acetone	.002	.005	.01	.01	.02	.006	.003	.007	.01
Methyl ethyl ketone	.03	.03	.02	.03	.04	.05	.32	.25	.19
Methyl isobutyl ketone	.54	.45	.43	.57	.57	.57	.49	.52	.54
2-pentanone	-	-	.008	.02	.01	.02	.003	.005	.04
Ethanol[a]	.17	.26	.2	.33	.22	.26	.47	.51	.37
Isopropanol[a]	.14	.13	.09	.22	.1	.17	.11	.15	.17
n-propanol	.02	.02	.02	.01	-	.03	-	.05	[a].39
Methyl chloroform	.1	.09	.07	.12	.13	.15	.07	.06	.33
Trichloroethylene	.48	.49	.5	.53	.42	.8	.66	.58	.44
Tetrachloroethylene	.23	.23	.13	.12	.27	.35	.25	.19	.22
Trimethyl silane	.04	.06	.05	.01	.08	.04	.07	.1	.06
Methyl methacrylate	.01	-	-	-	-	.008	.006	.009	.03
Mesitylene	.02	.02	.009	.02	.02	.03	.06	.02	.03
Silicones	.02	.068	.245	.077	.165	.055	.33	.04	.09

[a]A silicone-type compound elutes at the same time.

TABLE 7-II.- APOLLO 8 CRYOGENIC TRAP ANALYSES

Compound	Quantity on Sept. 16, 1968	
	Total mg	mg/m^3 (a)
Freons	12.1103	72.622
C_2 — C_3	.004	.02
C_4	.005	.03
n-hexane	.001	.008
Cyclohexane	.0005	.003
n-heptane	.008	.04
Benzene	.02	.12
Toluene	.12	.71
Ethyl benzene	.006	.03
Xylenes	.014	.1
Mesitylene	.0001	<.001
n-octane	.02	.1
Styrene	.18	1.1
Methanol	.005	.03
Ethanol	.02	.12
Isopropanol	.02	.11
Acetone	.008	.05
Methyl ethyl ketone	.1	.59
Methyl isobutyl ketone	.517	3.4
Butyl acetate	.01	.06

[a]Total sampling volume = 0.17 m^3.

TABLE 7-II.- APOLLO 8 CRYOGENIC TRAP ANALYSES - Concluded

Compound	Quantity on Sept. 16, 1968	
	Total mg	mg/m^3 (a)
Chloroform	.003	.01
Methyl chloroform	.23	1.3
Dichloroethane	.0003	.002
Trichloroethylene	.49	2.9
Tetrachlorcethylene	.14	1.1
Trimethyl silane	.02	.11
Methyl methacrylate	.006	.04
Silicones	1.136	6.7

[a]Total sampling volume = 0.17 m^3.

8.0 RADIOLOGICAL HEALTH

8.1 MONITORING OF RADIATION ENVIRONMENT AND CREW DOSIMETRY

8.1.1 Real-Time Dosimetry and Analysis

The Van Allen Belt dosimeter (VABD) and personal radiation dosimeter (PRD), the radiation survey meter (RSM), the nuclear particle detection system (NPDS), solar particle alert network (SPAN), and the riometer network provided real-time data to assure that the maximum operation radiation dose would not be exceeded during the mission.

8.1.1.1 Van Allen Belt Dosimeter - The VABD provided the real-time quantitative estimate of the radiation dose received by the Apollo 8 crew. This instrument provided the skin and depth dose rates and the accumulated doses during the mission. A typical console display of real-time radiation dose measurements is shown in figure 8-1. The dose rate (rad/hr) and the calculated accumulated dose (rad) are displayed under the letters VABD in the lower right corner of the console display. The remainder of the console display is data derived from the NPDS telemetry data. Total accumulated dose values calculated from the VABD data were as follows:

Skin dose, millirad 230

Depth dose, millirad 190

The maximum radiation dose rates recorded by the VABD during the Apollo 8 mission were as follows:

Ascending belt passage	
Skin dose, millirad/hour	17
Depth dose, millirad/hour	11
Descending belt passage	
Skin dose, millirad/hour	230
Depth dose, millirad/hour	170

8.1.1.2 Personal Radiation Dosimeter - There were apparent anomalies in the functioning of the PDR's. For example, one unit (S/N 018) indicated an integrated dose that was about a factor of 10 low, a second unit (S/N 010) indicated an integrated dose about a factor of 20 high while the third unit indicated an integrated dose in agreement with other dosimetry systems. Figure 8-2 is a plot of the readouts of two PRD's versus ground elapsed time (g.e.t.). The PRD's were exchanged by the crewmen inflight to assess the problem. The following total doses were calculated from PRD readings:

Serial Number	Dose, rad
010	0.19
012	3.31
018	0.01

8.1.1.3 Nuclear Particle Detection System - The NPDS flux and integrated dose display values were anomalous because the calibration data to be used by the real-time computer complex (RTCC) had not been established at the low levels of radiation.

8.1.1.4 Radiation Survey Meter - The RSM was reported to read zero at 04:53 g.e.t., indicating an instantaneous dose rate less than 10 millirad/hour.

8.1.1.5 Solar Flare and Nuclear Explosion Monitoring - Data from the SPAN and riometer sites were transmitted to the Space Environment Console (SEC) at the Mission Control Center by teletype, and unusual events were reported by telephone. Daily reports, forecasts, and the reports of radiation levels from the Vela, Pioneer, and Explorer-34 satellites were received by the SEC from the Space Disturbance Forecast Center at ESSA in Boulder, Colorado. No significant fluxes were reported during the entire mission. Four hours before reentry a low altitude nuclear test was reported. From the information received, it was predicted that there would be no enhancement of the trapped radiation belts nor significant fall-out in the recovery area.

8.1.1.6 Radiological Health Team - A Radiological Health Specialist was on duty at the Space Environment Console full-time during the mission. A careful assessment of incoming data led to the conclusions that the radiation level in space was on the order of 1 millirad per hour and that the data considered suspect were truly anomalous. The Radiological Health Team was involved in an extensive preflight evaluation of the potential radiation problems of the mission. A table of the statistical expectancy of medical effects for a wide range of skin-REM and depth-REM dosages and the approximate dose threshold of these effects were provided to the Flight Surgeon.

8.1.2 Postflight Dosimetry and Analyses

The postflight dosimetry and analyses included measurement of passive dosimeters, computer correction of the NPDS flux and dose calculations, a check of the dosimetry instruments, identification of activation products, qualitative analysis of radionuclides present in the astronauts by whole-body counting, and gamma spectroscopy of urine and fecal samples.

8.1.2.1 Passive Dosimeters - The Apollo 8 lithium fluoride thermoluminescent dosimeter (TLD) measurements are given in table 8-1. A TLD placed in a CSM film storage box read 180 millirad with an estimated accuracy of ± 10 percent.

8.1.2.2 Nuclear Particle Detection System - The radiation flux rates measured by the NPDS outside the Van Allen Belt were below the dose rates for which calibration data had been developed causing the calculation of the anomalous doses shown on the display. Low dose rate calibration data for NPDS will be incorporated into RTCC real-time calculations for subsequent missions.

8.1.2.3 Personal Radiation Dosimeter Postflight Analysis - Because two of the three PRD's gave unlikely dose readings during Apo-lo 8 mission, the PRD's underwent postflight evaluation by the Space Physics Division. All the PRD's met the specification requirement, that is, a functional test at 5 rads per hour with less than 10-percent error. The PRD's were also tested postflight under the following conditions:

a. Low-dose rate

b. 5-psia vacuum

c. 95 percent humidity

d. Vibration of 6g along 3 axes

e. Radio frequency signal presence

f. Slow rotation in a one g field

All tests demonstrated that these conditions had no apparent adverse effect on the performance of the PRD's used in the Apollo 8 mission.

The Apollo 8 PRD's passed the preflight quality assurance tests; however, the additional testing indicated that the PRD response curves show increasing deviation with decreasing dose rate as is typical with all radiation instruments designed for high dose rates (See figure 8-3). The PRD S/N 010, the unit reading excessively high, was of differing ionization chamber construction, which may have contributed to its error. The following changes to the PRD's have been adopted for subsequent Apollo missions:

a. The PRD's should be fabricated using an Aquadag coating in the ionization chamber.

b. Additional inspection points and quality control are added in assembly of the PRD's.

c. The PRD's are calibrated at low-dose rates before the mission.

d. The PRD dose-response characteristics are matched for each mission.

8.1.2.4 Gamma-ray Spectroscopy and Activation Analysis - Qualitative and quantitative data on activation products could provide additional information about the flux and spectrum of radiation experienced during the mission by the detection of secondary neutrons, high-energy galactic particles, and high-energy solar particles. Attempts were made to identify activation products from a number of sources:

a. Foils - A sample of thermal coating was removed from the CSM-103 soon after recovery. This piece of aluminized kapton was delivered to Battelle Northwest Laboratory for gamma-ray emission analysis. Data indicated that ^{22}Na was present in amounts that could be measured: 0.27 dpm per gram $\pm$ 16.4 percent corrected to splashdown. This correlated to a flux of 37 protons cm^{-2} sec^{-1} above 30 MeV incident upon the spacecraft. This number was consistent with all measured and calculated values for the cosmic proton flux, albeit somewhat low.

b. Urine - The urine samples were analyzed at Battelle Northwest Laboratory. Since all three crewmembers were injected with gamma-ray-emitting isotopes soon after recovery, both laboratories identified the injected isotopes: ^{51}Cr, ^{59}Fe, and ^{125}I.

The Battelle Northwest Laboratory also identified ^{40}K, ^{60}Co, and ^{137}Cs in each urine sample and ^{22}Na in one sample. The MSC facility also identified ^{60}Co in each sample.

The 40-potassium and 137-cesium activities appeared to be quite natural and normally excreted. The measured values for 22-sodium and 24-sodium had large uncertainties associated with them, giving a dose figure of 480 millirad plus or minus 310 millirad. This dose figure is not inconsistent with other data.

c. Fecal Samples - The postflight fecal samples were analyzed at Battelle Northwest Laboratory for gamma-ray emission. Three inflight fecal samples were also analyzed at the Battelle Northwest Laboratory. Each sample contained detectable amounts of the radionuclides found in the urine with the exception of ^{60}Co.

The ^{22}Na apparently is the result of space activation. Other nuclides were either injected for tracer studies, normal radioactive components, or resulted from weapons fallout. The ^{60}Co was apparently a contaminant of the ^{59}Fe injected tracer. The quantity of ^{60}Co injected was insufficient to cause significant biological damage.

d. Whole Body Counting - Gamma-ray emission analysis of the astronauts and two test subjects with identical injections of isotopes was made on R+8 days in the MSC low-level counting facility. Only ^{51}Cr and ^{59}Fe were positively identified. The relatively high activity of these isotopes (i.e., the activity was high for this type of low-level counting) would make identification of certain other isotopes difficult. Since ^{60}Co had been detected in the R+0 urine samples (first 24-hour sample after splashdown), the ^{60}Co region of the gamma-ray spectrum was checked carefully and none was detected. Quantitative measurements of radionuclides were not possible because installation of the whole body counting system was not completed.

8.2 CONCLUSIONS

The total radiation skin dose was about 200 millirads and the depth dose was estimated to be 190 millirads. Assuming the relative biological effectiveness (RBE) of the radiation exposure to be 1.0, the radiation exposure during the Apollo 8 mission was much less than the average dose for an abdominal x-ray (790 millirads) or four times that of a chest x-ray (45 millirads) based on average diagnostic x-ray exposure.

The NPDS and PRD raw data as received during the Apollo 8 mission was not satisfactory for real-time dose interpretation purposes. The ^{60}Co found in analysis of the first 24-hour postflight urine samples probably originated from the ^{59}Fe injections given on R+0.

8.3 RECOMMENDATIONS

If the average dose rate during subsequent missions approaches biologically significant levels for extended periods, accurate dosimetry using the PRD may require more frequent crew-status reporting periods, particularly when the dose is varying.

A preflight and postflight total body count for all astronauts is recommended.

To assist in interpretation of data from gamma emission analysis of crewmen and biological samples on subsequent missions, an early complete postflight report of the drugs and radioisotopes administered to the crewmen and test subjects is desirable.

Activation foils similar to those used for neutron dosimetry in the Skylab Program are desirable for the Apollo 10 and subsequent missions. Such foils may provide data complementing the radiation spectra detected by the present Apollo hardware. This is particularly important in characterizing the cosmic (galactic) and the solar (flare or winds) components of the radiation spectra.

TABLE 8-I

APOLLO 8 THERMOLUMINESCENT DOSIMETER READINGS

	TLD reading, millirad		
	Chest	Thigh	Ankle
Commander	152	155	141
Command Module Pilot	157	177	157
Lunar Module Pilot	140	133	140

LM0561 NPDS DATA TABLE AND DOSE RATES 1459

	MEV	FLUX	TOTAL FLUX		
PROTON 1	10- 20	3	9.35	E	4
PROTON 2	34- 45	1	4.97	E	4
PROTON 3	85- 95	2	4.91	E	4
PROTON 4	130- 170	0	1.93	E	4
ALPHA 1	42- 58	0	8.44	E	3
ALPHA 2	136- 170	0	1.57	E	4
ALPHA 3	266- 318	0	1.01	E	4
PROTON T > 15		29	1.05	E	6

TEMP DET °F
ST0840 89

TEMP ANA °F
ST0841 81

	PROTONS REM/HR	PROTONS REM	ALPHA REM/HR	ALPHA REM	VABD RAD/HR	VABD RAD
CM DEPTH	0.01	0.10	0.16	1.53	0.00	0.14
CM SKIN	0.03	0.25	0.25	2.35	0.00	0.15
LM SKIN	0.03	0.27	0.19	1.74		
SS SKIN	0.04	0.39	0.23	2.14		

RANGE VOLTS
CK1053 4.76

GMT 05:12:42:21 CTE 0119:51:17 GET 0119:51:20

Figure 8-1. - Typical console display of real-time radiation dose measurements.

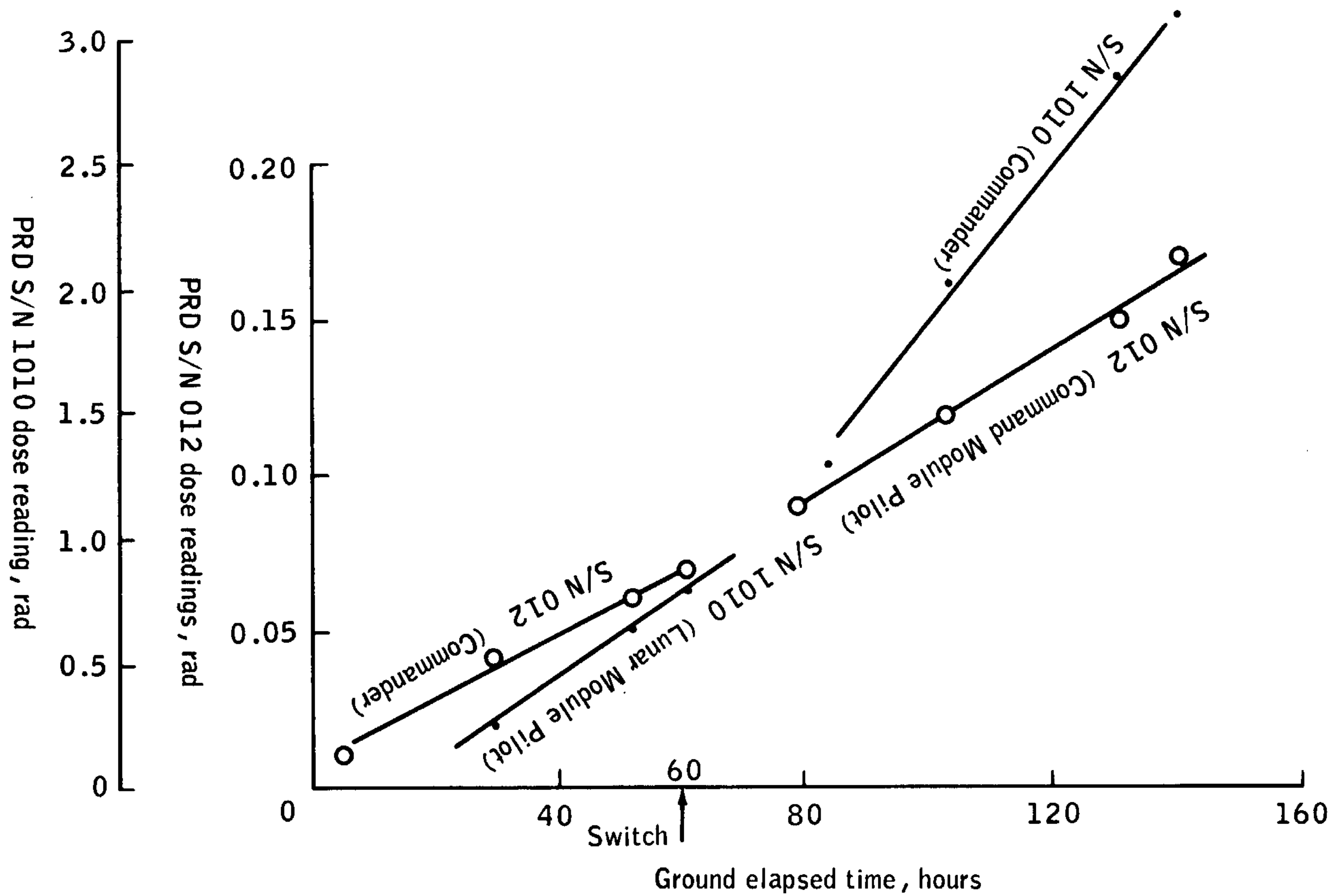


Figure 8-2. - Personal radiation dosimeter readings.

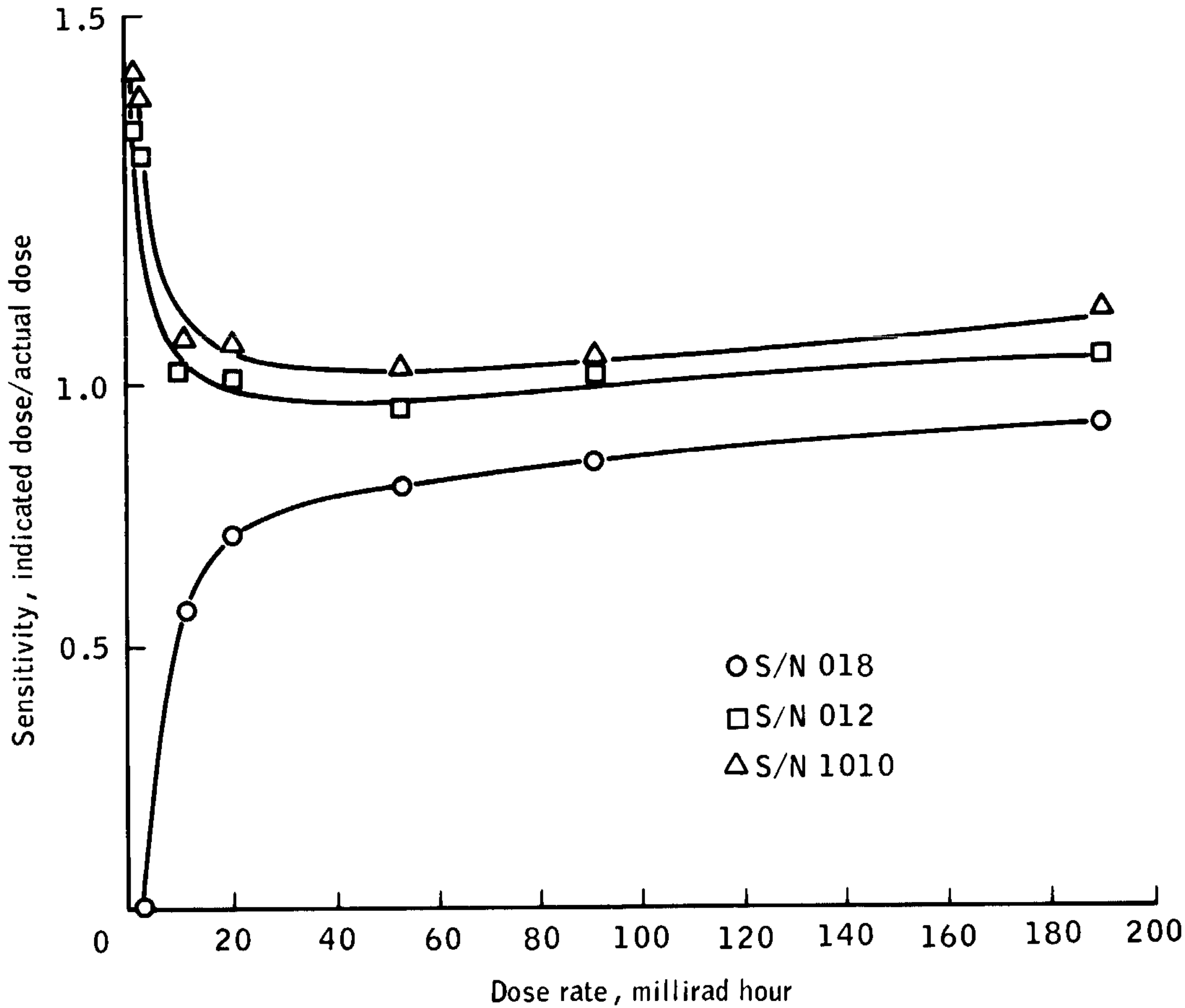


Figure 8-3. - Personal radiation dosimeter low dose rate response.

9.0 APOLLO 8 EXERCISE RESPONSE

9.1 INTRODUCTION

This series of exercise response tests was performed to obtain quantitative data on functional changes in the cardiopulmonary and musculoskeletal systems as a result of the combined stress factors (weightlessness, confinement, diet, work-rest schedules, atmospheric composition, and recovery) associated with a 6-day space mission. Specifically, these tests were designed to further document the changes that occurred during the Apollo 7 mission and were observed in exercise response immediately postflight.

9.2 METHODS

9.2.1 Test Intervals and Frequency

To obtain individual baseline data, the test protocol was replicated on F - 30, F - 14, and F - 4 days. These baseline responses were then used to evaluate the immediate postflight response measured within 4 to 6 hours of splashdown (R + 0). A second postflight response was taken after a 24-hour interval (R + 1) to determine if immediate postflight response had returned to normal within that time interval.

9.2.2 Test Protocol

The evaluation of ability to perform physical work was accomplished by employing a bicycle ergometer capable of producing preset levels of physiological stress through changing workload. The workload was varied by using feedback control to establish given levels of heart rate. The following work intensities and the time at each intensity were used as evaluation points:

a. Light intensity (heart rate - 120 beats/minute, 6 minutes).

b. Moderate intensity (heart rate - 140 beats/minute, 3 minutes).

c. Moderately heavy intensity (heart rate - 160 beats/minute, 3 minutes).

d. Heavy intensity (heart rate - 180 beats/minute, 3 minutes). This step was done only during the F - 14 and R + 1 tests.

During each test period, pulmonary function also was evaluated by performing a timed vital capacity test prior to each exercise period.

9.2.3 Data Evaluation

The data were evaluated by observing how the dependent variables of average workload, integrated workload, oxygen consumption, metabolic rate, blood pressure, and respiration changed in response to the set-levels of the independent variable (heart rate).

The three preflight tests provided a baseline response for each independent variable against which the postflight responses could be evaluated. Linear least-squares techniques were employed by determining exact evaluation points, that is, heart rate of 120, 140, 160, and 180 beats/minute.

9.2.4 Equipment

A Collins Physiologically Paced Ergometric System was used to produce set-levels of work intensity using feedback control of the heart rate. From this equipment the average workload, integrated workload, and true heart rate were determined for each step in the protocol.

Expired-gas collection for oxygen and metabolic rate determinations was accomplished using a modified Electro-Med, 10-liter spirometer which measures each expired breath and which integrates over 1-minute periods. A proportional sample of each 1-minute volume was saved for Scholander analysis to determine oxygen, carbon dioxide, and nitrogen concentration. In addition, an Oxygen Consumption Computer was used to obtain continuous oxygen consumption measurements.

Timed vital capacities were measured using the Electro-Med, 10-liter spirometer. Blood pressure, EKG, and respiration rate were recorded on standard strip chart and magnetic tape recordings.

9.2.5 Test Conditions

The ambient temperature range during the three preflight tests was 23.3° to 23.8° C. The ambient temperature at the recovery day test was 25.0° C and at 24-hour postflight test, it was 24.5° C.

9.2.6 Control Subjects

Three subjects, other than the Apollo 8 men, were used as controls to define individual variability in response to the test protocol and also to identify any unknown systematic changes in equipment or procedures. Since two of the control subjects were also used as controls during Apollo 7, two of their previous test results were used to identify any unknown changes in equipment or procedures between the two flights.

9.3 RESULTS

9.3.1 Pulmonary Function

The results of the pulmonary function studies are shown in table 9-I. Although several other forced expired volume (FEV) points were collected, only the FEV at 1 second ($FEV_{1.0}$) is presented as a representative point. Although two of the three crewmen exhibited a small decrease (less than 10 percent) in vital capacity (VC) and $FEV_{1.0}$, the $FEV_{1.0}/VC$ ratio was not significantly different from preflight values.

9.3.2 Exercise Response

Tables 9-II and 9-III show the heart rate during the last minute of each step of the protocol. Although heart rate is the independent variable, it was not always possible to regulate it to exact preset levels; therefore, the heart rate values in the table demonstrate this variability at each of the three work levels.

9.3.3 Workload

Tables 9-IV and 9-V show the average workload, in watts, during the last minute of each step in the protocol. The postflight workloads were considerably less[a] than preflight for two of the three crewmembers. All the controls increased from their preflight mean.

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[a]The statistical tests using analysis of the variance will be completed for the Apollo Missions 7 to 11. Changes on Apollo 7 were found significant at the P = 0.001 level.

To make a better comparison, a least-squares line was fitted to the linear relationship between heart rate and workload. Table 9-VI shows the interpolated values for workload required at heart rates of 120, 140, 160, and 180 beats/minute.

Figure 9-1 presents the mean workload responses (as well as the range of preflight values) for the crew and figure 9-2 shows the same for the control subjects. Since it was not possible to attempt the 180 heart-rate step during the recovery day test, there are no values for this rate shown on the two figures. The response at 180 had returned to normal by the 24-hour postflight test.

9.3.4 Oxygen Consumption

Tables 9-VII and 9-VIII show the oxygen consumption (in liters STPD) during the last minute of each step in the protocol. The fifteenth 1-minute sample was not obtained during the tests on account of procedural difficulties. However, a fourteenth 1-minute sample was collected in those instances. Table 9-IX shows the interpolated oxygen consumption rate at heart rates of 120, 140, and 160 beats/minute using a least-squares fit line. Figures 9-3 and 9-4 show the mean oxygen consumption of the three crewmembers and the three controls at each level of heart rate. As was seen in the workload response, the postflight decrease in oxygen consumption is well outside the preflight range for two of the three crewmen while the changes noted in the controls were within the preflight range.

9.4 DISCUSSION

9.4.1 Pulmonary Function

The pulmonary function data indicate that, immediately postflight, there were no significant decreases in lung volumes or ventilatory capacity. Therefore, the decrease in exercise response does not appear to be related to changes in ventilatory capacity or the ability to move air in and out of the lungs.

9.4.2 Heart Rate Versus Workload

The heart rate is dependent upon several factors. Although many of these factors are not associated with the energy metabolism of the organism, there is a close correlation between sustained heart rate levels and the work load. Since there is very little capacity for oxygen storage, the oxygen transport system must attempt to keep up with cellular metabolic requirements on a near realtime basis. Thus, pulmonary ventilation and blood flow must increase considerably to support the energy metabolism required for external work.

It is believed that under normal conditions, the cardiovascular system is the limiting factor in the ability to transport oxygen, and therefore, to accomplish work. Since the main factor in this system for increasing transport is heart rate (cardiac output = heart rate x stroke volume), this physiological variable becomes the basis for comparing any decrement in work capability as a result of combined stresses associated with space flight.

In this test protocol, heart rate was maintained at four levels of physiological stress corresponding to light, medium, moderately heavy, and heavy exercise. The bicycle ergometer used a feedback loop controlled workload to produce the desired heart rate.

The results of the preflight and postflight measurements of the workload required to sustain the prescribed heart rate levels indicate that much less work was required by two of the three crewmembers to produce the same heart rate postflight as preflight. This is another way of saying that if heart rate is the limiting factor in the ability to perform work, the astronauts were not capable of performing as much work at submaximal levels during the postflight examination as during the preflight examination. Since a maximal test was not attempted on the recovery day, it is not known whether a decrement would have been noted at this level. Similarily, the oxygen consumption for the specified levels of heart rate was also significantly decreased for two of the three crewmembers.

9.5 CONCLUSIONS

a. No decrement in ventilatory capacity was observed immediately postflight.

b. Immediately postflight, two of the three astronauts performed less external work and consumed less oxygen than they did preflight at the same levels of heart rate. Within 24 hours of splashdown their response had returned to the lower limits of the preflight ranges; therefore, it is recommended that the endocrine/metabolic mechanisms related to cardiovascular function be investigated as a source of these decrements.

TABLE 9-I.- PULMONARY FUNCTION SUMMARY

Subject	Preflight				Postflight			
	VC, liter	$FEV_{1.0}$, liter	$FEV_{1.0}/VC$	PEFR[a], liter/sec	VC, liter	$FEV_{1.0}$, liter	$FEV_{1.0}/VC$	PEFR, liter/sec
Commander	4.6 to 4.7	3.4 to 3.5	0.75	10.0 to 10.1	4.6	3.3	0.72	9.2
Command Module Pilot	4.5 to 4.8	3.7 to 3.8	.79	11.6 to 12	4.11	3.4	.83	7.3
Lunar Module Pilot	5.3	3.8 to 3.9	.74	11.1	4.9	3.3	.68	9.1
Control 1	4.9 to 5.2	4.3 to 4.6	.87	12.6	4.8	4.1	.85	11.1
Control 2	4.1 to 4.4	3.5 to 3.9	.88	12.0 to 12.5	4.3	3.8	.88	11.1
Control 3	5.2 to 5.5	4.1 to 4.4	.80	12.2 to 13.8	4.6	3.6	.78	12.0

[a]PEFR is the peak expiratory flow rate.

TABLE 9-II.- CREWMEN HEART RATE

Subject	Date	Heart rate, beats/minute, at elapsed time				
		6th minute	9th minute	12th minute	14th minute	15th minute
Commander	F-30	122	141	162		
	F-14	121	140	162	174	178
	F-5	119	140	163		
	R+0	134	137	154		
	R+1	123	140	161	178	
Command Module Pilot	F-30	119	142	161		
	F-14	120	141	157		174
	F-5	121	140	159		
	R+0	122	140	156		
	R+1	122	140	157	169	178
Lunar Module Pilot	F-30	122	143	163		
	F-14	122	140	164	177	183
	F-5	122	140	158		
	R+0	121	140	162		
	R+1	122	142	161	173	179

TABLE 9-III.- CONTROL HEART RATE

Subject	Date	Heart rate, beats/minute, at elapsed time				
		6th minute	9th minute	12th minute	14th minute	15th minute
Control 1	F - 30[a]	124	145	166		
	F - 14	124	146	165		
	F - 4	130	130	165		
	R + 1	121	144	164	178	
Control 2	F - 30	120	136	152		
	F - 14	122	141	165		179
	F - 4	122	143	163		
	R + 0	122	142	156		
Control 3	F - 30[a]	120	148	162		
	F - 14[a]	126	144	161		
	F - 4	124	147	167		
	R + 0	117	142	164		

[a]Apollo 7 values.

TABLE 9-IV.- CREWMEN WORKLOAD

Subject	Date	Work load, watts, at elapsed time				
		6th minute	9th minute	12th minute	14th minute	15th minute
Commander	F - 30	65	120	148	170	
	F - 14	75	120	150		182
	F - 4	60	115	160		
	R + 0	20	20	60		
	R + 1	65	100	150		185
Command Module Pilot	F - 30	60	112	190		
	F - 14	60	100	165		220
	F - 4	55	135	195		
	R + 0	50	115	150		
	R + 1	75	90	170	185	210
Lunar Module Pilot	F - 30	55	115	158		
	F - 14	65	110	145	195	200
	F - 4	55	105	170		
	R + 0	42	95	112		
	R + 1	45	105	145	190	200

TABLE 9-V.- CONTROL WORKLOAD

Subject	Date	Work load, watts, at elapsed time		
		6th minute	9th minute	12th minute
		Work load, watts		
Control 1	F - 30[a]	98	120	150
	F - 14	92	135	160
	F - 4	100	145	170
	R + 0	90	145	180
	R + 2			
Control 2	F - 30	55	95	135
	F - 14	60	80	120
	F - 4	65	110	165
	R + 0	80	125	160
	R + 2			
Control 3	F - 30	102	160	205
	F - 14	110	145	185
	F - 4	110	170	190
	R + 0	105	170	200
	R + 2			

[a]Apollo VII.

TABLE 9-VI.- WORKLOAD VERSUS HEART RATE

Subject	Date	Work load, watts, at a heart rate of			
		120 beats/ minute	140 beats/ minute	160 beats/ minute	180 beats/ minute
Commander	Preflight mean	70	109	148	187
	R + 0	--	30	72	--
	R + 1	57	101	145	190
Command Module Pilot	Preflight mean	56	118	181	243
	R + 0	48	107	166	--
	R + 1	60	111	163	215
Lunar Module Pilot	Preflight mean	57	104	152	199
	R + 0	48	81	144	--
	R + 1	43	92	142	192
Control 1	Preflight mean	89	121	153	184
	R + 0	90	132	174	--
	R + 1	--	--	--	--
Control 2	Preflight mean	58	97	137	177
	R + 0	74	121	168	--
	R + 1	--	--	--	--
Control 3	Preflight mean	101	143	186	229
	R + 0	115	156	196	--
	R + 1	--	--	--	--

TABLE 9-VII.- CREWMEN OXYGEN CONSUMPTION

Subject	Date	Oxygen consumption, liter STPD, at elapsed time				
		6th minute	9th minute	12th minute	14th minute	15th minute
Commander	F - 30	1.410	1.707	2.116		
	F - 14	1.446	1.729	2.132	2.217	
	F - 4	1.127	1.448	1.900		
	R + 0	0.879	0.796	1.268		
	R + 1	1.308	1.542	2.083	2.160	
Command Module Pilot	F - 30	1.014	1.519	2.338		
	F - 14	1.242	1.542	2.078	2.420	2.857
	F - 4	1.219	1.582	2.200		
	R + 0	1.033	1.467	2.216		
	R + 1	0.900	1.402	1.916		2.812
Lunar Module Pilot	F - 30	1.166	1.543	2.198		
	F - 14	1.171	1.706	2.292	2.218	2.550
	F - 4	1.283	1.461	1.850		
	R + 0	0.632	1.191	1.452		
	R + 1	1.165	1.439	1.814	2.341	

TABLE 9-VIII.- CONTROL OXYGEN CONSUMPTION

Subject	Date	Oxygen consumption, liter STPD, at elapsed time				
		6th minute	9th minute	12th minute	14th minute	15th minute
Control 1	F - 30[a]	1.555	1.843	2.312		
	F - 14[a]	1.550	2.010	2.520		
	F - 4	1.479	1.787	2.300		
	R + 0	1.497	1.956	2.407		
	R + 2					
Control 2	F - 30	1.122	1.270	1.843		
	F - 14	1.190	1.357	1.890		2.820
	F - 4	1.203	1.322	1.811		
	R + 0	1.241	1.579	2.171		
	R + 2					
Control 3	F - 30 R + 0[a]	1.627	2.083	2.530		
	F - 14 R + 2[a]	1.555	1.843	2.312		
	F - 4	1.6.6	2.130	2.474		
	R + 0	1.468	1.962	2.495		
	R + 2					

[a]Data from Apollo 7 mission.

TABLE 9-IX.- OXYGEN CONSUMPTION VERSUS HEART RATE SUMMARY

Subject	Date	Oxygen consumption, liter STPD, at a heart rate of			
		120 beats/ minute	140 beats/ minute	160 beats/ minute	180 beats/ minute
Commander	Preflight mean	1.295	1.639	1.983	2.327
	R + 0	.488	.932	1.376	
	R + 1	1.241	1.589	1.937	2.285
Comand Module Pilot	Preflight mean	1.065	1.657	2.249	2.841
	R + 0	.894	1.585	2.275	
	R + 1	.900	1.402	1.916	2.812
Lunar Module Pilot	Preflight mean	1.142	1.572	2.00	2.43
	R + 0	.668	1.068	1.468	
	R + 1	1.030	1.470	1.910	2.350
Control 1	Preflight mean	1.442	1.848	2.254	
	R + 0	1.463	1.885	2.307	
Control 2	Preflight mean	1.092	1.454	1.816	
	R + 0	1.126	1.658	2.190	
Control 3	Preflight mean	1.454	2.002	2.550	
	R + 0	1.516	1.952	2.389	

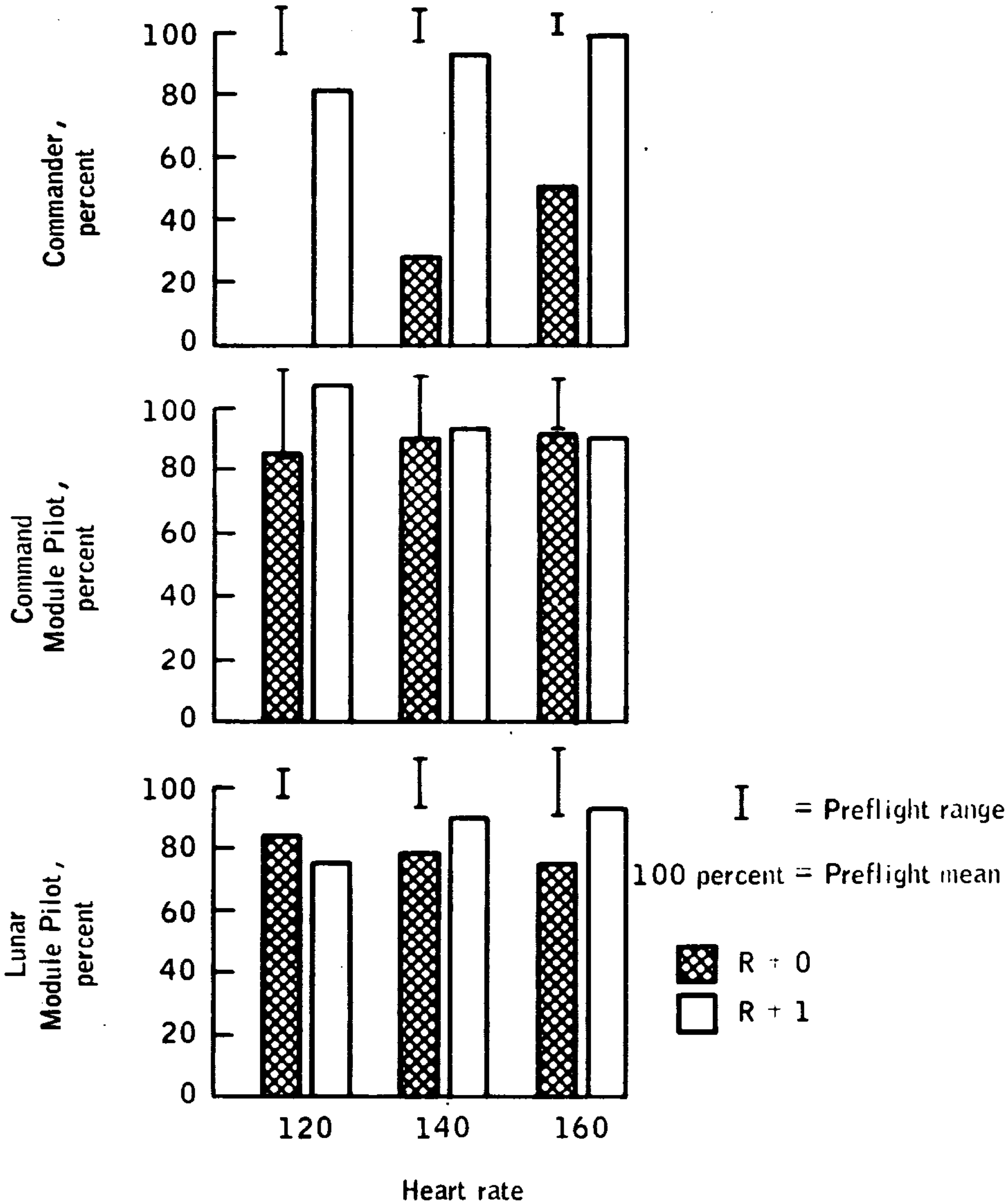


Figure 9-1. - Astronaut workload change.

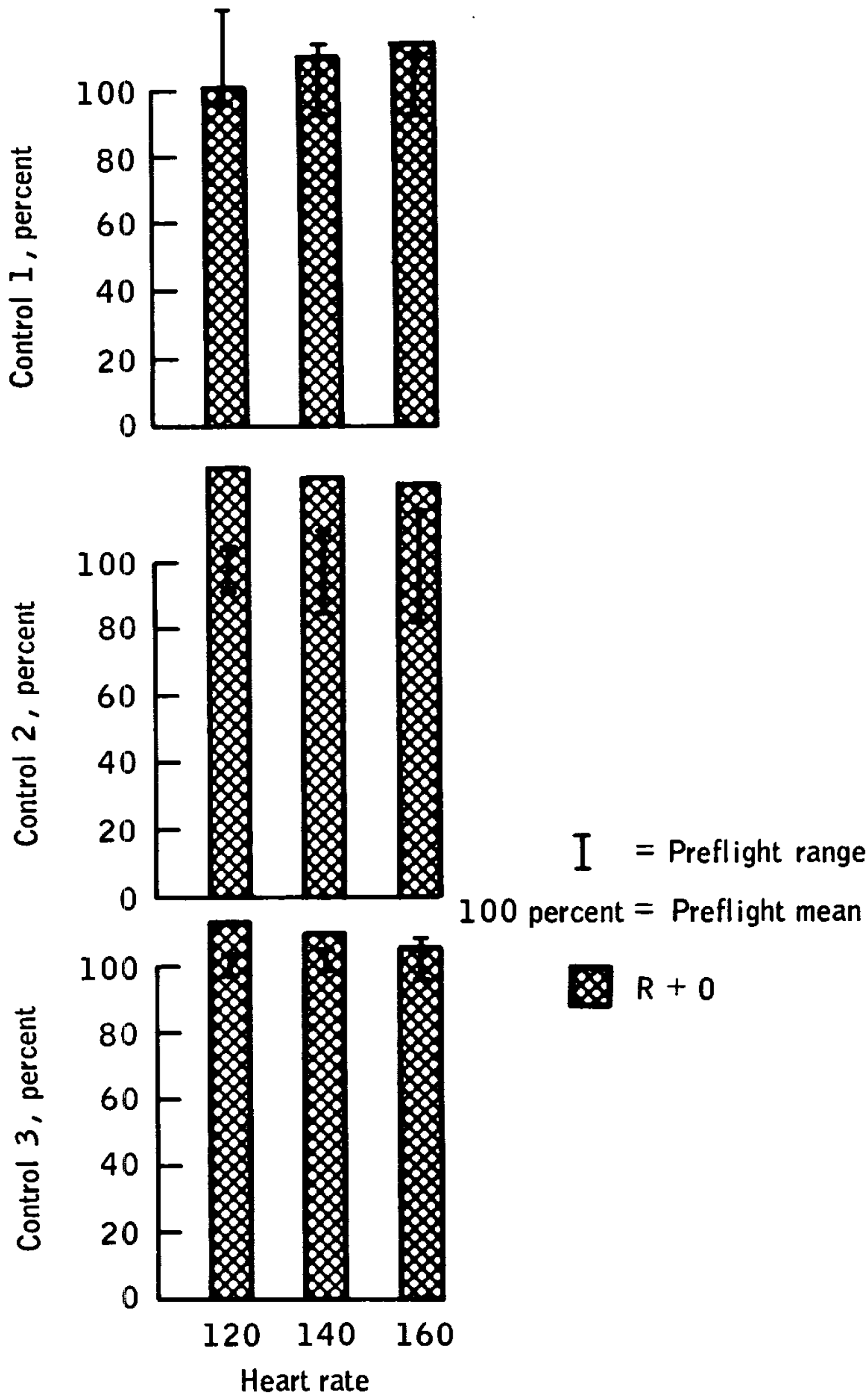


Figure 9-2. - Control workload change.

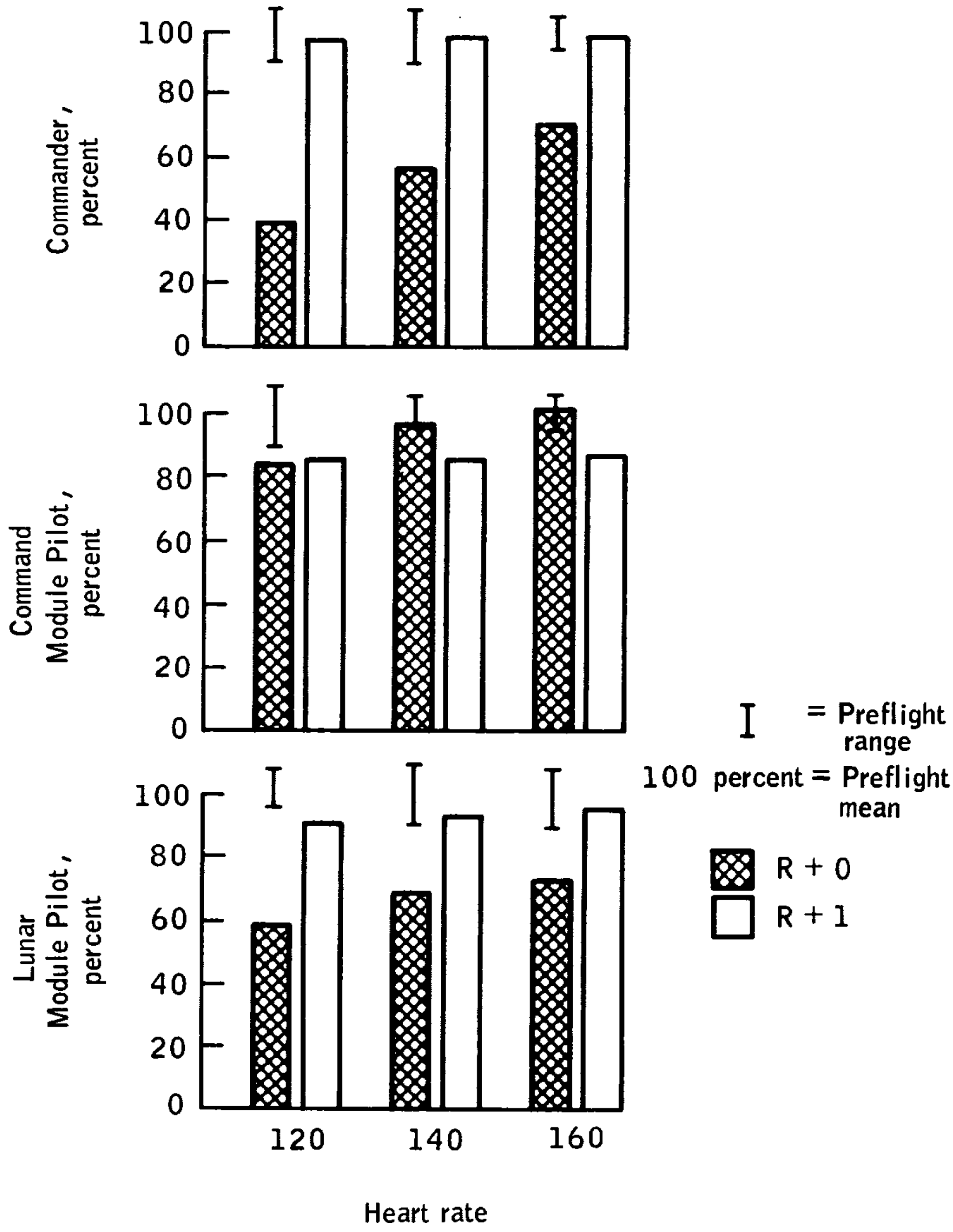


Figure 9-3. - Astronaut changes in oxygen consumption.

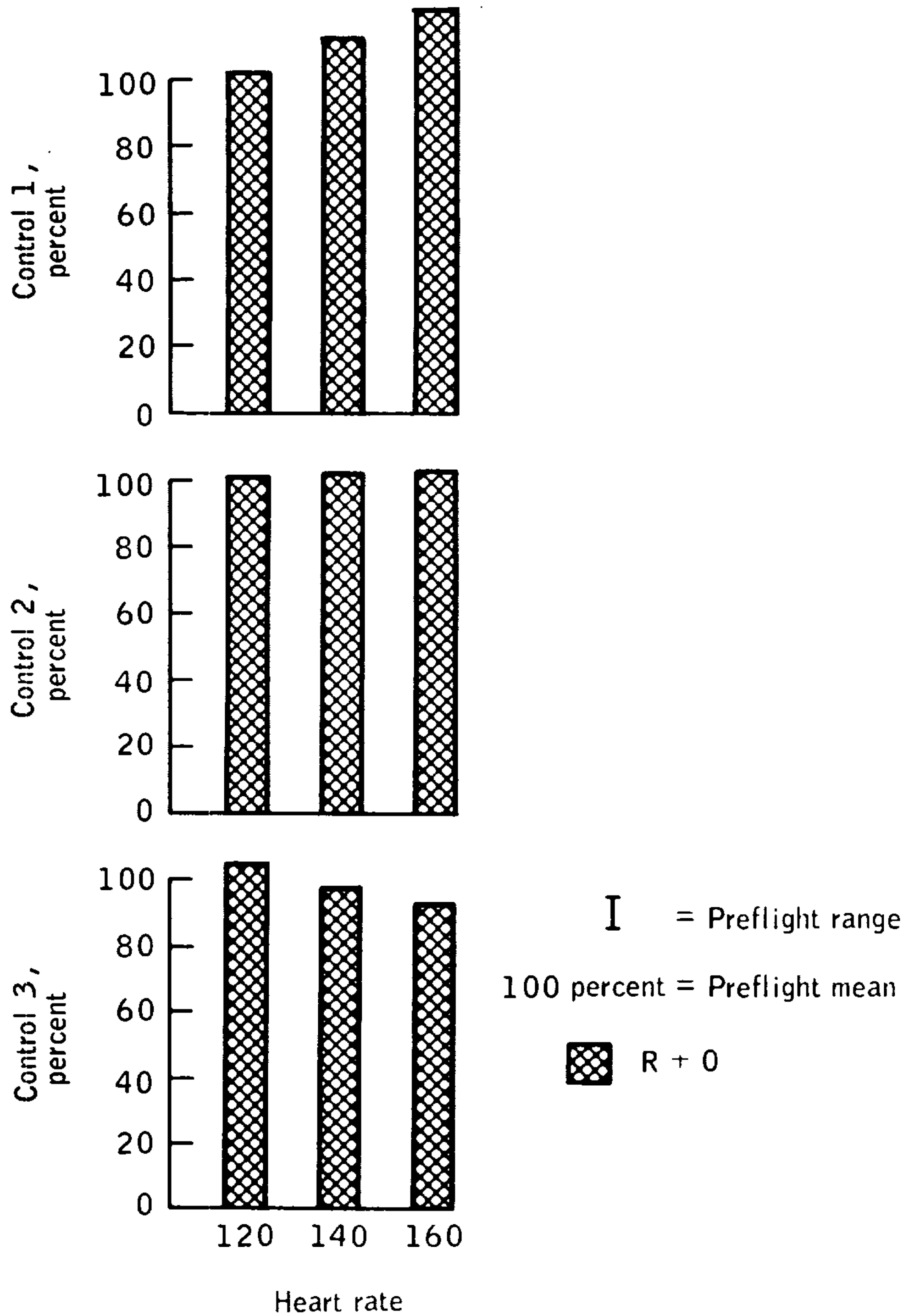


Figure 9-4. - Control changes in oxygen consumption.

10.0 CARDIOVASCULAR ASSESSMENT BY APPLICATION OF LOWER BODY NEGATIVE PRESSURE

10.1 INTRODUCTION

The application of lower body negative pressure (LBNP) as a gravity-stimulation stressor can be used to assess the extent, time course, and etiology of postflight decrement in cardiovascular antigravity response (orthostatism).

These measured cardiovascular responses of the Apollo 8 crewmen to LBNP have been related to data obtained from two of the crewmen who participated in Gemini missions. The future Apollo mission medical requirements and the current hypotheses concerning space flight phenomena on cardiovascular response were considered in evaluating the resulting test data.

10.2 METHODS

10.2.1 Test Intervals and Frequencies

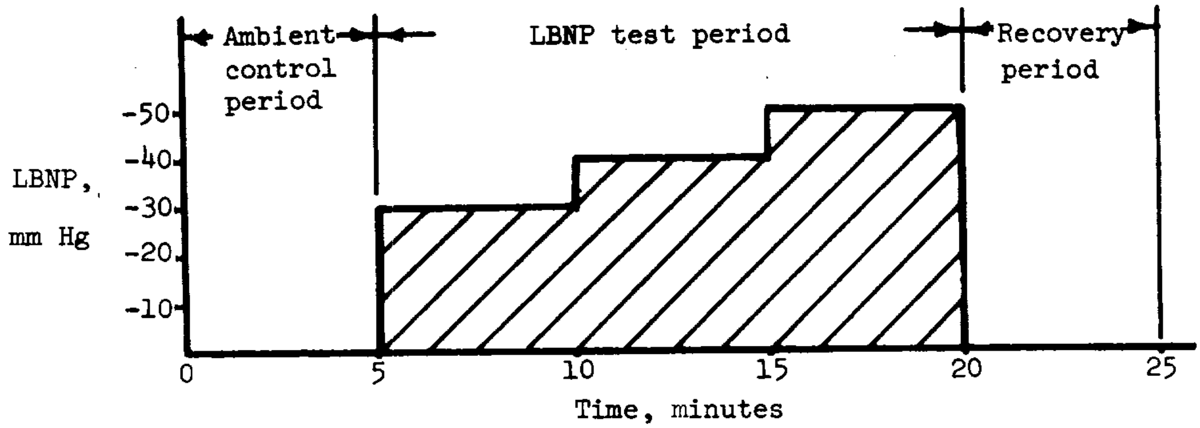
Before the mission, each crewman was tested on three occasions to establish individual baseline profiles during the LBNP tests. Measurements were recorded for heart rate, blood pressure, and change in leg volume. The change in leg volume was used as an indicator of the amount of pooled blood in the lower body. Two of the preflight tests were conducted at MSC on 28 and 14 days before launch. The final preflight tests were conducted at KSC, 5 days before launch (F - 5). Postflight LBNP tests were conducted on the recovery ship as soon as possible following recovery (R + 0) and on the day following recovery

(R + 1). Final LBNP tests were conducted at MSC from 51 to 53 hours after recovery (R + 2). The individual times of the postflight tests are shown in the following table.

Test day	Actual test time, hours after recovery		
	Commander	Command Module Pilot	Lunar Module Pilot
R + 0	3	4	5
R + 1	26	27	26
R + 2	51	53	52

10.2.2 Test Protocol

After the biomedical sensors were attached and operative, data were collected during a 25-minute test period. The subjects were resting supine on foam cushions. The lower portion of their bodies (from waist down) was sealed in the LBNP test box. The subjects were advised to minimize movement during the test. During the first 5 minutes of the test, sternal and biaxillary EKG recordings and blood pressure recordings were taken on each subject as an initial ambient control period. During the next 15-minute period, the lower portion of the subject's body was subjected to three 5-minute intervals of increasing increments of negative pressure. The test pressure tolerances were determined from the F - 28 day tests. Based on the initial testing, all three crewmen tolerated the same stress profile as shown in the following chart.



10.2.3 Test Conditions

Possible variables were fairly well minimized, but variations occurred in (1) amount of sleep, (2) time of venipuncture and last meal, and (3) time of day for testing. Inflight sleep cycles were often disrupted, and a 6-hour earth-time shift occurred between the R + 1 and R + 2 tests. Humidity and ambient temperature aboard the recovery ship exceeded the desired range. The only medication which might have affected an LBNP response was Seconal taken by the CMP on the night before the F - 5 test. Other conditions for the LBNP tests are presented in table 10-I.

10.2.4 Equipment

The LBNP box was designed to allow the test subject to enter from one end, to be sealed by the closure of two half-flanged end pieces, and to have negative pressure applied to the sealed box with a vacuum pump. The capacity of the pump was constant, and the pressure on the box was varied by an air inlet valve. The subject was supported on a narrow crotch saddle to prevent being pressed into the box during application of negative pressure. The saddle did not, however, constrict venous blood return. The remaining portions of the LBNP box consisted of appropriate electrical connections and a direct-reading manometer. Special strain gages, consisting of a double loop of silastic tubing filled with mercury, were placed around the maximum circumference of each calf and were used to measure changes in leg circumference during the tests. The signal conditioners for the EKG, blood pressure, and strain gage measurements were of special MSC or contractor construction. The other electronic recording equipment was obtained from commercial sources.

Since the electrical equipment on the recovery ship was such that the LBNP tests could not be performed at the same time as the ergometry tests (as in other testing periods), the LBNP tests were conducted prior to the ergometry test for each subject.

10.2.5 Ground-Control Subjects

While the nature of this test was such that the responses of the crewmen would be compared with their own preflight baseline data, parallel procedures were conducted on three nominally matched subjects who remained aboard the recovery ship during the Apollo 8 mission.

10.2.6 Data Requirements and Evaluations

Analog strip recorders were used to monitor subject response during the test and for the subsequent determinations of heart rate, blood pressure, and changes in leg volume. The data were also stored on magnetic tape as a permanent record for subsequent computerized analyses.

The reliability of the data appears to be very good. The data collected on the recovery ship had the greatest variation; some data were lost as the result of minor technical difficulties. However, the overall results were not significantly degraded by these losses.

10.3 RESULTS AND DISCUSSION

The heart rates and changes in leg volume during the postflight LBNP tests are presented in figure 10-1 and the blood pressure responses are shown in figure 10-2. The results of the statistical treatment of the data are summarized in table 10-II.

In all cases, the R + 0 heart rates measured during the 5-minute ambient control period were significantly ($P < 0.05$) above preflight values; but, the variability in blood pressures was not as marked. The cardiovascular antigravity responses immediately postflight, as shown by the maximum and minimum values recorded during the R + 0 LBNP test, returned to the preflight values during the R + 1 and R + 2 tests. The maximum heart rates during LBNP tests at R + 0 were elevated for all of the crewmen. Because of the great variation in the CMP's heart rate during the preflight tests, no statistical significance can be applied to this data. Significant elevations in the heart rate of the other crewmen were recorded during the R + 1 tests. The maximum leg volume change at R + 0 was significantly less than the preflight values for the CMP and the LMP. These results are in agreement with the findings from the Apollo 7 crewmen, but the results are in opposition to the tilt table measurements which showed an apparent increase in the pooling of blood in the legs of most of the Gemini crewmen. (The CDR and the CMP of the Apollo 8 mission had flown previously on the Gemini VII mission.)

Measurements of calf circumferences taken during the 5-minute ambient control period of all of the LBNP tests are listed in table 10-III. The postflight decrease in calf circumferences was statistically significant in the CDR and in the CMP.

Because of the consistency and magnitude of heart rate responses, heart rates have been given the greatest emphasis in comparing preflight and postflight cardiovascular responses to LBNP stress. High correlation coefficients were obtained when changes in leg volumes were compared with heart rates (table 10-IV). These results are in agreement with data from Apollo 7 mission. Significant ($P < 0.05$) departures were recorded in all crewmen responses for the R + 0 y-intercept values, which would equal the control mean heart rate if the correlations were perfect (i.e., $r = 1$). (See fig. 10-3.)

This method of data presentation is considered valid because all data points are used simultaneously. With the incremental variations of the LBNP stressor, the means of the measurements during the 15-minute test period are not considered as valid manipulations of the data.

The heart rate responses during cardiovascular testing with the 70° tilt table and the LBNP tests are shown in figure 10-4 for the CDR and in figure 10-5 for the CMP. The similarity of responses is striking.

In general, the data from the ground control group of test subjects remained similar to the Apollo 8 crewmen's preflight values, even with one test subject showing a "postflight" (R - 1) presyncopal episode (figs. 10-6 and 10-7 and table 10-V).

10.4 CONCLUSIONS

The Apollo 8 cardiovascular assessment by use of the LBNP test revealed significant postflight differences in heart rate, blood pressure, and leg volume change. The differences were comparable to the differences recorded from the Apollo 7 mission, but were not similar to those of the ground controls.

The heart rate response is considered the best indicator of cardiovascular orthostatic tolerance. The heart rate data of the LBNP tests from Apollo 8 compare favorably with tilt table data obtained from the Gemini missions. The heart rate responses correlate highly with leg volume changes in this study and in the Apollo 7 study.

Further flight data are required to validate these findings in a larger number of crewmen. At present, heart rate data are the sole physiological measurements available to the ground medical monitors for assessing crewmen conditions during the lunar landing missions where decelerative and gravity forces will be experienced in the vertical upright (G_z) axis.

TABLE 10-I.- ACCESSORY CONDITIONS FOR LBNP

Parameter	F - 28	F - 14	F - 5	R + 0	R + 1	R + 2
Commander						
Time of test initiation	08:29	08:25	07:19	08:00	06:50	13:25
Room temperature, °F	73	74	77	82.2	78.4	76.0
Oral temperature, °F	98	97.6	97.6	98.8	97.8	98.2
Weight, lb	168	168.5	170.0	160.5	163.25	165.5
Sleep, hr	8	8	6	5+	9	7
Time since eating, hr	14	13	13	~10	12.5	.5
Time since venipunctures, hr	--	1	--	1	--	--
Command Module Pilot						
Time of test initiation	09:25	09:14	08:02	09:20	08:05	15:10
Room temperature, °F	73.5	74.0	77.0	82.2	82.0	75.0
Oral temperature, °F	98.4	98.6	97.6	98.8	98.8	98.5
Weight, lb	168.5	171	168.5	164.0	164.75	165.75
Sleep, hr	6.5	6.0	7.5	4+	7.0	5.5
Time since eating, hr	13.0	2.5	10.0	.5	1.0	4.0
Time since venipuncture, hr	.75	1.5	.67	1.0	1.0	1.5
Lunar Module Pilot						
Time of test initiation	10:30	07:30	08:45	10:00	07:25	14:15
Room temperature, °F	74.0	73.0	77.0	83.8	80.6	76.0
Oral temperature, °F	98.2	97.8	97.4	98.2	97.9	98.1
Weight, lb	145.5	148.0	145.5	138.0	138.5	N.A.
Sleep, hr	6	5	[a]2	2	14	5
Time since eating, hr	[b].5	.75	[c]14.0	1	.5	4.0
Time since venipuncture, hr	1.5	--	1+	1.5	.5	1.0

[a]Restless.
[b]Doughnut.
[c]Coffee, 0.5 hr.

TABLE 10-II.- CONTROL MEANS AND LBNP MAXIMUM AND MINIMUM VALUES

Variable	Ambient control (resting) mean values				Maximum and minimum values with LBNP test			
	Average, preflight	R + 0	R + 1	R + 2	Average, preflight	R + 0	R + 1	R + 2
Commander								
Heart rate, beats/min	70.4 ± 3.4	86.9	69.5	[a]80.4	95.4 ± 14.2	[a]161.6	[a]111.9	102.9
Leg volume change, percent	--	--	--	--	2.8 ± 0.6	2.4	2.8	2.9
Systolic blood pressure, mm Hg	111.6 ± 3.3	110.0	113.8	[a]127.8	97.0 ± 5.2	[a]70.0	92.0	[a]112.0
Diastolic blood pressure, mm Hg	68.9 ± 3.7	75.2	61.0	64.5	75.3 ± 7.0	72.0	72.0	68.0
Command Module Pilot								
Heart rate, beats/min	72.6 ± 1.6	[a]94.0	[a]75.7	[a]65.7	104.0 ± 28.6	130.9	128.4	92.6
Leg volume change, percent	--	--	--	--	2.9 ± 0.3	[a,b]2.3	3.2	2.6
Systolic blood pressure, mm Hg	114.7 ± 5.2	116.1	[a]123.3	[a]127.6	92.0 ± 7.0	[a]68.0	[a]80.0	[a]114.0
Diastolic blood pressure, mm Hg	68.5 ± 3.7	[a]77.3	[a]63.1	[a]75.5	81.3 ± 9.2	[a]68.0	84.0	[a]92.0
Lunar Module Pilot								
Heart rate, beats/min	75.1 ± 5.7	[a]91.0	80.6	70.7	105.0 ± 11.6	[a]145.5	[a]142.9	110.0
Leg volume change, percent	--	--	--	--	3.7 ± 0.7	[a,b]2.6	4.2	3.9
Systolic blood pressure, mm Hg	111.2 ± 5.8	106.8	111.5	[a]120.4	85.7 ± 26.8	68.0	76.0	88.0
Diastolic blood pressure, mm Hg	65.8 ± 4.0	64.0	[a]57.8	[a]76.2	76.0 ± 17.0	66.0	76.0	88.0

[a]Deviation from preflight average > 2 S.D.

[b]This value is maximum during LBNP test interval for heart beat, leg volume change, and diastolic blood pressure. The value is minimum for systolic blood pressure.

TABLE 10-III.- CALF CIRCUMFERENCES MEASURED DURING AMBIENT CONTROL PERIOD

Date	Calf circumferences (right and left) and mean, inch								
	Commander			Command Module Pilot			Lunar Module Pilot		
	Left	Right	Mean	Left	Right	Mean	Left	Right	Mean
F - 28	13.5	14.25	13.875	15.5	15.75	15.625	14.5	14.875	14.6875
F - 14	13.75	14.0	13.875	15.5	15.5	15.5	14.5	14.5	14.5
F - 5	13.625	14.25	13.9375	15.375	15.625	15.5	14.5	14.75	14.625
	Preflight mean = 13.89 2 S.D. = 0.08			Preflight mean = 15.54 2 S.D. = 0.14			Preflight mean = 14.60 2 S.D. = 0.19		
R + 0	13.5	14.0	[a]13.75	15.25	15.5	[a]15.375	14.375	14.625	14.5
R + 1	13.625	14.125	13.875	15.25	15.5	15.375	14.1875	14.5	14.1875
R + 2	13.1875	14.9375	13.5625	15.25	15.5	15.375	14.75	14.5	14.625

[a]These values are > 2 S.D. below preflight means.

TABLE 10-IV.- REGRESSION DATA FOR HEART RATE

VERSUS CHANGES IN LEG VOLUME

Regression data	Symbol	F - 28	F - 14	F - 5	Mean ± 2 S.D. (3 preflight values)	R + 0	R + 1	R + 2
Commander								
Correlation coefficient	r	0.88	0.92	0.75	0.85 ± 0.18	0.96	0.96	0.97
Sum of y-axis times x-axis	Sy·x	3.31	1.72	4.62	3.22 ± 2.9	4.53	3.02	1.81
Slope	b	9.34	8.26	9.47	9.02 ± 1.3	[a]30.26	[a]17.96	9.76
Intercept	a	74.45	64.50	72.29	70.41 ± 10.5	[a]93.24	60.93	74.60
Control heart rate, beats/min	$\bar{x}$	71.7	69.3	70.3	70.4 ± 2.4	[a]86.9	69.5	[a]80.4
Command Module Pilot								
Correlation coefficient	r	0.97	0.94	0.93	0.95 ± 0.04	0.71	0.94	0.89
Sum of y-axis times x-axis	Sy·x	2.07	2.09	3.21	2.46 ± 1.3	3.33	3.38	3.04
Slope	b	15.57	10.68	13.35	13.20 ± 4.9	10.95	12.56	13.20
Intercept	a	76.16	58.17	53.89	62.79 ± 23.6	[a]107.45	84.57	55.72
Control heart rate, beats/min	$\bar{x}$	83.7	68.6	65.6	72.7 ± 19.4	[a]94.0	75.7	65.7
Lunar Module Pilot								
Correlation coefficient	r	0.91	0.91	0.96	0.93 ± 0.56	0.87	0.91	0.97
Sum of y-axis times x-axis	Sy·x	2.21	4.00	2.92	3.05 ± 1.8	6.33	7.35	2.39
Slope	b	6.41	9.69	15.30	10.47 ± 9.0	[a]23.63	17.37	10.78
Intercept	a	73.68	66.73	56.38	65.60 ± 17.4	[a]96.08	67.53	64.29
Control heart rate, beats/min	$\bar{x}$	77.2	74.1	74.4	75.2 ± 3.4	[a]91.0	[a]80.6	[a]70.7

[a]Deviation from preflight > 2 S.D.

TABLE 10-V.- ACCESSORY CONDITIONS FOR LBNP TESTS ON GROUND CONTROL SUBJECTS

Parameter	F - 30	F - 26	F - 15	F - 6	R - 1
Control 1					
Negative pressure, mm Hg	-30,-40,-50	--	-30,-40,-50	-30,-40,-50	--
Time of test initiation	[a]10:45	--	[a]10:10	[b]11.47	15.35
Room temperature, °F	76.0	--	77.0	78.0	83.0
Oral temperature, °F	98.3	--	98.8	98.5	99.0
Weight, lb	155.5	--	154.0	155.75	154.0
Sleep, hr	6.0	--	6.0	7.5	8.5
Time since eating, hr	17.0	--	15.5	4.0	3.0
Time since venipuncture, hr	--	--	1.75	2.5	--
Control 2					
Negative pressure, mm Hg	--	-20,-30,-40	-20,-30,-40	-20,-30,-40	--
Time of test initiation	--	[a]08.29	[a]09.30	[b]10.43	14.25
Room temperature, °F	--	73.0	76.0	76.0	83.0
Oral temperature, °F	--	99.0	98.4	98.6	98.6
Weight, lb	--	177.5	175.25	175.25	179.0
Sleep, hr	--	6.0	5.0	5.0	5.0
Time since eating, hr	--	12.0	17.0	17.0	2.5
Time since venipuncture, hr	--	--	1.25	1.25	--
Control 3					
Negative pressure, mm Hg	--	-30,-40,-50	-30,-40,-50	-30,-40,-50	--
Time of test initiation	--	[a]10:59	[a]09.45	[b]09.45	13.40
Room temperature, °F	--	75.0	77.0	76.0	83.0
Oral temperature, °F	--	98.8	98.8	98.2	98.8
Weight, lb	--	170.0	171.0	170.5	172.0
Sleep, hr	--	7.0	6.5	6.5	6.0
Time since eating, hr	--	3.5	[c]1.0	1.25	1.0
Time since venipuncture	--	--	--	--	--

[a]Central standard time.
[b]Eastern standard time.
[c]Coffee and doughnut.

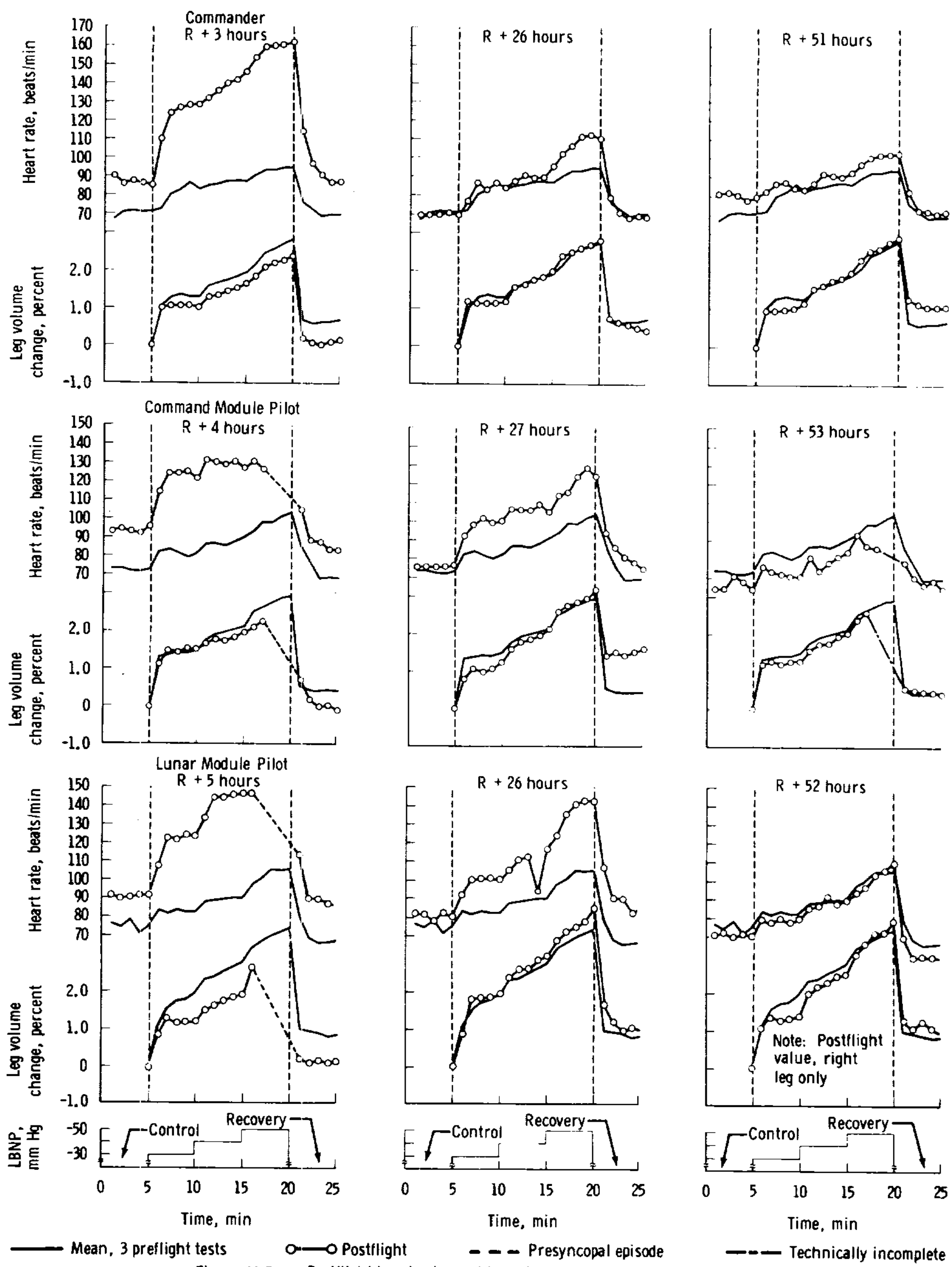


Figure 10.3-1 - Postflight heart rates and leg volume changes during LBNP tests.

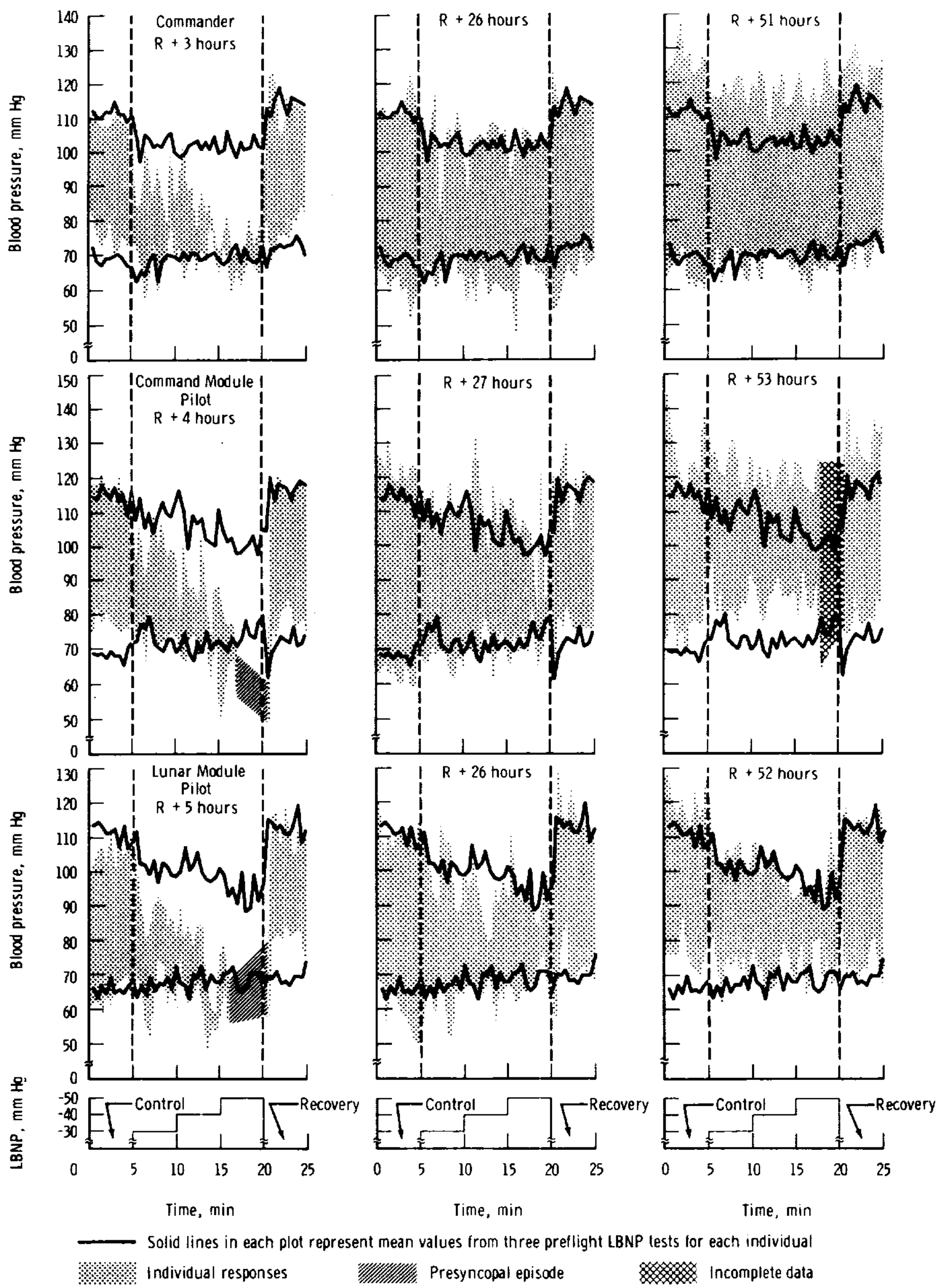


Figure 10.3-2 - Blood pressure responses during postflight LBNP tests on Apollo 8 crew members.

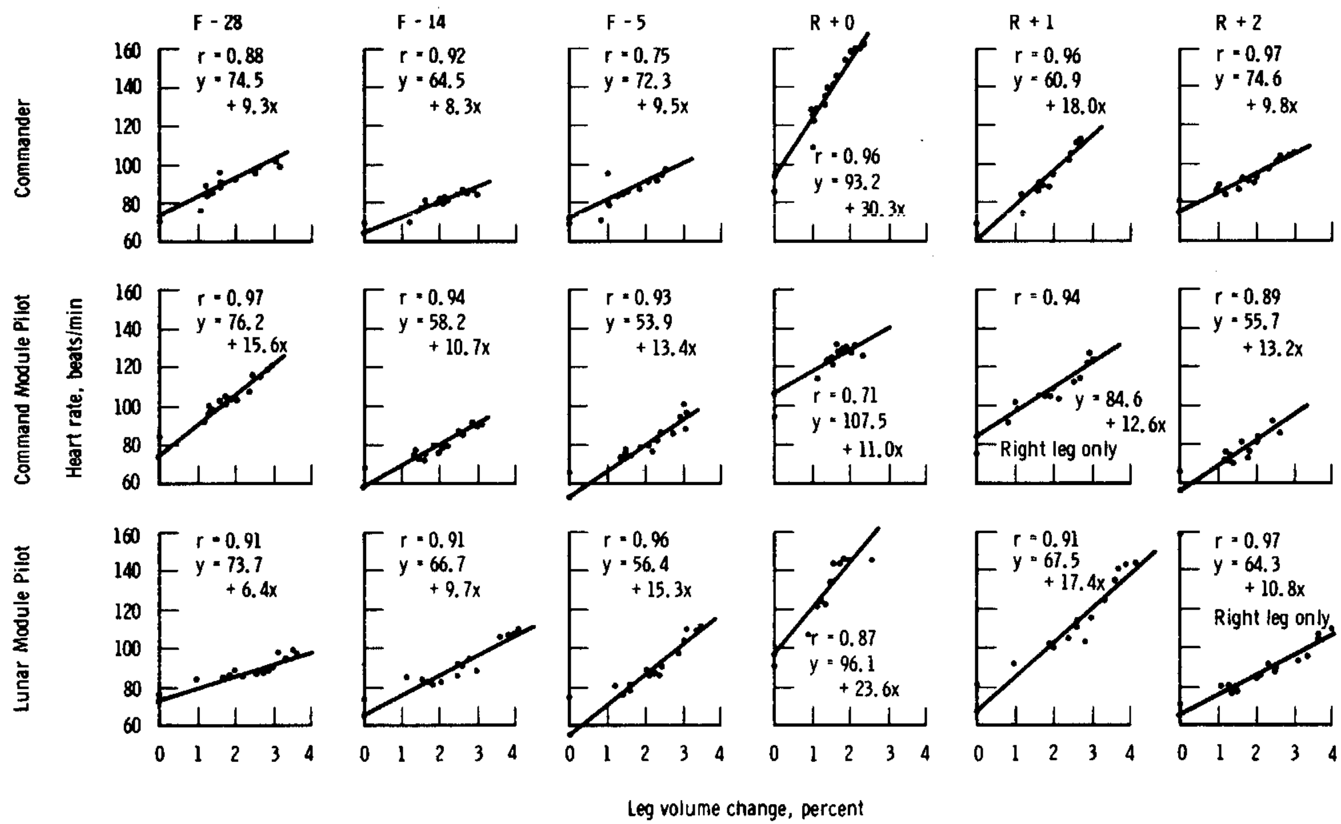


Figure 10.3-3 - Plots of regression data for heart rate versus leg volume change.

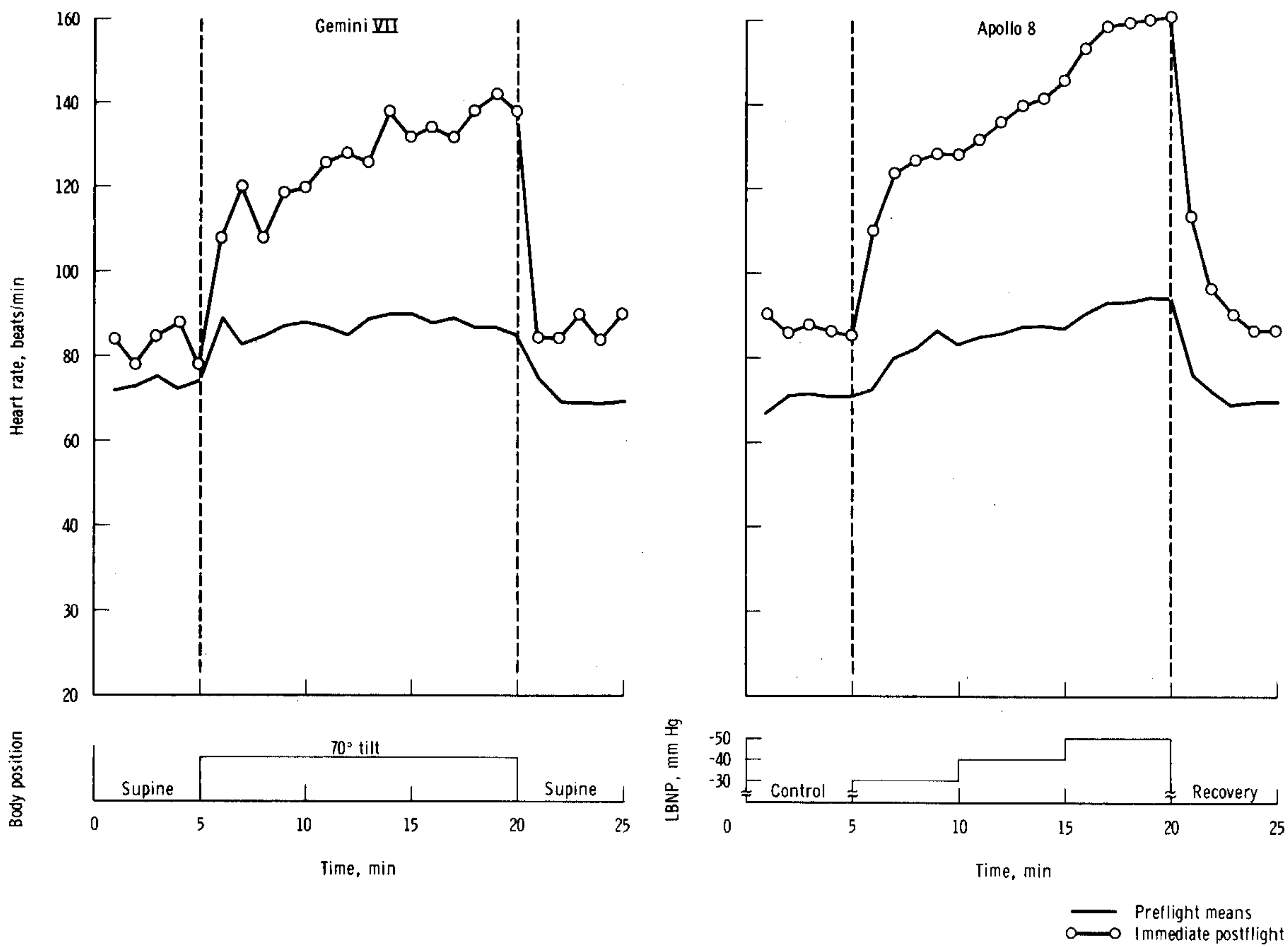


Figure 10.3-4 - Comparison of Commander Borman's heart rate response after Gemini VII and Apollo 8 missions.

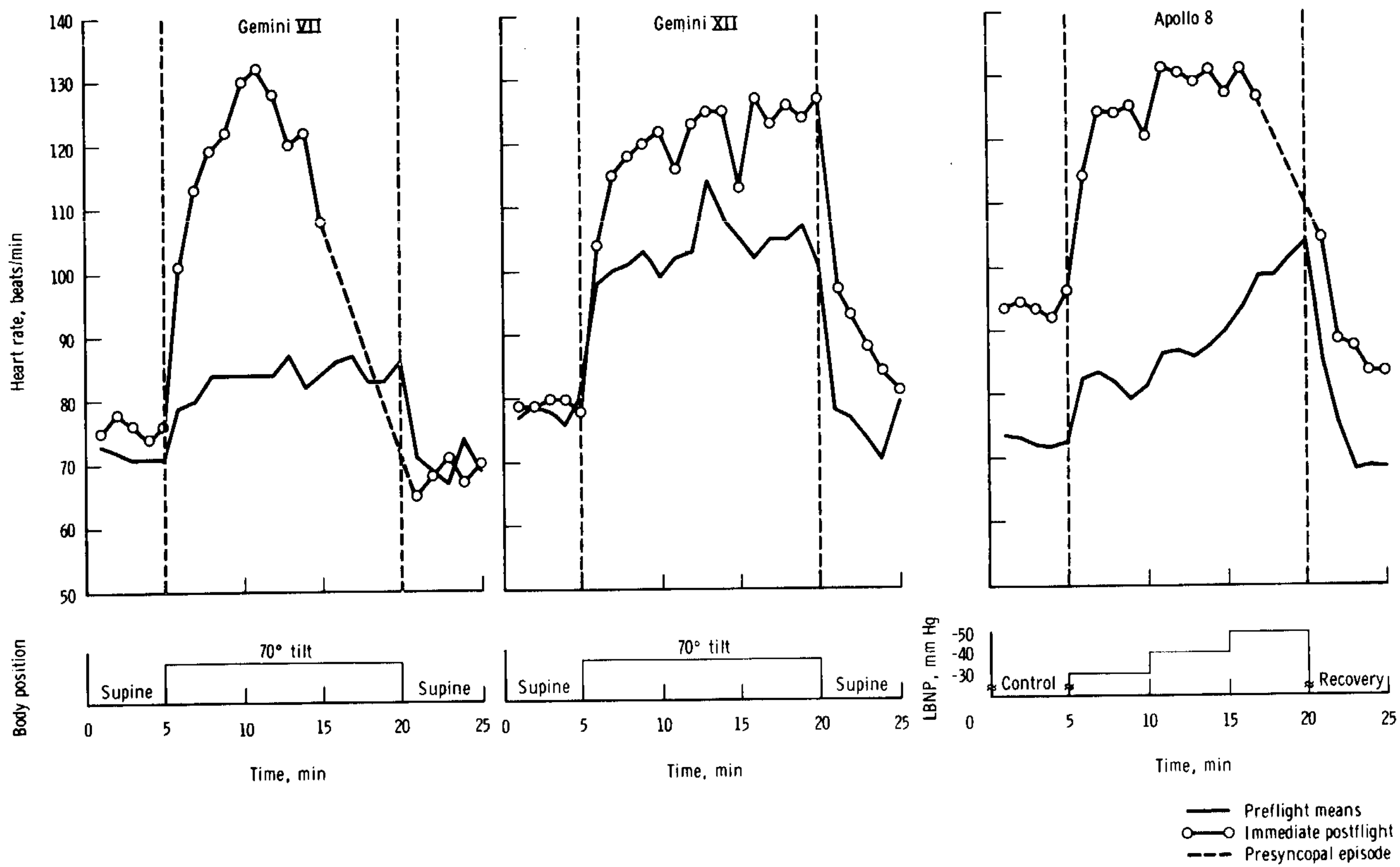


Figure 10.3-5 - Comparison of Command Module Pilot Lovell's heart rate responses after Gemini VII, Gemini XII, and Apollo 8 missions.

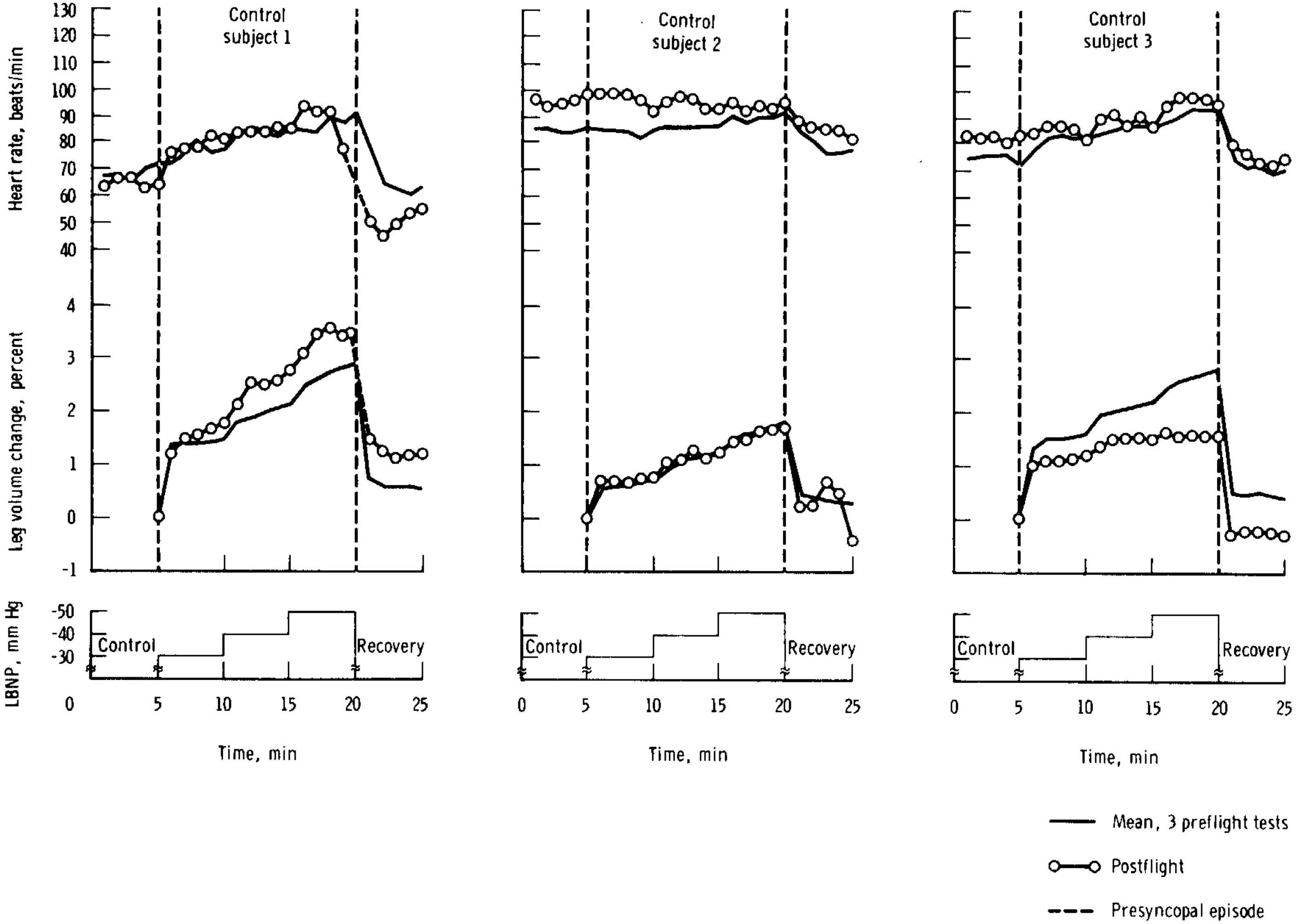


Figure 10.3-6 - Heart rate and leg volume measurements from LBNP tests on ground control subjects.

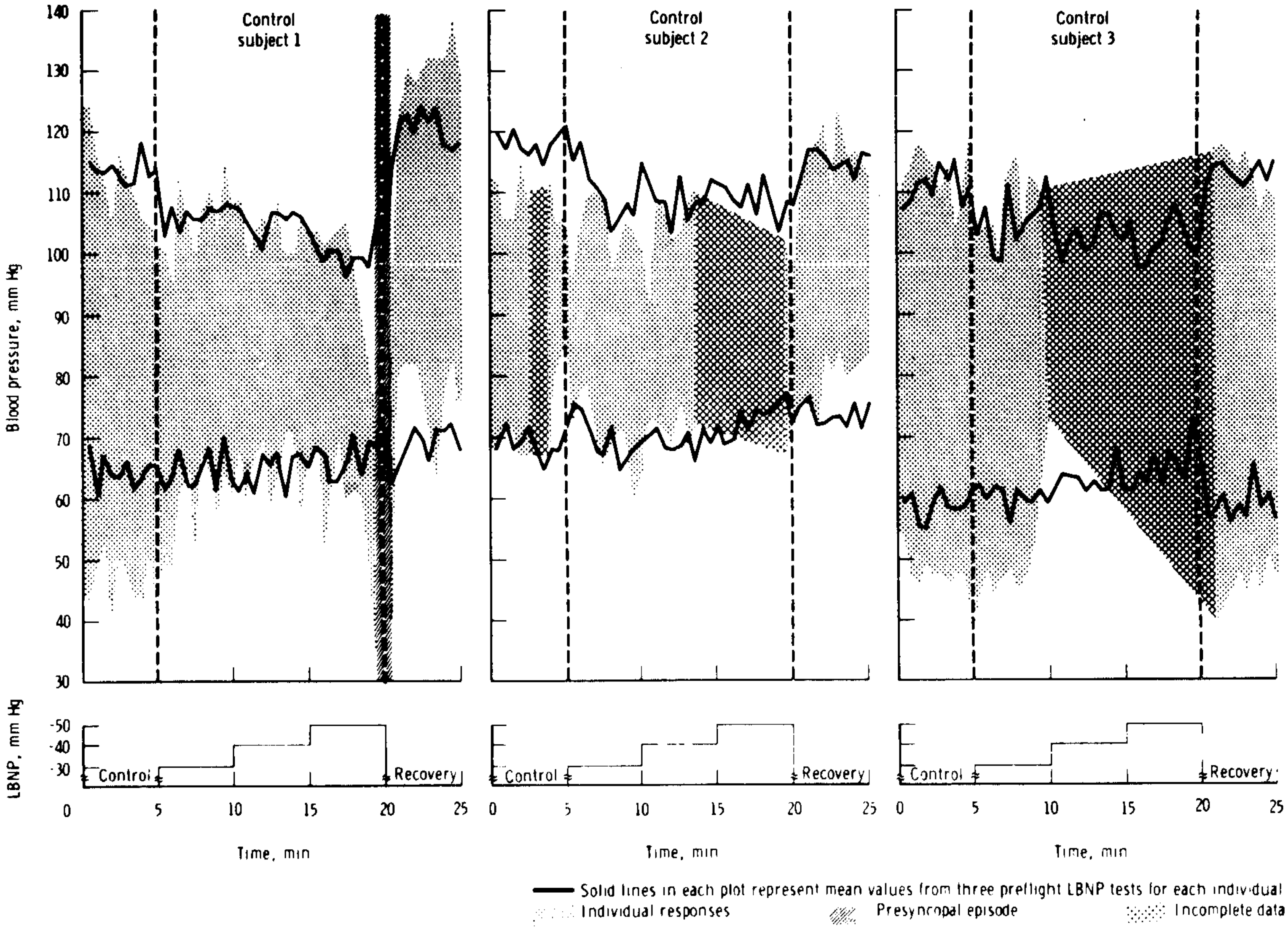


Figure 10.3-7 - Blood pressure measurements during LBNP tests on the ground control subjects.

11.0 BONE DEMINERALIZATION

11.1 INTRODUCTION

The bone mineral status of the crewmen before and after orbital space flight was measured to discover whether the integrity of the skeleton was maintained, and to determine the length of time required to rebuild any loss of minerals.

The objective of the bone demineralization study was threefold:

1. To determine the preflight skeletal status of the individual crewman and, from this information, to give the crewman a protocol for preventing extreme mineral losses during flight, particularly if his initial status is not optimum.

2. To determine the extent of demineralization in representative anatomic sites during flight, and to periodically test the crewmen after flight until all lost mineral is regained.

3. To acquire more information of value for future missions concerning bone demineralization during space flight.

During previous missions in which bone demineralization tests were made, individual differences in the crewmen were apparent with respect to their initial bone mineral status and their loss of bone mineral during space flight. The differences in bone demineralization during flight were directly related to the amount of mineral and other nutrients consumed in the diet during flight and to the extent of the exercise program.

11.2 PROCEDURE

11.2.1 Reference Wedge

To calibrate the exposed film, an aluminum alloy reference wedge was placed on each film adjacent to the bone being evaluated. The alloy in the wedge was selected because it had an X-ray absorption coefficient similar to that of bone, and because it provided a standard for correcting deviations resulting from slight differences in film characteristics or development techniques.

Bone mass was determined first as wedge mass equivalency. The wedge was calibrated in terms of calcium hydroxyapatite $\left(3Ca_3(PO_4)_2 \cdot Ca(OH)_2\right)$ by X-raying the wedge on the same film with a series of different quantities of the hydroxyapatite encased in thin-walled leucite containers. In this way, the values obtained from scanning certain sections of bone can be equated in terms of calcium hydroxyapatite mass with a conversion factor.

Under the conditions of exposure used in this study, the mass absorption coefficients for calcium hydroxyapatite and for soft tissue have been measured as 0.70 and 0.17, respectively, with the soft tissue effect further reduced by the comparatively small amount present. In all evaluations made in this study, the thickness of underlying and overlying soft tissue did not change, as shown by radiographs made at right angles to the film used for density evaluations. Therefore, the changes reported are regarded as representing the changes in bone sections scanned.

11.2.1 Standardization of X-Ray Machines

Because more than one X-ray machine was used in taking serial radiographs of the crewmen, the X-ray units and procedures required standardization for comparative purposes. The following methods were used for the standardization of radiographs made on more than one X-ray unit:

a. A Victoreen roentgen meter was used immediately before making a radiograph to determine calibrated kilovoltage which would produce identical X-ray beam qualities with all X-ray units used.

b. At each testing period, a standard composed of a bone impregnated in an organic matrix was radiographed before and after each series of radiographs. For example, milliamperes, kilovolts, and time were set for the os calcis to give an exposure level of 167 ± 2 milliroentgens for each radiograph which was made.

11.2.3 Radiographs

The radiographs of the crewmen consisted of exposures of the hand in the posterior-anterior aspect, and of the foot in the lateral projection. Four minutes were needed to make the two X-rays required for each man.

11.2.4 Anatomic Sites Investigated

The anatomic sites at which bone sections were evaluated for bone density included a single section of the central os calcis, single section across the talus, multiple parallel scans covering approximately 60 percent of the os calcis, parallel cross sections covering hand phalanges

4-2 and 5-2, a single diagonal section across the capitate among the wrist carpals, and numerous scans across the distal ends of the radius and the ulna.

Cancellous or trabecular tissue is represented in a major area of the os calcis and in the central portion of hand phalanges 4-2 and 5-2. Cortical or compact tissue is present in the perimeter of all the individual bones, and is found in generous amounts in the distal end of the os calcis. All types of skeletal tissue may lose some bone mass, although the lacy trabecular tissue in the central portion of the os calcis is most liable to experience a major loss.

11.3 RESULTS

11.3.1 Bone Density Changes of the CDR

Table 11-I (a) gives a summary of the bone density values of the major skeletal sites which have been evaluated for the CDR.

11.3.1.1 Central section of the os calcis - Figure 11-1 and table 11-I show that the CDR had a bone density of 11 900 computer counts at the time of the first test (F - 14). This decreased slightly to a value of 11 856 computer counts at the time of launch.

During the flight, this central os calcis site decreased by 2.13 percent, as shown in table 11-II. Possibly because of stress and of failure to consume an adequate diet, the CDR showed before the flight a slight decrease in bone density of this highly trabecular skeletal section that continued during flight. Also, he continued to lose bone density for 3 days after recovery. At the close of his series of tests, the CDR was 4.45 percent higher in bone density of this site than at his first test.

The bone density level of the central os calcis of the CDR during this study for the Apollo 8 mission is compared below to his bone density level during the Gemini VII mission:

Central Section of Os Calcis	Computer counts
Preflight bone density, Nov. 24, 1965 (Gemini VII)	11 973
Preflight bone density, Dec. 7, 1968 (Apollo 8)	11 900
Postflight bone density, Jan. 3, 1966 (Gemini VII)	12 823
Postflight bone density, Jan. 23, 1969 (Apollo 8)	12 429

Additional data on the central os calcis section of the CDR are given in table 11-II.

11.3.1.2 Multiple os calcis sections - Table 11-I (a) shows that on the radiograph the sum of the 1.0-mm wide sections of the os calcis that were needed to cover all the bone parts not overlapped by the image of other bones, totalled 305 814 computer counts with slight gains in bone density during the prelaunch tests. During flight, the total sections experienced a loss of 7.08 percent.

At the time of the final test, the sections comprising the os calcis scans totalled 328 165 computer counts, with an increase of 7.31 percent during the mission.

11.3.1.3 Talus - As shown in table 11-I, the CDR gained slightly in the density of this bone during the prelaunch period, lost 2.62 percent during the mission, and gained 6.22 percent from the first to the last test during the postrecovery period.

During the Gemini VII mission in 1965, this crewman lost 7.06 percent during the flight, with the final test for this bone section being 7.54 percent higher than the initial test.

11.3.1.4 Hand phalanges 4-2 and 5-2 - During the Apollo flight, the CDR had a slight loss in the multiple sections across hand phalange 4-2 and phalange 5-2 before launch, and had a loss of 2.19 and 2.07 percent, respectively, during flight. From the first to the last test (figs. 11-2 and 11-3), the multiple sections across hand phalange 4-2 gained 2.43 percent, with no gain in phalange 5-2.

11.3.1.5 Capitate - As shown in table 11-I, the CDR had a slight preflight loss in the diagonal section of the capitate. This anatomic site was further reduced by 9.60 percent during the flight. At the close of the study, he had essentially the same level of bone density as when the study began (fig. 11-4). During the Gemini VII mission, he lost 4.31 percent during flight, with an overall gain of 9.98 percent from the first to the last test.

11.3.1.6 Distal sections of the radius and ulna - The CDR lost 8.76 percent from a section of the distal end of the radius and 6.42 percent from the corresponding site of the ulna during the flight. No substantial changes in these skeletal sites occurred from the first to the last test (fig. 11-4).

11.3.2 Bone Density Changes of the CMP

Data for the CMP skeletal sites, table 11-I (b), lists the same parameters measured on the CDR.

11.3.2.1 Central section of the os calcis - Table 11-I (b) gives bone density values for the CMP skeletal sites evaluated at each of the seven test periods. This crewman had a loss in bone density measured at the two prelaunch tests, with a 6.95 percent decrease in bone density in the central os calcis section during the flight. A postrecovery gain during the first test of this period and a continuing gain through the subsequent postflight tests resulted in a slight increase (2.54 percent) from the first to the last test of the entire study (fig. 11-5).

Since the CMP also flew on the Gemini VII mission, the results of bone density studies on that mission may be compared with those of Apollo 8. During the Gemini VII study, the initial computer count for the central os calcis was 13 367 and the final value was 13 984 counts. The corresponding first and last values for this crewman during the Apollo 8 mission were 13 093 and 13 425 computer counts, respectively. The change during the flight was -2.84 percent for the Gemini VII mission and -6.95 percent during the Apollo 8 mission. See figure 11-5 for a linear diagram of the changes in the central section of the os calcis.

11.3.2.2 Multiple os calcis sections - The total value of the 47 sections required to cover the part of the CMP's os calcis not overlapped by other bones on the radiograph was 390 914 computer counts when this study began, and 385 384 when it ended. This represented a difference of only 1.41 percent. During the flight, there was a loss of 3.36 percent in the total os calcis sections.

11.3.2.3 Central section of the talus - When the Apollo 8 study began, the computer count across the central section of the CMP's talus was 4908 with a final count of 5045 and a gain of 2.79 percent. During the flight period, there was a loss of 2.81 percent in this skeletal section.

During the Gemini VII mission, he had a loss of 4.00 percent during flight, and a slight loss of 2.18 percent from the first to the last test.

11.3.2.4 Hand phalanges 4-2 and 5-2 - As shown in table 11-I (b), the CMP had an initial computer count of 33 374 for the 26 crosssectional scans required to cover the phalange 4-2, with a final count of 33 421 during the mission. This change represented a very minor increase in bone density. The phalange 4-2 had a loss of 2.41 percent.

Phalange 5-2, which had an initial computer count of 16 183, experienced almost no change from the first to the last test. A loss of 3.09 percent occurred in this bone during flight.

During the Gemini VII mission, the CMP's phalange 4-2 had a change of -3.82 percent during flight, with virtually no change during the overall study. During the same mission, his phalange 5-2 had a change of -7.03 percent and -3.36 percent from the initial to the final test.

11.3.2.5 Capitate - The CMP had a change of -12.11 percent in the bone density of the capitate during the Apollo 8 mission, with almost identical values in the first and last tests. In the Gemini VII mission, this crewman lost 9.30 percent in the capitate during the flight, and gained a sufficient amount during the recovery period to have an overall gain during the study of 10.65 percent (fig. 11-6).

11.3.2.6 Distal sections of the radius and ulna - As shown in table 11-I (b) and figure 11-6, the section across the distal end of the radius lost some bone density during the first part of the Apollo 8 preflight period, but regained most of the loss before the launch. Inflight, the CMP sustained the preflight change of -11.06 percent in the distal section of the radius, which was regained postflight.

The bone density of the distal end of the ulna (table 11-I (b) and figure 11-6) had the same preflight and postflight trends as the distal section of the radius. The CMP's ulna experienced a bone density change of -12.41 percent during the mission (table 11-II).

11.3.3 Bone Density Changes of the LMP

Table 11-I (c) gives the computer counts for the bone densities that have been determined. During the preflight period, the LMP had an overall decrease in bone density of different magnitudes for all major skeletal sites. For all skeletal locations except one, losses in bone density ranging from -1.00 to -16.17 percent occurred during flight.

On January 2, 1969, (R+6), the LMP was lower in bone density than his original level, with relatively distinct losses in the wrist, fingers, and distal radius not yet rectified. The other two crewmen, especially the CMP, had not regained all of the bone density lost in the skeletal locations tested Janaury 2, 1969; but they had returned to their initial status or higher on January 23, 1969, (R+27).

TABLE 11-I.- BONE DENSITY VALUES FROM THE DENSITOMETER

COMPUTER ASSEMBLY FOR MAJOR SKELETAL SITES

(a) Commander

Skeletal sites	Bone density, computer counts, on						
	F + 14	F + 5	F + 0	R + 0	R + 3	R + 5	R + 27
Central section of os calcis	11 900	11 894	11 856	11 603	11 418	11 913	12 429
Multiple sections of os calcis	305 814	309 894	314 985	292 683	307 100	311 519	328 165
Central section of talus	4611	4465	4689	4566	4575	4713	4898
Multiple section of hand phalange 4-2	28 081	27 717	27 579	26 976	25 368	28 138	28 764
Multiple section of hand phalange 5-2	14 143	13 909	12 903	12 636	11 890	13 332	14 147
Section of capitate	3261	3076	3073	2778	2994	3277	3298
Section across distal end of radius	4080	3619	3802	3469	3827	3917	4086
Section across distal end of ulna	2264	2026	2055	1923	2035	2249	2287

TABLE 11-I.- BONE DENSITY VALUES FROM THE DENSITOMETER

COMPUTER ASSEMBLY FOR MAJOR SKELETAL SITES - Continued

(b) Command Module Pilot

Skeletal sites	Bone density, computer counts, on						
	F + 14	F + 5	F + 0	R + 0	R + 3	R + 5	R + 27
Central section of os calcis	13 093	12 657	12 698	11 815	12 705	12 918	13 425
Multiple sections of os calcis	390 914	378 435	372 984	350 439	372 074	377 074	385 384
Central section of talus	4908	4630	4655	4524	4929	4816	5045
Multiple section of hand phalange 4-2	33 374	30 179	30 932	31 185	31 763	28 624	33 421
Multiple section of hand phalange 5-2	16 183	15 125	15 650	15 167	15 465	14 552	16 190
Section of capitate	3597	3306	3485	3063	3118	3402	3602
Section across distal end of radius	4943	4623	4871	4332	4408	4901	4945
Section across distal end of ulna	2261	2030	2167	1898	2075	2324	2332

TABLE 14-I.- BONE DENSITY VALUES FROM THE DENSITOMETER

COMPUTER ASSEMBLY FOR MAJOR SKELETAL SITES - Concluded

(c) Lunar Module Pilot

Skeletal sites	Bone density, computer counts, on					
	F + 14	F + 5	F + 0	R + 0	R + 5	R + 27
Central section of os calcis	10 951	11 345	10 088	9 792	10 825	11 458
Multiple section of hand phalange 4-2	25 611	25 758	23 272	24 391	23 602	24 334
Multiple section of hand phalange 5-2	14 538	14 619	12 924	12 800	13 249	13 383
Section of capitate	3029	2829	2886	2694	2836	2900
Section across distal end of radius	4323	3742	4011	3554	3947	4043
Section across distal end of ulna	2145	1955	1972	1653	2034	2106

TABLE 11-II

SUMMARY OF CHANGES IN BONE DENSITY OF

APOLLO 8 ASTRONAUTS DURING FLIGHT

Skeletal sites	Inflight bone density change, percent		
	Commander	Command Module Pilot	Lunar Module Pilot
Central section of os calcis	-2.13	-6.95	-2.93
Multiple section of os calcis	-7.08	-6.04	-6.50
Central section of talus	-2.62	-2.81	-3.18
Multiple section of hand phalange 4-2	-2.19	-2.41	+4.81
Multiple section of hand phalange 5-2	-2.07	-3.09	-1.00
Section of capitate	-9.60	-12.11	-6.65
Section across distal end of radius	-8.76	-11.06	-11.39
Section across distal end of ulna	-6.42	-12.41	-16.17

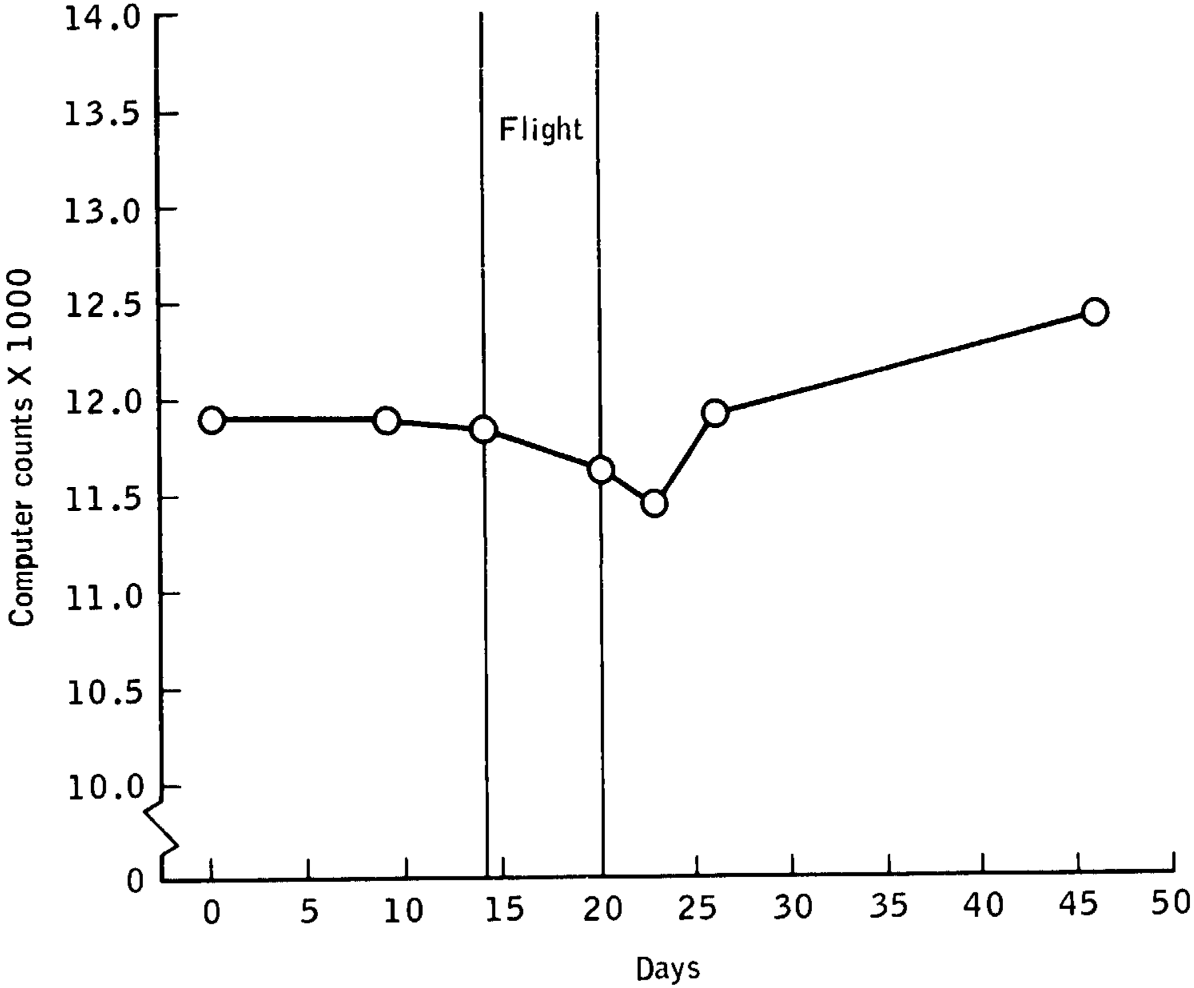


Figure 11-1. - Bone density values of the central section of the os calcis of the Commander at the respective test periods.

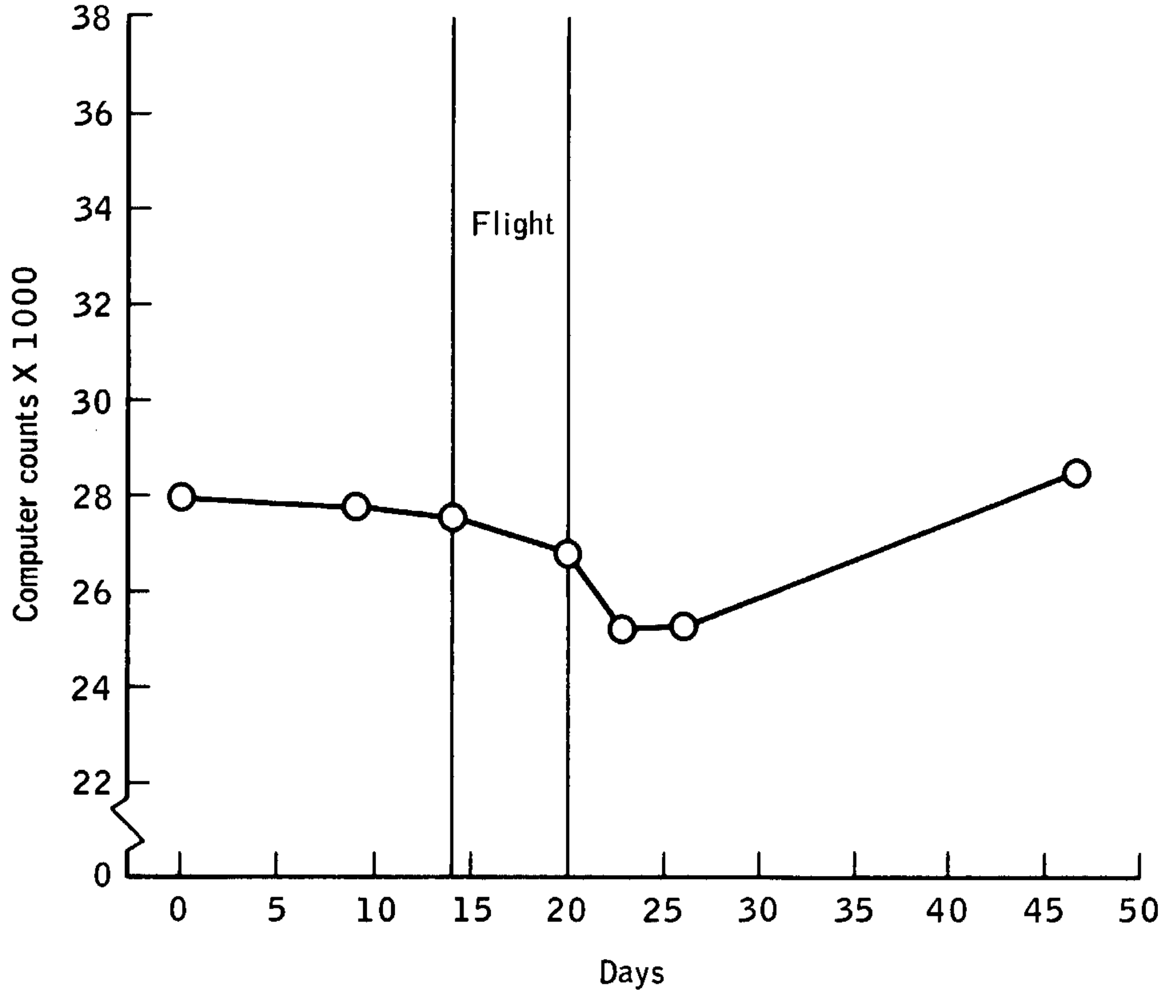


Figure 11-2. - Bone density values of multiple sections of hand phalange 4-2 of the Commander at respective test periods.

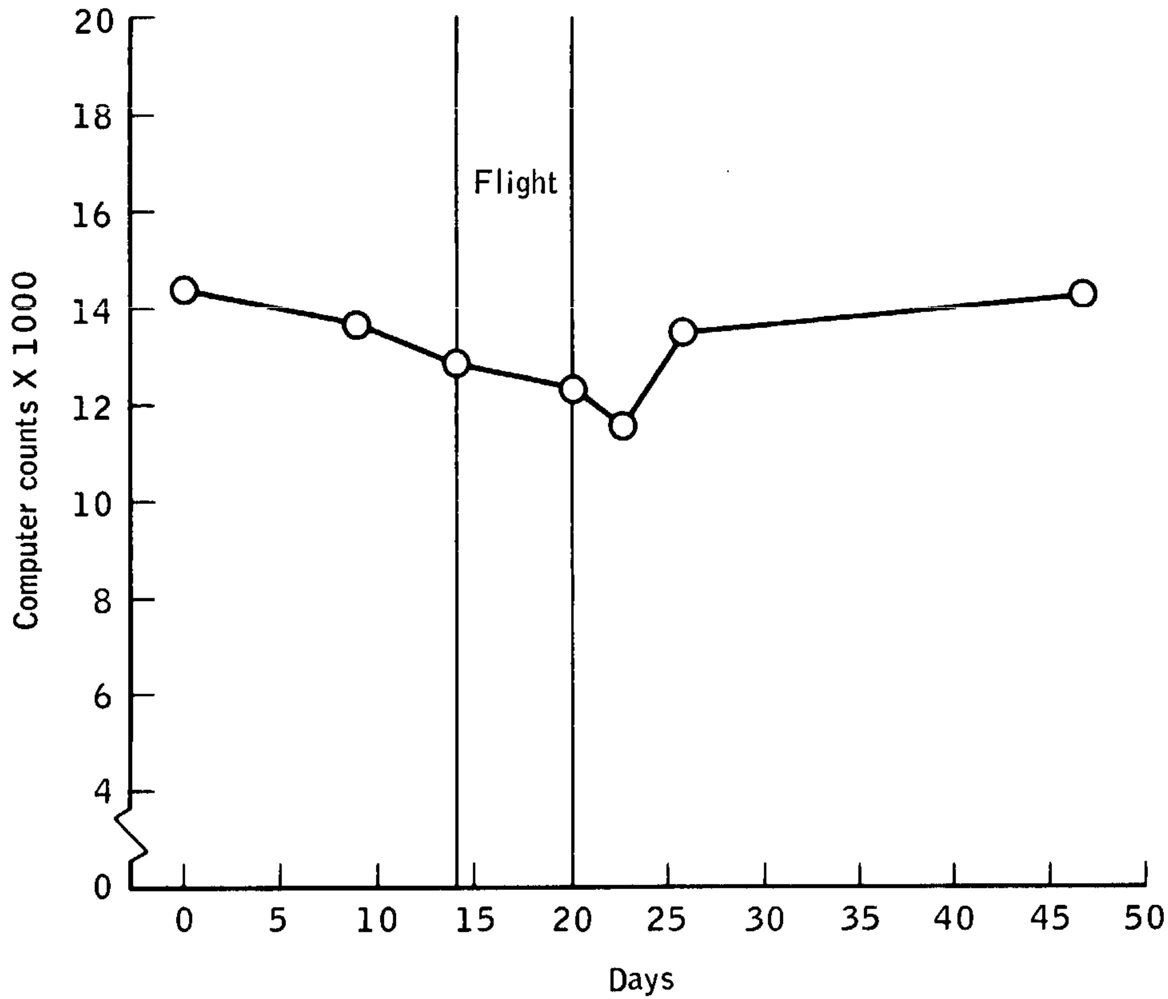


Figure 11-3. - Bone density values of multiple sections of hand phalange 5-2 of the Commander at respective test periods.

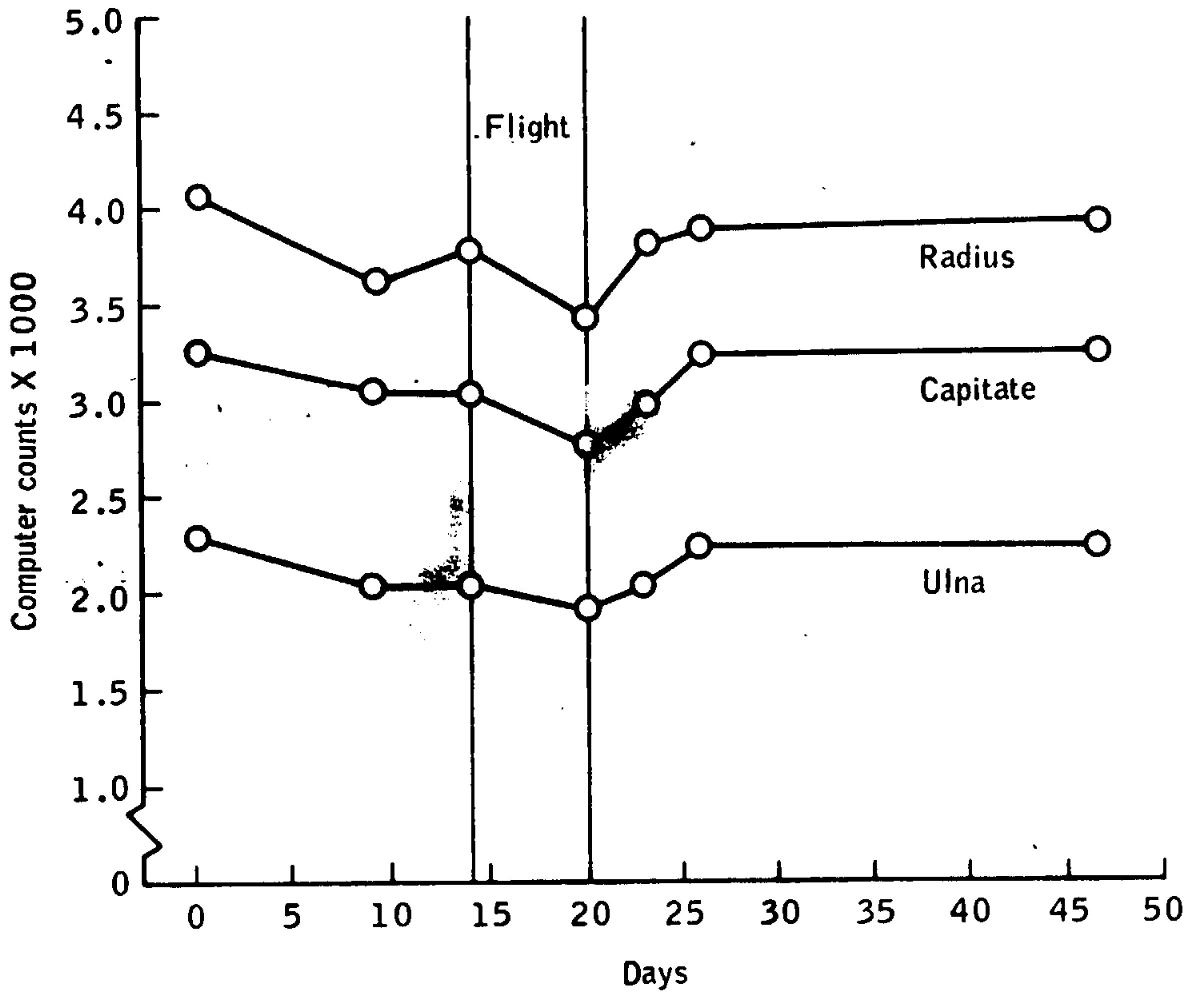


Figure 11-4. - Bone density values of capitate sections and of distal ends of radius and ulna of the Commander at respective test periods.

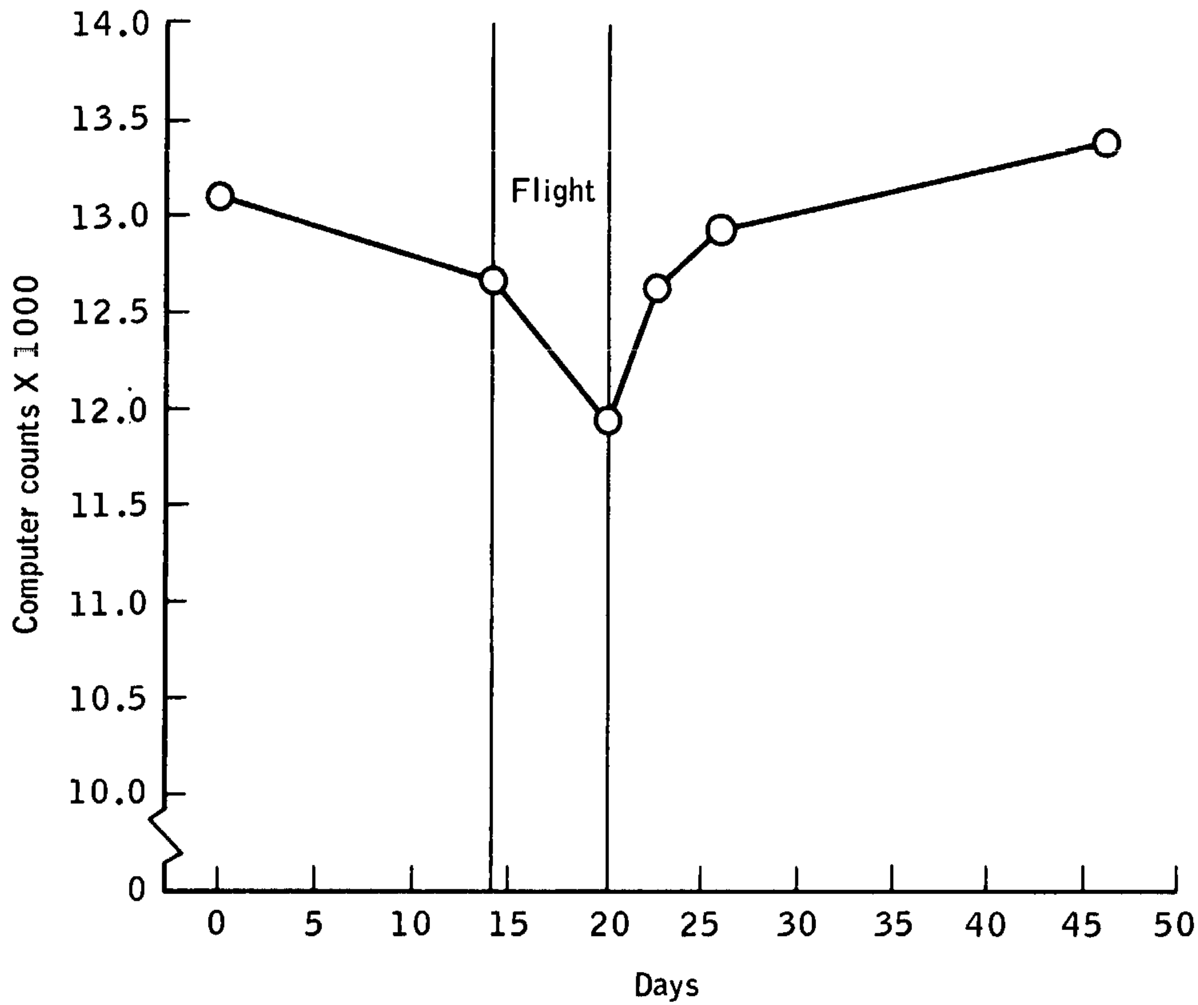


Figure 11-5. - Bone density values of the central section of os calcis of the Command Module Pilot at respective test periods.

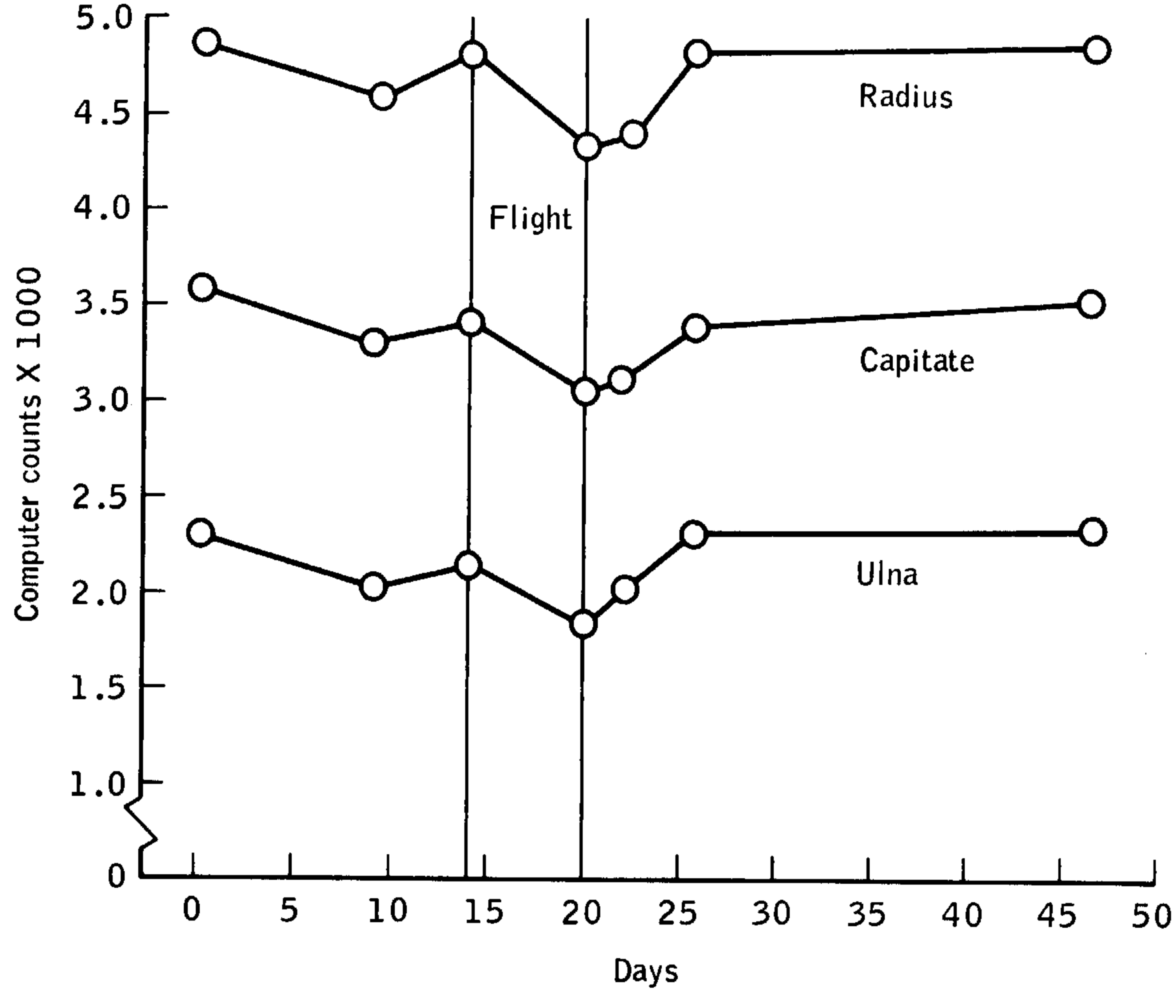


Figure 11-6. - Bone density values of sections of the capitate and of the distal ends of the radius and ulna of the Command Module Pilot at respective test periods.

12.0 MICROBIOLOGY

12.1 INTRODUCTION

Representative microbiological samples were obtained from the crewmembers and the spacecraft to determine the effects of space flight on flora and to differentiate terrestrial organisms from possible extraterrestrial organisms on lunar landing missions. The data obtained also will determine if any significant changes between preflight and postflight flora occur and whether the variations in microbial balance are harmful.

12.2 METHODS

The microbiological samples were obtained from the Apollo 8 crewmembers at 30, 14, and 0 days before the flight and immediately postflight. Body surface swab samples were obtained from the following areas:

a. Scalp

b. External auditory canal

c. Nasal

d. Axilla

e. Umbilicus

f. Inguinal region

g. Toes

h. Hands

Other samples taken from each crewmember included a throat-gargle/mouth rinse, stool, and urine specimens.

The sampling procedures and handling methods during transport are delineated in the Medical Requirements Document for Apollo Mission C Prime.

12.3 RESULTS

Morphological and biochemical data were obtained on all micro-organisms isolated from each sample. The bacteria and fungi of possible medical importance (tables 12-I to 12-IV), isolated from the crewmen, represent less than 10 percent of the total isolates.

Data on isolated micro-organisms, their counts, morphological characteristics, stain reactions and biochemical reactions are stored in computers as baseline data for use on lunar landing missions. These stored data are essential to aid in the identification of terrestrial micro-organisms that may be found as contaminants in the lunar soil sample or on crewmembers.

Future work will include the development of methods for computer analyses of accumulated data to determine the effects of the spacecraft environment on human microflora. The volume of data collected and the variation of the microfloral response prevent immediate analysis.

TABLE 12-I.- AEROBIC BACTERIA ISOLATED FROM ASTRONAUT A

Area	30-day preflight		14-day preflight		Immediate preflight		Immediate postflight	
	Bacteria	Count per ml	Bacteria	Count per ml	Bacteria	Count per ml	Bacteria	Count per ml
Scalp	*Corynebacterium bovis*	3.0×10^3	--	--	*Corynebacterium bovis*	10	--	--
External auditory canal	--	--	--	--	--	--	--	--
Nose	*Corynebacterium pyogenes*	3.0×10^1	--	--	*Corynebacterium pyogenes*	40	--	--
Axilla	--	--	--	--	--	--	--	--
Umbilicus	--	--	--	--	--	--	--	--
Inguinal region	*Corynebacterium bovis* Aerobacter species	1.0×10^6 100	Aerobacter species	<100	Aerobacter species	<100	--	--
Toe webs	*Corynebacterium bovis*	50	--	--	--	--	*Proteus vulgaris* Bacillus species (2041)	<100 <100
Hands	*Staphylococcus aureus*	20	--	--	*Corynebacterium bovis*	10	Bacillus species (1050)	<100
T-M gargle	*Staphylococcus aureus*	>10	--	--	*Diplococcus pneumoniae*	2.0×10^3	*Diplococcus pneumoniae* Alpha Streptococcus	5.0×10^4 7.0×10^4
Urine	Alpha Streptococcus and *Sarcina urea*	Total count = 100	Alpha Streptococcus and *Micrococcus species*	Total count = 100	Unidentified species	Total count = 100	Alpha Streptococcus	<100
Stool[1]	*Escherichia coli* *Escherichia coli* variety	3.6×10^6 4.9×10^6	*Escherichia coli* Streptococci species	3.0×10^6 1.0×10^4	*Escherichia coli* variety	4.0×10^4	*Escherichia coli* variety 1 variety 2 variety 3	7.5×10^7 1.2×10^7 5.3×10^7

[1]Count is per gram instead of per milliliter.

TABLE 12-II.- AEROBIC BACTERIA ISOLATED FROM ASTRONAUT B

Area	30-day preflight		14-day preflight		Immediate preflight		Immediate postflight	
	Bacteria	Count per ml	Bacteria	Count per ml	Bacteria	Count per ml	Bacteria	Count per ml
Scalp	Alpha Streptococcus	<100	--	--	--	--	--	--
External auditory canal	--	--	--	--	--	--	Bacillus subtilis	<100
Nose	Proteus mirabilis	2.0×10^3	Proteus mirabilis	2.0×10^2	Proteus mirabilis Klebsiella and Aerobacter	9.0×10^1 <100	Proteus mirabilis Klebsiella and Aerobacter	9.0×10^1 <100
Axilla	--	--	--	--	--	--	--	--
Umbilicus	--	--	--	--	--	--	--	--
Inguinal region	Corynebacterium bovis	2.4×10^5	Aerobacter species	1.7×10^3	Aerobacter species Proteus mirabilis	4.0×10^3 <100	Aerobacter species	4.1×10^3
Toe webs	Staphylococcus aureus Proteus vulgaris	4.5×10^3 <100	--	--	Staphylococcus aureus	2.0×10^1	Pseudomonas aeroginosa Bacillus species (1010)	<100 <100
Hands	Staphylococcus aureus	1.0×10^1	--	--	--	--	--	--
T-M gargle	Klebsiella and Aerobacter Proteus mirabilis	3.0×10^1 <10	Alpha Streptococcus Proteus mirabilis Klebsiella and Aerobacter	5.0×10^4 <10 <10	Klebsiella and Aerobacter Beta Streptococcus	1.0×10^1 4.0×10^2	Proteus species Klebsiella and Aerobacter Gamma Streptococcus	<100 4.2×10^2 4.0×10^4
Urine	Alpha Streptococcus	<10	Alpha Streptococcus	Total count <100	--	Total count <100	Proteus mirabilis	<100
Stool[1]	Escherichia coli Beta Streptococcus Proteus morganii	3.1×10^5 1.3×10^5 <100	Beta Streptococcus Proteus morganii Clostridium perfringes	7.0×10^5 <100 Heat shock	No sample	--	Escherichia coli variety Proteus morganii	1.9×10^7 <100

[1]Count is per gram instead of per milliliter.

TABLE 12-III.- AEROBIC BACTERIA ISOLATED FROM ASTRONAUT C

Area	30-day preflight		14-day preflight		Immediate preflight		Immediate postflight	
	Bacteria	Count per ml	Bacteria	Count per ml	Bacteria	Count per ml	Bacteria	Count per ml
Scalp	--	--	--	--	--	--	--	--
Extra auditory canal	--	--	--	--	--	--	--	--
Nose	Klebsiella and Aerobacter	<100	--	--	Corynebacterium pyogenes	100	--	--
Axilla	Corynebacterium bovis	40	Diplococcus pneumoniae	1.8×10^2	Corynebacterium bovis	1.9×10^3	Corynebacterium bovis	2.2×10^2
Umbilicus	--	--	Alpha Streptococci	<100	--	--	Yeast	90
Inguinal region	Corynebacterium bovis	2.0×10^3	--	--	--	--	Escherichia species	<100
	Corynebacterium pyogenes	6.0×10^2	--	--	--	--	Berella species	<100
Toe webs	Corynebacterium bovis	60	--	--	--	--	Pseudomonas aeroginosa	<100
	Bacillus species (1010)	<100	--	--	--	--	--	--
Hands	Staphylococcus aureus	100	--	--	Corynebacterium bovis	1.0×10^1	Staphylococcus aureus	1.2×10^2
T-M gargle	Staphylococcus aureus	1.0×10^5	Diplococcus pneumoniae	4.7×10^5	Diplococcus pneumoniae	2.3×10^6	Diplococcus pneumoniae	2.0×10^5
	Gamma Streptococcus	4.0×10^4	--	--	--	--	Mima polymorpha vans exidans	1.0×10^4
	Klebsiella and Aerobacter	<10	--	--	--	--	--	--
	Diplococcus pneumoniae	1.2×10^6	--	--	--	--	--	--
Urine	--	Total count <100	Alpha Streptococcus	Total count <100	Escherichia coli hemolytic	67	Escherichia coli Beta	5.0
							Gamma Streptococcus	38
Stool[1]	Escherichia coli	1.8×10^7	Escherichia coli	7.0×10^6	Escherichia coli	1.0×10^5	Klebsiella and Aerobacter	1.9×10^5
	Clostridium perfringes	Heat shock	Streptococci	5.6×10^5	Gamma Streptococcus	2.4×10^5	Escherichia coli	2.9×10^5

[1]Count is per gram instead of per milliliter.

TABLE 12-IV.- MEDICALLY IMPORTANT FUNGI ISOLATED FROM

APOLLO 8 CREWMEN

Crewman	30-day preflight	14-day preflight	Immediate preflight	Immediate postflight
A	*Candida albicans* (throat-mouth)	*Candida albicans* (throat-mouth)	--	--
	Candida albicans (feces)	*Candida albicans* (feces)	--	--
	Microsporum canis (arm)	*Microsporum canis* (arm)	*Microsporum canis* (arm)	*Microsporum canis* (arm)
B	None reported	None reported	None reported	None reported
C	None reported	None reported	Chrysosporium species (toe web)	*Trichophyton mentagrothytes*

13.0 BIOCHEMISTRY AND IMMUNO-HEMATOLOGY

13.1 INTRODUCTION

Biochemical and immuno-hematological analyses of the Apollo 8 crewmen's body fluids were performed to determine the time course, extent, and etiology of any changes in these fluids as a result of exposure to space flight. The immunology analyses will also assess human ability to combat infection and repair traumatized tissues after exposure to weightlessness, sublethal ionizing radiation, and monotonous immunologic stimulation of a closed environment.

13.2 PROCEDURES

Samples of blood, urine, and feces were taken at F - 30, F - 14, and F - 7 days for the preflight intervals and at recovery (ASAP sample) and R + 24 hours for the postflight interval of this test. Additional blood samples were taken at F - 5, R + 6, and R + 21 days. All samples were analysed as required in the Medical Requirements Document, Apollo Mission C Prime, using standard clinical procedures wherever possible.

13.3 RESULTS

Clinical laboratory data which are presently available are given in tables 13-I to 13-XVII. These data are summarized as follows.

a. No significant changes in the red blood cell mass or survival rate were ncted.

b. Small, but significant, decreases in plasma volume were observed (-7.6 ± 2.6 percent). These decreases were comparable to plasma volume decreases in bedrest studies of similar duration.

c. There was no alteration of any routine red blood cell parameter.

d. A significant postflight absolute neutrophilia was observed.

e. No significant alteration in any humoral or cellular immunity, secondary to the flight interval, was noted.

f. A depression of plasma 17-OH corticosteroid values was observed in the immediate postflight interval. This depression was not ACTH-mediated and the exact etiology or significance is unknown at this time.

g. A marked increase in urinary catecholamine levels was observed in the ASAP postflight urine samples which correlates with the concomitant postflight absolute neutrophilia seen in all crewmen.

TABLE 13-I.- CALCULATED TOTAL APOLLO 8 RADIATION EXPOSURE

Isotope	mrem/μCi (a)	μCi/test	No. of test	Total exposure, mrem	Gemini total exposure, mrem
^{14}C-glycine	0.6	50	1	30.0	-
^{51}Cr	.35	25	2	17.5	58.3
^{59}Fe-citrate	35.0	2	1	70.0	-
^{125}Albumin	.7	2	2	2.8	5.2
Total mrem/subject				120.3	63.5

[a]Assuming a standard 70-kilogram man.

TABLE 13-II.- RED BLOOD CELL MASS

Time Date	Commander	Command Module Pilot	Lunar Module Pilot	Control 1	Control 2	Control 3
RBC mass, ml						
Preflight	2003	2098	1945	2097	2002	1689
Postflight	2050	2051	1868	2058	2062	1709
Difference, actual	+47	-47	-77	-39	+60	+20
Difference, percent	+2.3	-2.2	-4.0	-1.9	+3.0	+1.2
RBC mass, ml/kgBW						
Preflight	26.2	27.0	28.9	28.9	28.4	21.1
Postflight	28.2	27.5	29.8	—	29.5	21.0
Difference, actual	+2.0	+0.5	+0.9	—	+1.1	-0.1
Difference, percent	+7.6	+1.8	+3.1	--	+4.0	-0.5

TABLE 13-III.- PLASMA VOLUME CHANGES

	Plasma volume, ml					
	Commander	Command Module Pilot	Lunar Module Pilot	Control 1	Control 2	Control 3
Preflight	3397	3450	3142	3350	3294	3029
Postflight	3856	2963	2896	3725	3850	3257
Difference, actual	-541	-487	-246	+375	+556	+228
Difference, percent	-15.9	-14.1	-7.8	+11.2	+16.9	+7.5
	Plasma volume, ml/kgBW					
Preflight	44.4	44.4	46.8	46.1	46.7	37.9
Postflight	39.2	39.8	46.3	-	55.1	40.1
Difference, actual	-5.2	-4.6	-0.5	-	+8.4	+2.2
Difference, percent	-11.7	-10.4	-1.1	-	+18.0	+5.9

TABLE 13-IV.- BLOOD VOLUME CHANGES

Date	Commander	Command Module Pilot	Lunar Module Pilot	Control 1	Control 2	Control 3
	Blood volume, ml					
Preflight	5400	5548	5087	5447	5296	4718
Postflight	4906	5014	4764	5783	5912	4966
Difference, actual	-494	-534	-323	+336	+616	+248
Difference, percent	-9.0	-9.6	-6.3	+6.2	+11.6	+5.2
	Blood volume, ml/kgBW					
Preflight	70.6	71.5	75.7	75.0	75.0	58.9
Postflight	67.4	67.3	76.1	--	84.6	61.1
Difference, actual	-3.2	-4.2	+0.4	--	+9.6	+2.2
Difference, percent	-4.5	-5.9	+0.5	--	+12.8	+3.7

TABLE 13-V. - RED BLOOD CELL ^{51}Cr DATA

Time	RBC ^{51}Cr, estimated T1/2 days					
	Commander	Command Module Pilot	Lunar Module Pilot	Control 1	Control 2	Control 3
Preflight	25	24	28	23	24	27
Inflight	32	31	29	31	30	29
Postflight	23	22	26	24	26	28

TABLE 13-VI.- HEMOGLOBIN ^{14}C DATA

^{14}C, μCi/mg Hgb × 10^{-8}						
Day	Commander	Command Module Pilot	Lunar Module Pilot	Control 1	Control 2	Control 3
F - 15	336	326	272	298	252	322
F - 6	330	330	322	318	336	366
ASAP	337	310	361	335	290	364
R + 1	-	320	382	304	-	348
R + 6	352	314	354	330	276	344
R + 12	356	298	346	304	286	-

TABLE 13-VII.- IRON KINETICS

Subject	Serum Fe, μg%	T-1/2, minute	Fe turnover	Fe reappearance, percent
Commander	110	156	0.27	93
Command Module Pilot	110	153	0.28	92
Lunar Module Pilot	122	122	0.46	86
Control 1	110	125	0.45	88
Control 2	105	105	0.55	100
Control 3	90	95	0.38	100

TABLE 13-VIII.- RED BLOOD CELL 1-HOUR UPTAKE OF SODIUM

Date	Sodium uptake, meq/liter RBC					
	Commander	Command Module Pilot	Lunar Module Pilot	Control 1	Control 2	Control 3
F - 30	14.2	15.6	15.0	13.0	13.6	14.0
F - 15	16.0	15.2	16.0	14.4	15.2	16.0
[a]F - 4	28.8	30.4	24.0	27.2	23.2	24.8
ASAP	19.2	16.0	21.6	14.4	13.6	15.2
[a]R + 1	38.4	19.2	24.0	22.4	19.2	24.8

[a]The 24-hour storage of blood was at the wrong temperature.

TABLE 13-IX.- RED BLOOD CELL 1-HOUR UPTAKE OF POTASSIUM

Date	Potassium uptake, meq/liter RBC					
	Commander	Command Module Pilot	Lunar Module Pilot	Control 1	Control 2	Control 3
F - 30	2.1	2.3	2.0	2.4	1.7	2.0
F - 15	2.0	2.1	2.0	2.5	1.7	2.2
[a]F - 4	3.3	3.1	2.8	3.1	2.5	3.0
ASAP	1.8	2.1	2.0	2.5	1.7	2.1
[a]R + 1	2.1	1.9	2.3	2.3	1.8	2.1

[a]The 24-hour storage of blood was at the wrong temperature.

TABLE 13-X.- HEMATOLOGY

PART 1

Subject	Date	Hemoglobin, g%	Hematocrit, %	RBC, $\frac{1 \times 10^6}{mm^3}$	Mean corpuscular volume, μ^3	Mean corpuscular hemoglobin, μμg	Mean corpuscular hemoglobin content, %	Platelets, 1×10^5	Reticulocytes, %
Commander	F - 30	15.1	45.0	5.26	85.4	28.7	33.6	1.84	0.8
	F - 14	15.0	46.0	5.32	86.8	28.2	32.9	1.91	0.8
	F - 5	15.2	45.0	4.99	90.2	30.2	33.8	2.13	.7
	ASAP	15.5	47.0	5.44	86.4	28.5	33.0	-	1.1
	R + 1	15.1	42.0	4.91	85.5	30.8	36.0	-	1.1
	R + 2	15.1	40.0	4.78	83.7	31.6	37.8	1.43	1.6
	R + 6	13.8	41.0	4.69	87.4	29.4	33.7	1.47	2.0
	R + 12	15.3	42.0	4.82	87.1	31.5	36.2	2.23	1.2
Command Module Pilot	F - 30	15.3	46.0	5.29	87.0	29.0	33.3	2.32	0.8
	F - 14	14.6	45.0	5.04	89.5	28.9	32.8	1.82	0.6
	F - 5	15.3	45.5	5.14	88.7	29.8	33.9	1.25	0.6
	ASAP	15.5	45.6	5.05	90.1	30.7	34.1	-	0.5
	R + 1	15.2	43.5	4.75	91.6	32.0	34.9	-	.5
	R + 2	15.1	42.0	4.89	85.9	30.9	36.0	1.88	.9
	R + 6	14.2	41.0	4.56	89.9	31.1	34.6	2.55	1.5
	R + 12	15.6	43.0	4.80	89.6	31.7	35.3	1.65	.7
Lunar Module Pilot	F - 30	14.8	45.0	5.22	86.4	28.3	32.8	3.52	0.5
	F - 14	14.4	45.0	5.19	87.3	27.9	32.2	3.03	0.7
	F - 5	15.3	46.0	5.27	87.6	29.2	33.5	2.05	0.3
	ASAP	15.4	47.0	5.75	81.7	26.8	32.8	-	1.0
	R + 1	15.1	44.0	4.71	93.4	32.0	34.3	-	0.5
	R + 2	14.1	39.0	4.62	84.4	30.6	36.2	1.80	0.7
	R + 6	13.6	40.5	4.67	86.7	29.1	33.6	1.75	1.2
	R + 12	14.3	41.0	4.79	86.7	30.2	34.9	1.92	0.7

TABLE 13-X.- HEMATOLOGY

PART 2

Subject	Date	WBC, mm^3	Total leukocytes						
			Segmented polymophonuclear leukocyte	Lymphocytes	Monocytes	Eosinophils	Basophils	Stab	Morphology
Commander	F - 30	5830	4136 (71%)	1166 (20%)	408 (7%)	0	0	117 ([illegible])	N
	F - 14	4730	2554 (54%)	1987 (42%)	142 (3%)	47 (1%)	0	0	N
	F - 5	5720	3089 (59%)	2231 (39%)	229 (4%)	114 ([illegible])	57 (1%)	0	[illegible]
	ASAP	9700	7469 (77%)	1940 (20%)	97 (1%)	97 (1%)	0	97 (1%)	N
	R + 1	6500	3510 (54%)	2340 (36%)	455 (7%)	130 ([illegible])	65 (1%)	0	N
	R + 2	5500	2750 (50%)	2255 (41%)	385 (7%)	55 (1%)	0	55 (1%)	N
	R + 6	6160	3819 (62%)	1663 (27%)	431 (7%)	123 (2%)	[illegible] (2%)	[illegible]	N
	R + 12	5170	3619 (70%)	1189 (23%)	103 (2%)	207 (4%)	0	[illegible] (1%)	N
Command Module Pilot	F - 30	5940	3029 (51%)	2257 (38%)	594 (10%)	59 (1%)	0	0	N
	F - 14	6490	4348 (67%)	1623 (25%)	454 (7%)	0	0	64 ([illegible])	N
	F - 5	5830	3323 (57%)	1924 (33%)	525 (9%)	58 (1%)	0	[illegible]	N
	ASAP	9100	7280 (80%)	1729 (19%)	0	0	0	[illegible] (1%)	N
	R + 1	8000	4880 (61%)	2720 (34%)	160 (2%)	240 (3%)	0	0	N
	R + 2	8690	4693 (54%)	2868 (33%)	695 (8%)	261 (3%)	0	174 (2%)	N
	R + 6	5720	2917 (51%)	2059 (36%)	515 (9%)	229 (4%)	0	0	N
	R + 12	6050	3570 (59%)	2178 (36%)	61 (1%)	182 (3%)	0	61 (1%)	N
Lunar Module Pilot	F - 30	6710	3154 (47%)	2416 (36%)	671 (10%)	40 (6%)	[illegible] (1%)	0	N
	F - 14	7480	3890 (52%)	3067 (41%)	374 (5%)	74 (1%)	95 (1%)	74 (1%)	N
	F - 5	9790	4797 (49%)	4112 (42%)	392 (4%)	29 (3%)	0	98 (1%)	N
	ASAP	14500	8410 (58%)	5510 (3%)	145 (1%)	14 (1%)	0	145 (1%)	N
	R + 1	9500	4180 (44%)	4750 (50%)	285 (38%)	95 (1%)	0	95 ([illegible])	N
	R + 2	5720	2746 (48%)	2574 (45%)	343 (6%)	57 (1%)	0	0	N
	R + 6	11000	8360 (76%)	1760 (16%)	220 (2%)	33 (3%)	0	330 (3%)	N
	R + 12	6700	4489 (67%)	2010 (30%)	67 (1%)	13 (2%)	0	0	N

TABLE 13-XI.- SERUM CHEMISTRY

Astronaut	Date	Gluose mg%	Blood urea nitrogen, mg%	Bilirubin total, mg%	Bilirubin direct, mg%	Creatinine, mg%	Uric acid, mg%	Na, meq/l	K, meq/l	Cl, meq/l	Mg, mg%	Ca, mg%	PO_4, mg%	Alkaline phosphatase, IU	Creatinine phosphokinase, IU	Lactic dehydrogenase, IU	Serum glutomic oxalacetic transaminase, IU
Commander	F - 30	85	16	0.53	--	1.1	5.6	144	4.3	105	2.0	9.4	3.0	37	9	46	33
	F - 14	94	17	.55	--	1.1	5.8	143	3.8	103	2.0	9.6	3.3	16	10	47	19
	F - 5	94	20	.65	--	1.2	6.2	141	4.0	106	2.1	9.1	3.5	27	12	37	29
	ASAP	104	16	.95	--	1.1	5.0	142	3.5	101	2.0	9.6	3.5	26	11	40	25
	R + 1	97	17	.90	--	1.0	5.3	142	4.0	102	2.2	9.4	3.2	26	20	39	27
	R + 6[a]	118	13	.23	--	1.1	4.3	143	4.1	105	2.2	9.0	3.4	31	13	37	26
Command Module Pilot	F - 30	89	25.0	2.10	0.75	1.2	5.0	145	3.6	100	2.0	9.7	3.1	22	8	42	33
	F - 14	92	22.0	1.20	.38	1.1	4.0	143	3.6	102	1.9	9.7	3.2	16	11	46	22
	F - 5	84	13.5	1.30	.55	1.3	4.4	140	3.1	97	2.2	9.4	3.2	21	10	35	29
	ASAP	87	29.0	2.38	.60	1.3	3.9	141	3.4	100	2.0	9.2	3.7	20	9	36	25
	R + 1	92	25.5	2.50	.75	1.1	3.9	141	3.6	102	2.1	9.7	2.8	19	17	43	31
	R + 6[a]	113	14.5	.63	--	1.3	3.7	142	4.0	105	2.0	9.4	3.3	19	19	42	29
Lunar Module Pilot	F - 30	82	15.5	0.75	--	1.2	6.1	145	4.5	101	1.9	9.7	3.2	34	6	45	38
	F - 14	77	16.5	.61	--	1.2	5.0	144	4.0	105	1.9	9.8	3.9	20	8	43	20
	F - 5	76	21.0	.91	--	1.3	6.0	139	4.3	102	2.2	10.3	4.0	27	9	37	29
	ASAP	90	15.5	1.1	--	1.3	4.1	139	3.7	98	1.8	9.8	4.1	25	16	45	28
	R + 1	73	19.5	.75	--	1.1	5.7	141	4.1	101	2.2	9.6	3.4	24	9	37	28
	R + 6[a]	124	12.9	.32	--	1.2	3.6	143	3.9	102	2.1	9.7	3.5	29	7	36	24

[a]Nonfasting

TABLE 13-XII.- SERUM PROTEINS

PART I

Subject	Date	Total serum protein, g%	Albumin, g%	α_2-globulin, g%	γ-globulin, g%	γG-globulin/ I_gG, mg%	γA-globulin/ I_gG, mg%	γM-globulin/ I_gM, mg%	Transferrin, mg%	α_2M-globulin, mg%	B_1A/B_1C globulin (C′3), mg%
Commander	2-8-68	7.6	4.0	0.8	1.6	872	128	72	231	240	54
	F-30	6.7	3.7	.6	1.3	1043	152	96	241	325	72
	F-7	7.1	4.2	.6	1.3	907	149	89	255	325	67
	F-5	6.9	3.8	.7	1.4	987	153	82	243	303	66
	ASAP	8.1	4.6	.7	1.5	1165	200	99	301	397	106
	R + 6	6.5	3.9	.6	1.0	885	136	89	227	297	75
Command Module Pilot	10-31-66	6.5	4.4	0.5	0.9	--	--	--	--	--	--
	11-16-66	8.5	5.5	.8	1.1	--	--	--	--	--	--
	3-19-68	6.9	3.3	.8	1.6	995	193	158	220	225	52
	F-30	7.2	3.6	.7	1.9	1216	275	207	261	376	69
	F-7	7.5	3.7	.8	1.9	1243	281	264	271	325	86
	F-5	7.1	3.7	.7	1.6	1237	289	191	260	332	80
	ASAP	8.1	4.3	.7	1.9	1237	312	202	256	359	80
	R + 6	7.0	3.9	.6	1.5	1164	264	224	249	333	73
Lunar Module Pilot	10-6-67	7.0	5.1	0.6	0.8	1000	152	240	224	312	
	F-30	6.6	3.5	.6	1.5	1064	173	354	284	565	70
	F-7	7.8	4.0	.9	1.8	1000	155	472	279	512	63
	F-5	7.5	3.7	.8	1.9	979	167	336	275	560	66
	ASAP	8.4	4.2	.8	1.9	1085	201	390	292	680	81
	R + 6	6.9	4.1	.6	1.2	835	145	392	233	511	69

TABLE 13-XII.- SERUM PROTEINS

PART II

Subject	Date	RNA-Synthesis		DNA-Synthesis	
		PHA-Stimulation	Unstimulated	PHA-Stimulation	Unstimulated
Commander	2-8-68	--	--	--	--
	F-30	19.865	1.471	23.117	3.725
	F-7	17.675	1.843	14.411	2.453
	F-5	16.129	1.277	13.051	.297
	ASAP	(a)	(a)	(a)	(a)
	R + 6	17.900	.876	11.000	1.700
Command Module Pilot	10-31-66	--	--	--	--
	11-16-66	--	--	--	--
	3-19-68	--	--	--	--
	F-30	18.473	2.326	16.932	.473
	F-7	17.243	.742	23.843	2.885
	F-5	15.395	.890	17.132	.607
	ASAP	(a)	(a)	(a)	(a)
	R + 6	21.600	3.000	18.975	1.562
Lunar Module Pilot	10-6-67	--	--	--	--
	F-30	15.971	2.152	16.978	1.367
	F-7	22.684	1.127	18.800	3.705
	F-5	14.365	1.215	16.904	.308
	ASAP	(a)	(a)	(a)	(a)
	R + 6	13.000	1.250	15.500	.900

TABLE 13-XIII.- PLASMA LIPIDS

Subject	Date	Total lipids, mg%	Total Cholesterol, mg%	Free Cholesterol, mg%	Free fatty acids	Triglycerides	Free Cholesterol/ total Cholestrol	Vitamin E	Vitamin C	Lysolecithin	Sphingomyelin phospholipid	Lecithin
Commander	F - 30	565	175	23.8	3.3	25.0	0.14	1.37	0.52	3.6	15.4	87.0
	F - 14	527	152	31.8	3.3	45.0	0.21	1.39	0.01	5.0	19.0	76.0
	F - 4	445	180	27.5	3.3	43.8	0.15	1.15	0.62	4.9	16.0	78.7
	ASAP	395	144	33.2	3.3	32.5	0.23	1.00	0.04	8.2	21.1	70.9
	R + 1	416	137	30.0	3.3	20.0	0.22	0.82	0.09	5.7	13.4	80.6
	R + 12	455	154	17.5	3.3	21.9	0.11	1.31	0.76	10.1	32.8	56.6
Command Module Pilot	F - 30	440	172	30.8	12.5	35.0	0.175	1.38	0.49	8.0	22.0	70.0
	F - 14	505	189	33.8	12.5	32.5	0.175	1.58	--	7.3	20.7	71.8
	F - 4	350	158	33.8	15.6	35.0	0.214	1.25	0.22	4.9	18.3	76.7
	ASAP	390	140	17.5	15.0	17.5	0.125	1.25	0.05	11.4	33.1	54.1
	R + 1	387	149	36.3	15.7	27.5	0.244	0.87	0.07	13.1	19.4	66.3
	R + 12	510	168	32.0	12.7	53.8	0.190	1.40	0.16	11.4	18.8	69.8
Lunar Module Pilot	F - 30	925	223	29.5	5.0	43.3	0.13	1.77	0.72	10.0	28.8	61.1
	F - 14	645	224	32.0	7.5	79.3	0.14	1.86	--	10.5	29.5	59.9
	F - 4	553	226	43.8	9.5	79.3	0.19	1.64	0.08	5.2	31.0	62.7
	ASAP	735	163	55.0	37.5	79.3	0.33	0.97	0.06	4.6	33.9	61.2
	R + 1	535	186	33.3	7.5	67.0	0.17	1.25	0.02	4.5	33.2	61.9
	R + 12	590	198	38.3	7.5	34.5	0.19	1.71	1.30	6.0	24.0	69.7

TABLE 13-XIV.- RED BLOOD CELL LIPIDS

Subject	Date	Total lipids, mg%	Cholesterol, mg%	Vitamin E, mg%	Lysolecithin	Sphingomyelin phospholipids	Lecithin	Phosphatidyl-ethanolamine
Commander	F - 30	4.57	0.533	0.19	12.5	28.5	30.0	28.8
	F - 14	4.72	0.874	0.43	4.6	37.3	34.1	23.6
	F - 4	3.60	0.881	0.38	12.3	43.9	33.3	10.5
	ASAP	6.23	0.752	0.27	9.3	43.7	28.1	18.7
	R + 1	3.82	0.758	0.24	8.3	45.0	31.6	15.0
	R + 12	5.67	0.808	0.28	12.3	35.1	33.3	19.3
Command Module Pilot	F - 30	4.00	0.712	0.22	13.8	20.7	35.6	29.3
	F - 14	4.29	1.05	0.82	11.3	34.0	39.7	14.3
	F - 4	3.89	1.00	0.39	13.0	29.5	36.6	18.9
	ASAP	4.03	0.98	0.27	11.8	28.7	31.6	27.8
	R + 1	4.24	1.10	0.16	10.0	30.7	30.7	27.8
	R + 12	5.40	1.10	0.43	13.7	30.2	31.7	23.8
Lunar Module Pilot	F - 30	--	0.845	0.24	2.2	30.4	32.6	34.7
	F - 14	4.97	1.2	0.36	4.5	29.5	38.6	27.2
	F - 4	3.76	0.977	0.41	2.4	31.6	38.9	26.2
	ASAP	4.67	0.994	0.37	6.0	31.6	38.7	23.6
	R + 1	4.32	1.06	0.23	6.1	29.2	38.1	26.4
	R + 12	5.10	0.830	0.36	8.1	33.6	36.0	22.0

TABLE 13-XV.- URINE CHEMISTRY

Subject	Date	24-Hour volume, ml	Specific gravity	Total protein,	Total Hydroxyproline	Creatinine	Uric acid	Inorganic PO_4	Na	K	Ca	Mg	Cl_2	Osmosity, milliosmols
Commander	F-10	1720	1.016	<10.0	37.5	172.0	77.4	61.9	95.5	92.0	90.3	73.3	77.4	580.1
	F-5	2030	1.009	<10.0	43.0	125.9	52.8	60.9	104.5	63.9	68.0	53.2	97.4	346.8
	ASAP	1520	1.019	<10.0	64.0	197.6	71.4	100.3	49.0	51.0	41.0	40.0	38.0	737.6
	R+6	2625	1.009	—	66.2	141.7	44.6	86.6	106.88	76.1	78.7	68.0	102.9	386.0
Command Module Pilot	F-10	1220	1.024	10.0	40.7	190.3	57.3	104.9	126.9	82.4	61.0	80.0	123.2	915.9
	F-5	750	1.027	10.0	35.3	210.0	45.7	66.0	116.6	52.9	60.0	88.6	98.2	936.2
	ASAP	1200	1.032	10.0	51.2	254.4	116.4	153.0	112.0	74.0	44.0	73.0	86.0	1199.8
	R+6	740	1.018	10.0	19.5	115.4	35.5	40.0	107.3	34.04	40.0	36.4	118.4	775.0
Lunar Module Pilot	F-10	DATA NOT AVAILABLE												
	F-5													
	ASAP													
	R+6													

TABLE 13-XVI.- HYDROCORTISONE CONTENT IN PLASMA AND URINE

Subject	Date	Plasma hydorcortisone[1], µg/100ml	Urine hydrocortisone[2]	
			µg/liter	µg/24 hours
Commander	F - 30	14.1	-	-
	F - 14	9.9	33	40
	F - 5	12.7	31	62
	ASAP	6.5	86	131
	R + 1	11.8	-	-
	R + 6	10.8	24	63
Command Module Pilot	F - 30	16.6	-	-
	F - 14	12.2	79	136
	F - 5	18.8	69	52
	ASAP	6.9	152	182
	R + 1	10.9	-	-
	R + 6	14.5	68	50
Lunar Module Pilot	F - 30	12.8	-	-
	F - 14	14.5	38	49
	F - 5	19.3	92	100
	ASAP	5.0	142	34
	R + 1	15.4	-	-
	R + 6	11.5	45	86

[1]Plasma hydrocortisone normal range is 10 to 20 µg/100ml.

[2]Urine hydorcortisone normal range is 20 to 100 µg/24 hours.

TABLE 13-XVII.- CATECHOLAMINE

Subject	Date	Catecholamine, mg/liter of urine		
		Total	Epinephrine	Norepinephrine
Commander	F - 14	17.5	4.0	13.5
	F - 5	21.7	4.6	17.1
	ASAP	16.4	4.8	11.6
	R + 6	15.5	4.0	11.5
Command Module Pilot	F - 14	25.2	5.6	19.6
	F - 5	21.6	4.2	17.4
	ASAP	62.3	16.6	45.7
	R + 6	29.1	6.3	22.8
Lunar Module Pilot	F - 14	23.8	4.0	19.8
	F - 5	15.0	3.3	11.7
	ASAP	40.5	8.2	32.3
	R + 6	18.7	6.0	12.7

14.0 SUMMARY

The three-crewman Apollo 8 mission logged a total of 447 man-hours of space flight experience, during a 6.1-day lunar orbital flight.

The three primary medical objectives, namely, to insure crew safety from a medical standpoint, to provide medical information necessary for mission management, and to advance understanding of biomedical changes incident to space flight, were met.

Problem areas included the presence of a high nickel concentration in the spacecraft hot water system, a chlorine leak during an inflight chlorination, and mild motion sickness which was experienced by all members of the crew. In addition to motion sickness, the CDR experienced an inflight illness of unknown etiology.

Overall performance of the modified bioinstrumentation system was good, with the exception of the decreased quality of the LMP's sternal ECG signal, which dropped at approximately 115 hours. A loose connection of the biosensor to the skin was probably responsible and postflight examination of the bioharness failed to demonstrate any impairment. None of these anomalies seriously compromised the mission or crew safety.

Postflight medical examinations showed that all crewmen were moderately fatigued and demonstrated slight cardiovascular deconditioning.

Both corrective and preventive measures, where possible, will be instituted for the Apollo 9 mission.

APPENDIX

CHRONOLOGY OF APOLLO 8 MEDICAL EVENTS

Time, hr:min	Event
00:00	Lift-off was at 12:51:01 G.m.t.
00:05	Maximum heart rate (HR) on the Commander (CDR) was 130 beats/min.
00:08	The CDR reported a slight longitudinal oscillation which was dampened out approximately 30 seconds later.
01:30	Biomedical telemetry switch changed from the CDR to the Command Module Pilot (CMP). CMP HR was 72 beats/min.
01:55	The Lunar Module Pilot (LMP) reported inadvertent inflation of one side of the CMP's May West.
02:10	CDR called the Mission Control Center (MCC) and identified himself initially as "Gemini VII"; however, he corrected himself immediately.
02:26	The Flight Director gave go for Translunar Injection (TLI).
02:36	Cabin oxygen regulator began operation at 4.8 psia.
02:49	The biomedical telemetry switch was in the LMP position instead of the CDR position.
02:50	The S-IV B TLI burn. The burn duration was 5 min 15 sec and the burn acceleration was approximately 1.5g.
02:53	Maximum LMP heart rate was 110 beats/min during TLI.
03:23	CSM/S-IV B separation completed.
04:53	The crew reported the initial personal radiation dosimeter (PRD) readings: CDR - 0.01 rem; CMP - 0.64 rem; LMP - 0.03 rem. Prelaunch background levels on the PRD's were 0 except for CMP-0.64 rem.
05:55	CDR reported window No. 5 was fogging up.

Time, hr:min	Event
06:16	The CMP began removing his pressure suit.
06:30	Biomedical telemetry received via the high gain antenna. The biomedical data quality remained excellent.
07:58	The waste management dump valve was closed - the cabin oxygen concentration estimated at approximately 75 percent.
08:50	Passive thermal control (PTC) roll rate reported at 450°/hr, i.e., (approximately 48 min/spacecraft revolution).
09:20	The CMP reported difficulty sighting stars through the sextant optics due to the brilliance of sunshine.
10:59	The MCC_1 burn performed. The burn duration was 2 sec. The LMP maximum HR was 122 beats/min during the burn.
11:30	Apollo 8 was outside the earth's magnetosphere. The maximum radiation received during traverse through the Van Allen Belt was approximately 10 millirem, i.e., approximately 1/20th the amount of a normal chest roentgenogram.
12:58	The Flight Surgeon gave permission to deflate the Mae West life preserver into the cabin.
13:13	The CDR requested permission from the Flight Surgeon to take 100-mg of Seconal for sleep. The Flight Surgeon approved. Five hours of a 7-hour CDR sleep period remained at this time.
14:40	The crew requested that radio silence be maintained in order to help the CDR go to sleep. The LMP gave the following report on the window fogging situation: windows nos. 1 and 5 had moderate haze, but were satisfactory for visual observation; window no. 3 was opaque: window nos. 2 and 4 were clear.
15:03	The biomedical telemetry switch was cycled from the CMP to the LMP position per Flight Surgeon request.
18:00	The scheduled biomedical switch change to the CDR position was deferred since the CDR's sleep period was extended by 1 hour.
18:50	Excellent quality biomedical data received on the CDR.
19:05	The CMP and LMP began their first sleep period.

Time hr:min	Event
19:34	The CDR gave a crew status report stating that he was behind on food and water consumption. The food tasted good but he was not very hungry. The CDR reported that he had 5 hours of fitful sleep.
21:45	The Flight Surgeon approved a 2-hour delay in the scheduled water chlorination in order to permit the CMP and LMP to obtain more sleep.
23:12	No MCC_2 was needed.
23:41	The CDR queried the MCC concerning thermal control of the cabin. The cabin temperature had ranged between 60° to 65° F.
24:43	The CDR queried the MCC about tape dumps and in particular the voice quality.
24:54	The CMP and LMP were awake and reported that they could not sleep any longer. Each estimated less than 5 hours of sleep.
25:12	The LMP reported that MCC should look at the voice tape dump and check it for voice quality.
27:35	The voice tape dump from Madrid was played back and contained the following query: "We have some sort of medical problem here that could be serious and want to ask your advice. The CDR has loose bowels and has thrown up twice, and feels nauseated and sore throat. The LMP is feeling sort of medium so-so. The CMP is fine. We would like instructions on whether to take medication of some kind and want to advise you of the situation." The preceding events occurred 7 to 8 hours prior to being received at MCC.
28:15	The Flight Surgeon had a private air-to-ground conversation with the Apollo 8 flight crew. This conversation provided the following information: a. All crewmen had some nausea and/or uneasy feeling in the "stomach" when they got out of their couches. b. At approximately 19 to 20 g.e.t., the CDR vomited twice, passed one soft stool, developed a headache, and possibly had had a slight fever. c. The CMP and LMP both had taken one Lomotil tablet prophylactically.

Time, hr:min	Event
	d. The LMP had taken one Marezine tablet to combat his nausea.
	e. All crewmen were feeling well at this time and were not experiencing any further symptomotology. The CDR also verified that he did not have a fever.
	The Flight Surgeon recommended that the CDR take one Lomotil tablet now and Marezine if any nausea should return.
31:03	Biomedical telemetry switch was changed to the CMP position.
31:05	The first Apollo 8 television pass - the crew presented inside views of the spacecraft.
31:40	The CDR reported that the first water chlorination was completed. He also stated that the CMP had 4 hours of sleep and the LMP had 3 hours. The CDR requested that more frequent sleep periods of shorter duration be considered to help reduce the accrued sleep deficit. The Flight Surgeon concurred with that proposal.
32:00	The CDR was still awake and communicating 2 hours into his second scheduled sleep period.
32:45	The LMP requested permission to take 50-mg Seconal for sleep induction. The Flight Surgeon approved Seconal and advised the CDR that we would like his current oral temperature.
33:34	The CDR reported his temperature at 97.5° F, i.e., no change since earlier this morning. He also reported that the CMP and LMP were beginning their sleep periods.
34:12	The present plan for readjusting the crew sleep periods was as follows:
	a. The CDR would stand the watch presently and go to sleep at approximately 37 hrs g.e.t.
	b. The LMP would begin his sleep period at 34:30 g.e.t. and would continue until 40 hrs.
	c. The CMP would terminate his sleep period at 36 hrs. g.e.t.
35:30	The CMP was awake again and ready to work.

Time, hr:min	Event
36:10	The Flight Surgeon recommended that the CDR take another Lomotil tablet at this time. The CDR replied, "Thank you."
37:23	The CDR was still communicating.
38:46	The CDR was awake and communicated regarding the communications uplink.
41:59	The CDR reported everyone was a bit drowsy at this time.
42:45	The CDR stated that the cabin temperature was decreasing and getting a bit chilly; therefore, he requested that the environmental control people work on correcting the temperature problem.
42:53	The environmental control engineer recommended that the suit heat exchanger operating temperature be increased.
42:54	The Flight Director recommended deletion of the MCC_3.
43:09	The cabin temperature had increased from 60° to 68° F.
43:31	The CDR and CMP were awake at this time but dozing intermittenly. The LMP apparently remained asleep.
45:15	The LMP was awake now.
46:48	The CMP and LMP gave the following crew status report:
	a. The CDR was asleep and obtained 5 hours of fair sleep during his second sleep period.
	b. The LMP obtained 6 hours of fair sleep during his second sleep period.
	c. The CMP obtained 4 hours of fair sleep during his second sleep period.
	d. All crewmen were feeling better now and had experienced no additional medical problems.
	e. Water consumption had varied between 40 and 60 aliquots today.
	f. Meal 2, day 2 was consumed.

Time, hr:min	Event
49:19	All three crewmwn were awake and feeling fine. The CMP was going to resume sleep shortly.
50:10	The second water chlorination was completed.
50:55	The crew reported on the spacecraft window status as follows: Windows nos. 1 and 5 were cloudy; the hatch window was opaque, and windows nos. 2 and 4 were clear.
52:20	The LMP was resuming sleep at this time.
52:27	Per Flight Surgeon request, the personal radiation dosimeter readings on the three crewmen were reported as follows: CDR - 0.06 rem; CMP - 0.64 rem; LMP - 0.64 rem.
52:40	The biomed telemetry switch was changed to the CDR position.
52:55	The CDR gave a crew status report. He reported that everyone was feeling fine. The LMP had taken one Marezine tablet yesterday as prescribed by the Flight Surgeon. No medication was taken since, except for the LMP's 50-mg Seconal tablet for sleep. All three crewmen had eaten breakfast (Meal A, day 3) and all planned to get more sleep prior to lunar orbit insertion (LOI) at 69 hrs. g.e.t.
55:05	The biomed telemetry switch was changed to the CMP position. The CMP reported that the earth's size was approximately as big as the end of his thumb. The second Apollo 8 TV pass began at this time. The TV picture quality was excellent.
57:27	The biomed telemetry switch was cycled to the LMP position. The LMP reported that the CDR and CMP were asleep now.
58:39	The radiation officer recommended that the CDR and LMP switch their personal radiation dosimeters in order to evaluate whether or not the disparity in readouts was due to an instrumentation error or a local hot spot in the spacecraft. The Flight Surgeon approved this recommendation and referred it to the Cap Comm for transmission to the crew.
60:21	The flight crew was busy preparing for the MCC_4 burn. This burn, performed by the SM RCS, was approximately 11 seconds in duration.

Time, hr:min	Event
60:59	The MCC_4 burn was performed at this time. The maximum heart rate observed on the CDR was 80 beats/min.
61:11	The CMP transmitted the crew status report previously delayed by the MCC_4 burn. He stated that everyone had eaten two meals today, A and B, and had consumed everything except the hard bites. The pudding was reported as outstanding. The CMP reported that the personal radiation dosimeters had been exchanged as follows: a. The CDR now had the LMP's dosimeter. b. The CMP now had the CDR's dosimeter. c. The LMP now had the CMP's dosimeter. The personal radiation dosimeter read-outs prior to switching at 60 hrs g.e.t. were the following: CDR - 0.07 rem; CMP - 0.64 rem; LMP - 0.80 rem. The crew water consumption for the day was also transmitted. The CDR had 25 oz, the CMP had 21-1/2 oz, and the LMP had 22 oz. Both the CDR and the CMP reported 2 hours of fair sleep.
61:54	The Flight Surgeon advised the Flight Director that all crewmen required more sleep prior to the LOI burn. At this point, the CDR and the LMP had logged only 2 hours of sleep and the CMP 4 hours. The Flight Director concurred and stated that following the flight plan update, radio silence would be maintained.
62:40	The CDR reported completing Meal C, day 3. He also reported that each crewman was going to take one more rest period prior to LOI. The Cap Comm rogered and stated that the MCC was recommending the same.
63:08	The CDR requested permission for the LMP to take 50-mg Seconal for sleep induction. The Flight Surgeon approved.
67:59	The MCC gave the go for LOI.
68:04	The Apollo 8 spacecraft was go for LOI.

Time, hr:sec	Event
68:36	The pre-LOI crew status report was deferred until after LOI.
68:54	MCC advised the crew that the LOI burn was predicted at 69:08:19.
68:58	The Apollo 8 spacecraft LOS due to disappearance of the spacecraft behind the Moon.
69:31	The Apollo 8 AOS was predicted at this time if the LOI burn was performed.
69:32	AOS confirmed; however, no voice contact. The LOI burn also was confirmed.
69:33	Voice contact was established with the CMP. The lunar orbit was 169.1 x 60.5 n. mi.
69:36	Crew stated that the LOI burn was nominal and on time.
69:51	The CMP reported that the Moon was gray in color and the terrain had a beach-like appearance.
70:04	The CDR reported that he was monitoring the spacecraft systems while the other crewmen were looking at the lunar surface.
70:21	Playback of the LOI biomed data on the CDR was received. His heart rate ranged from 90 to 120 beats/min.
71:40	First lunar real-time TV was transmitted to the MCC. Quality of the TV picture was excellent.
72:18	The MCC gave the go to Apollo 8 for the LOI_2 burn, i.e., circularization of the elliptical lunar orbit.
72:31	The biomedical telemetry switch was changed to the CDR position.
73:51	The new lunar orbit was 62 x 60.8 n. mi.
74:53	The CDR reported that the third water chlorination was performed at 73:23 hrs g.e.t. The LMP reported that the water smelled "Like a bucket of Clorox."
76:38	The biomedical telemetry switch was changed to the CMP position. The crew reported that they each got 2 hours of sleep prior to LOI.

Time, hr:min	Event
79:00	The crew reported the following personal radiation dosimeter readouts: CDR - N/A due to sleep cycle; CMP - 0.09 rem; LMP - 0.64 rem.
80:09	The crew reported that the area which they were over looked volcanic. They also stated that the backside of the Moon appeared to be a worse site for a lunar landing.
80:20	The CDR was still asleep.
81:45	The CDR was awake.
83:55	The CDR reported that he had 3 to 4 hours of sleep and that his current personal radiation dosimeter readout was 1.44 rem. This represents an approximate dosage rate of 28 millirem/hr.
84:31	The Flight Surgeon requested that the CDR cycle the biomed switch to his position.
	The CDR rogered and complied.
85:40	The second lunar TV pictures were transmitted to the MCC during the 9th revolution of the Moon. The TV picture quality remained excellent. Each crewman gave his impressions of the Moon. The CDR characterized it as a desolate place; the CMP as awesome; and the LMP as a vastness of black and white. The Apollo 8 crew transmitted their inspiring Christmas message to all the people on the "good Earth."
86:10	The TV transmission was terminated.
87:10	The final and 10th lunar revolution was initiated.
87:58	The Flight Surgeon gave the medical go for the Transearth Injection (TEI) burn.
88:03	The crew was given a go for the TEI burn.
88:30	A discussion with the radiation officer revealed that the personal radiation dosimeter readouts of 1.44 rem and 0.64 rem were suspect because the VABD indicates a skin dose of approximately 110 millirem and a depth dose of 90 millirem at the present time.

Time, hr:min	Event
88:47	All spacecraft systems remained go for the burn. The predicted burn time was 89:19:16 and the Aquisition of Signal (AOS) following the burn was 89:28:40. The TEI burn duration was 3 min, 18 sec.
89:34	The CMP reported that there was a Santa Claus, i.e., the TEI burn was nominal. The burn duration was 5 seconds longer than predicted; however, this would not have produced any operational problem. The CDR reported that the burn gave a sensation of climbing.
89:43	The high gain antenna locked on and the CDR biomed data were acquired. The initial heart rates ranged from 70 to 80 beats/min.
89:59	The MCC advised the CDR that time was available now for a well earned sleep period. The CDR rogered.
90:00	Real-time biomed data were interrupted to get the postpass TEI burn data on the CDR. The highest rate seen during the TEI burn was approximately 155 beats/min.
91:12	The CDR reported that the CMP and LMP got approximately 2 hours of sleep prior to the TEI preparation. He also stated that the crew planned to sleep in short periods until they tagged up with the nominal flight plan time line again. The LMP would assume the first watch while the CDR and CMP slept.
92:57	The LMP awoke momentarily and communicated. All crewmembers were either dozing or asleep.
94:59	The LMP requested that he be allowed to take 50-mg Seconal for sleep induction. The Flight Surgeon approved.
95:00	The crew gave another status report. They were feeling fine, and had eaten 2 hours ago. They also reported consuming a large amount of water. The CDR and CMP had about 4 hours of sleep during the last scheduled rest period.
95:05	The CDR was awake and assumed the watch.
95:22	The fourth chlorination of the Apollo potable water supply was confirmed by the CDR. The biomedical telemetry switch was cycled to the CDR position.

Time, Hr:min	Event
102:00	The LMP was awake.
102:22	All three crewmen were awake at this time.
103:00	The LMP gave his status report. He stated that he had 5-1/2 hours of good sleep and was feeling well. The LMP was on schedule for water and food intake. The LMP also reported the following personal radiation dosimeter readouts: a. CDR - 2.02 rem. b. CMP - 0.12 rem. c. LMP - 0.64 rem. The current VABD reading was 0.13 rad.
104:23	The crew transmitted another series of excellent quality TV pictures from within the Apollo 8 spacecraft. The CMP reported that the Christmas turkey dinner was excellent.
106:10	The MCC had received approximately 4 hours of continuous biomed data.
106:52	The CDR was awake now. He reported that he may have dozed off for about 1 hour.
107:00	Biomedical telemetry switch was cycled to the CDR position.
108:10	The CDR was asleep, according to the CMP. The LMP was now occupying the CDR's couch.
108:45	The CMP was doing the P-23 navigation update. He appeared to be tired as evidenced by the quality of his voice and the fact that he made an error in the P-23.
110:18	The LMP reported that the CDR was still asleep and that the CMP had just fallen asleep.
110:22	The Flight Surgeon recommended that the CMP's eat period at 111 hrs g.e.t. be deleted since the CMP was now asleep.
111:13	The LMP reported that the CDR was now awake and manning the helm.

Time, hr:min	Event
111:32	The LMP requested permission to take 50-mg Seconal for sleep induction. The Flight Surgeon approved. The CDR was asked for his latest sleep report and he transmitted that he had about 4 to 5 hours of sleep. The CMP was asleep at this time.
112:15	The MCC reviewed the entry check list with the CDR.
112:27	The CDR requested that the ground monitor the gimbal angles closely because he was becoming a little sleepy at this time.
112:48	The CDR reported several minor anomalies:
	a. The bootees for the CDR's overalls were badly frayed and have been removed.
	b. One Y-adapter had failed.
	c. The lightweight headsets were useless.
112:50	The CDR reported that the crew would stow their pressure garments under their couches per the vendor's recommendations; also, the helmets would be stowed in the empty food storage compartments. Any leftover food packages would be placed inside their pressure suits.
113:42	The spacecraft was in the auto-tracking mode, i.e., 30 minutes of biomedical data would be received out of every hour.
113:50	The CDR again requested that the ground monitor gimbal angles closely (probably because the CDR was very sleepy at this time).
113:59	The CDR's heart and respiratory rate pattern indicated that he was resting or perhaps even dozing at this time.
114:20	The CDR's heart rate was 58 beats/min. The Cap Comm gave the CDR a call for a null bias test on the EMS. The CDR's heart rate increased immediately to 75 beats/min. This response was very suggestive of light sleep.
115:36	The LMP awoke and assumed the watch in the left couch. The CMP remained asleep and the CDR would begin his sleep period shortly. The LMP's sternal EKG had deteriorated in quality. The baseline was shifting frequently and blocking the signal conditioner

Time, hr:min	Event
	output. However, the ZPN remained intact and excellent. The LMP was advised by the Flight Surgeon to check his sternal sensors and apply pressure to each. The LMP complied without any success.
116:24	The Flight Surgeon gave the Cap Comm a biomed harness troubleshooting procedure to transmit to the LMP. The LMP also reported a slight irritation of the upper sternal sensor area at this time.
117:20	Flight Surgeon queried the LMP per Cap Comm as to whether the biomed troubleshooting had been completed. The LMP stated that he had gone over all his sensors and could not find any anomalies. The Flight Surgeon's plan of action was to disconnect the blue sternal leads and the yellow axillary leads from their respective signal conditioners. The yellow axillary ZPN leads were then to be switched and connected to the blue EKG signal conditioner and the blue sternal EKG leads connected to the yellow impedance pneumogram signal conditioner. Implementation of this plan would result in an axillary EKG in lieu of the previous sternal EKG. A modified impedance signal would be received from the sternal leads. The LMP rogered and requested that we hold off with any more major fix for several hours.
117:45	The LMP performed the reconfiguration of the bioinstrumentation harness at this time. The axillary EKG was very clean and noise-free. Receipt of a good impedance signal also verified that a loose connection, either a biosensor or input lead connector was responsible for the degraded sternal EKG signal. In view of the excellent quality data since reconfiguration, and the fact that only 6 hours of LMP biomedical data remained to be obtained per the biomedical telemetry switching program, the decision to remain in the modified bioinstrumentation configuration was made by the Flight Surgeon.
120:53	The CDR gave a crew status report at this time. He reported that all crewmen had 7 hours of good sleep. He also stated that the water consumption had been adequate and that everyone was in good shape.
121:23	The fifth chlorination of the potable water system was performed at this time.
123:29	The LMP was reported as sleeping.

Time, hr:min	Event
124:14	Flight Surgeon requested the biomedical telemetry switch be changed to the CDR position; however, the CDR was involved with personal hygiene at this time and would switch as soon as he was back on line according to comments by the CMP.
124:45	Biomedical telemetry switch was cycled to the CDR position on request by the Flight Surgeon.
126:27	All crewmen were awake at this time.
127:16	The biomedical telemetry switch was changed to the LMP position.
127:45	The final TV from the Apollo 8 spacecraft was received at this time. The TV picture quality was excellent.
128:30	The LMP requested 50-mg Seconal for sleep. The Flight Surgeon approved the medication.
130:20	The CMP reported that everyone was tired or "pooped".
130:57	The CDR reported his personal radiation dosimeter read-out as 2.85 rem.
131:35	The CMP reported his personal radiation dosimeter reading as 0.15 rem.
132:19	The CMP was standing watch; the CDR and LMP were asleep.
133:07	The LMP awoke and assumed the watch at the helm. He reported his personal radiation dosimeter read-out as still being 0.64 rem. The CMP reported beginning his sleep period.
133:13	The LMP reported that he had 3 hours of sleep during his previous sleep period.
136:02	The CDR was now awake and assumed the watch.
138:00	The CDR was dozing on and off.
139:22	The CMP was awake now. The LMP remained on watch in the left couch.
139:32	The secondary SM RCS was activated. The noisy cabin analyzer was also taken off line at this time.

Time, hr:min	Event
140:28	The CDR awoke and assumed the watch at this time. The Flight Surgeon requested that a crew status report on the crew was required at this time.
140:38	The CDR reported that everyone had obtained "real good rest last night." Everyone was in good shape. The CMP was just awakening at this time and the LMP was beginning the initial cabin stowage. The Cap Comm also passed up the request for the final personal radiation dosimeter read-outs at approximately 145 hrs g.e.t.
141:41	The recovery zone weather was passed up to the spacecraft.
141:47	The final personal radiation dosimeter read-outs were given by the crew at this time because stowage had been completed early: CDR - 3.10 rem; CMP - 0.17 rem; LMP - 0.64 rem.
	The spacecraft altitude at final readouts was 37 075 n.mi. The CDR also reported the crew's estimate of their sleep: CDR - 5 or 6 hrs; CMP - 5 hrs; and LMP - 5 hrs.
143:39	The Cap Comm passed up the entry path data to the crew.
143:42	The cabin temperature was decreased prior to entry - decreased from 77° to 70° F over the past 3 hours. The maximum predicted g load during entry was approximately 6.5 g.
143:59	A 50 percent drop in the potable water quantity was noted during the last few minutes; i.e., a decrease of approximately 18 pounds. The environmental control engineer suspected that the water quantity transducer had failed.
145:11	The Flight Surgeon reminded the crew that Marezine tablets should be taken now, per their option, if the maximum post-landing effect was desired. The cabin temperature was now 68° F.
146:01	The cabin temperature now was 62° F.
146:14	The entry batteries were activated.
146:27	The MCC gave the spacecraft go for pyro arm. The cabin temperature was 61° F.
146:29	CM/SM separation: The maximum observed heart rate on the CDR during separation was 132 beats/min.

Time, hr:min	Event
146:34	All recovery aircraft reported on station. Entry battery life was estimated at 81 hours on the water.
146:45	Entry velocity was now 36 000 ft/sec.
146:46	The Apollo 8 spacecraft entered blackout. The last observed heart rate on the CDR was 110 beats/min.
146:47	The Apollo 8 spacecraft was right on target.
146:51	Radio contact with Apollo 8 established through the Aria aircraft.
146:52	The USS Yorktown had radar contact with the spacecraft at 190 n. mi.
146:58	The Apollo 8 spacecraft passed over the USS Yorktown. Splashdown was 2.5 n. mi. from the ship.
147:08	The Apollo 8 flight crew gave their status as excellent. The swimmers would be deployed from the recovery helicopters as soon as sunrise occurred.

G.m.t., hr:min	Event
16:35	The first swimmer was deployed.
16:37	The spacecraft sea anchor was deployed.
16:40	All rescue swimmers were in the water.
16:45	The flotation collar was secured around the spacecraft.
16:53	Two liferafts were deployed.
17:38	The spacecraft hatch was opened.
17:05	The CDR egressed the spacecraft.
17:05	The CMP egressed the spacecraft and was in the liferaft.
17:06	The LMP egressed the spacecraft and was in the liferaft.

G.m.t., hr:min	Event
17:09	All astronauts were in the second liferaft.
17:10	The CDR was aboard the rescue helicopter.
17:12	The CMP was aboard the rescue helicopter.
17:14	The LMP was aboard the rescue helicopter.
17:20	Rescue helicopter landed on the USS Yorktown.

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