25. MAN'S RESPONSE TO LONG-DURATION FLIGHT IN THE GEMINI SPACECRAFT

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Summary

The biomedical data from the Gemini III through VII missions support the conclusion that man is able to function physiologically and psychologically in space and readapt to the earth's 1-g environment without any undue symptomatology. It also appears that man's response can be projected into the future to allow 30-day exposures in larger spacecraft.

Introduction

When contemplating such titles as "4 Days in June," "8 Days in August," and "14 Days in December," it is difficult to realize that just 2 years ago, only an uncertain answer could be given to the question, "Can man's physiology sustain his performance of useful work in space?" This is particularly true on this great day for space medicine when man has equaled the machine.

Prior to our first manned space flight, many people expressed legitimate concern about man's possible response to the space-flight environment. This concern was based upon information obtained from aircraft experience and from conjecture about the effects of man's exposure to the particular environmental variables known to exist at that time. Some of the predicted effects were anorexia, nausea, disorientation, sleeplessness, fatigue, restlessness, euphoria, hallucinations, decreased g-tolerance, gastrointestinal disturbance, urinary retention, diuresis, muscular incoordination, muscle atrophy, and demineralization of bones. It will be noted that many of these are contradictory.

This Nation's first probing of the space environment was made in the Mercury spacecraft which reached mission durations of 34 hours. The actual situation following the completion of the Mercury program may be summarized as follows:

No problem: Launch and reentry acceleration, spacecraft control, psychomotor performance, eating and drinking, orientation, and urination.

Remaining problems: Defecation, sleep, and orthostatic hypotension.

This first encounter with the weightless environment had provided encouragement about man's future in space, but the finding of orthostatic hypotension also warned that there might be some limit to man's exposure. The reported Russian experiences strengthened this possibility. No serious gross effects of simple exposure to the space-flight environment had been noted, but the first hint was given that the emphasis should shift to careful methods for observing more subtle changes. These findings influenced the planning for the Gemini mission durations, and the original plan was modified to include a three-revolution checkout flight, followed by an orderly approximate doubling of man's exposure on the 4-day, 8-day, and 14-day missions which have been completed. It was felt that such doubling was biologically sound and safe, and this has proved to be the case. The U.S. manned space-flight missions are summarized in table 25-I.

This plan required the use of data procured from one mission for predicting the safety of man's exposure on a mission twice as long.

Medical Operational Support

The Gemini mission operations are complex and require teamwork in the medical area, as in all others. Space-flight medical operations have consisted, in part, of the early collection of baseline medical data which was started at

TABLE 25–I.—*U.S. Manned Space Flights*

Astronauts	Launch dates	Duration, hr: min
Shepard_____	May 5, 1961	00:15
Grissom_____	July 21, 1961	00:15
Glenn_____	Feb. 20, 1962	4:56
Carpenter_____	May 24, 1962	4:56
Schirra_____	Oct. 3, 1962	9:14
Cooper_____	May 15, 1963	34:20
Grissom_____ Young_____	}Mar. 3, 1965	4:52
McDivitt_____ White_____	}June 3, 1965	96:56
Cooper_____ Conrad_____	}Aug. 21, 1965	190:56
Borman_____ Lovell_____	}Dec. 4, 1965	330:35
Schirra_____ Stafford_____	}Dec. 15, 1965	25:21

the time of the original selection of the astronauts and which has been added to with each exposure to the simulated space-flight environment during spacecraft testing. Physicians and paramedical personnel have been trained to become a part of medical recovery teams stationed in the launch area and at probable recovery points in the Atlantic and Pacific Oceans. Flight surgeons have been trained and utilized as medical monitors at the various network stations around the world, thus making possible frequent analysis of the medical information obtained in flight. A team of Department of Defense physician-specialists has also been utilized to assist in the detailed preflight and postflight evaluations of the condition of the flight crews. Without the dedicated help of all of these personnel functioning as a team, the conduct of these missions would not have been possible (fig. 25–1).

A high set of standards has been adhered to in selecting flight crews. This has paid off very well in the safety record obtained thus far. The difficult role that these flight crews must play,
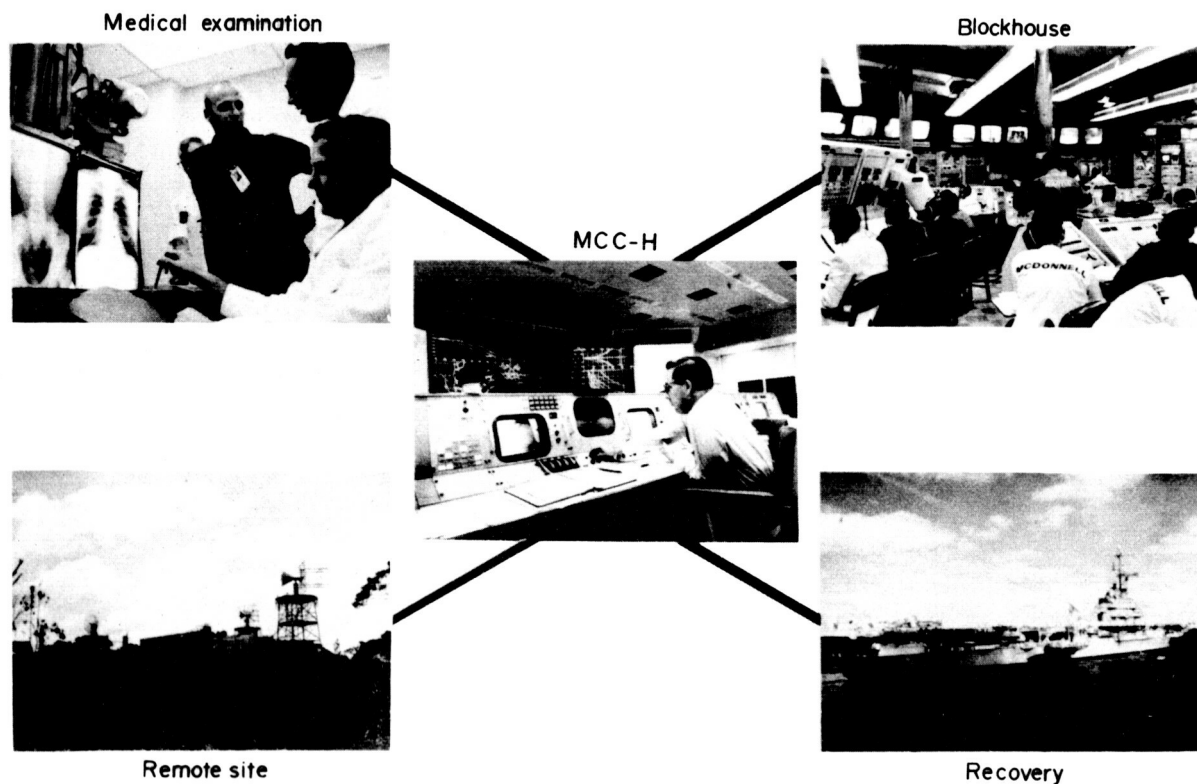

FIGURE 25–1.—Medical operational support.

both as experimenters and as subjects, deserves comment. From a personal point of view, the simpler task is to be the experimenter, utilizing various pieces of equipment in making observations. On these long-duration missions, the crews have also served as subjects for medical observations, and this requires maximum cooperation which was evidenced on these flights.

Data Sources

Physiological information on the flight crews has been obtained by monitoring voice transmissions; two leads of the electrocardiogram, a sternal and an axillary; respiration by means of an impedance pneumograph; body temperature by means of an oral thermistor; and blood pressure. These items make up the operational instrumentation, and, in addition, other items of bioinstrumentation are utilized in the experiments program. Also, some inflight film footage has been utilized, particularly during the extravehicular exercise on the 4-day mission. The biosensor harness and signal conditioners are shown in figure 25-2. A sample of the telemetered data, as received at the Mission Control Center, is shown in figure 25-3. These data were taken near the end of the 8-day flight, and it can be seen that the quality is still excellent. The Gemini network is set up to provide real-time remoting of medical data from the land sites to the surgeon at the Mission Control
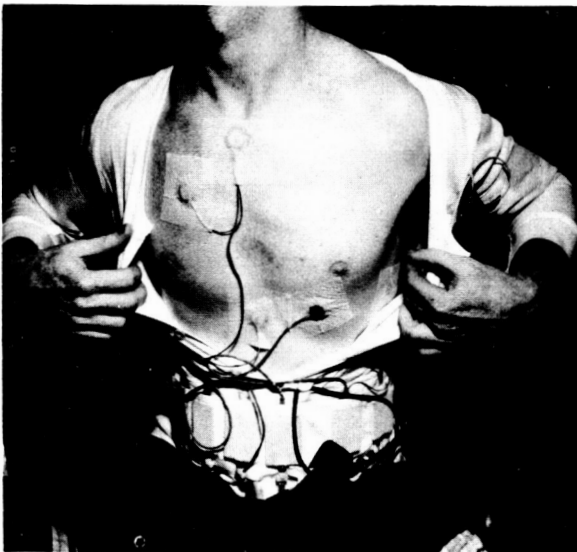

FIGURE 25-2.—Biosensor harness and signal conditioners.

Center. If requested, the medical data from the ships can be transmitted immediately after each spacecraft pass. The combined Gemini VI-A and VII mission posed a new problem in monitoring, in that it required the simultaneous monitoring of four men in orbit. The network was configured to do this task, and adequate data were received for evaluation of both crews.

It must be realized that this program has involved only small numbers of people in the flight crews. Thus, conclusions must be drawn from a minimum amount of data. Individual variability must be considered in the analysis of any data. Aid is provided in the Gemini Program by having two men exposed to the same conditions at the same time. Each man also serves as his own control, thus indicating the importance of the baseline data.

Preflight Disease Potential

As missions have become longer, the possibility of an illness during flight has become greater, particularly in the case of communicable diseases to which the crew may have been exposed prior to launch. The difficult work schedules and the stress imposed by the demands of the prelaunch period tend to create fatigue unless watched carefully, and thus become an additional potential for the development of flu-like diseases. They also preclude any strict isolation. On each of the Gemini missions a potential problem, such as viral upper respiratory infections or mumps exposure, has developed during the immediate preflight period, but the situation has been handled without hampering the actual mission. No illness has developed in the flight crews while in orbit. However, strenuous effort must be exerted toward protecting the crew from potential disease hazards during this critical period.

Denitrogenation

The 5-psia cabin pressure and the 3.7-psia inflated suit pressure create the potential for the development of dysbarism, and this was particularly true on the 4-day mission which involved extravehicular activity. Care has been taken to denitrogenate the crews with open-loop breathing of 100 percent oxygen for at least 2 hours prior to launch. No difficulty has been experienced with this procedure.
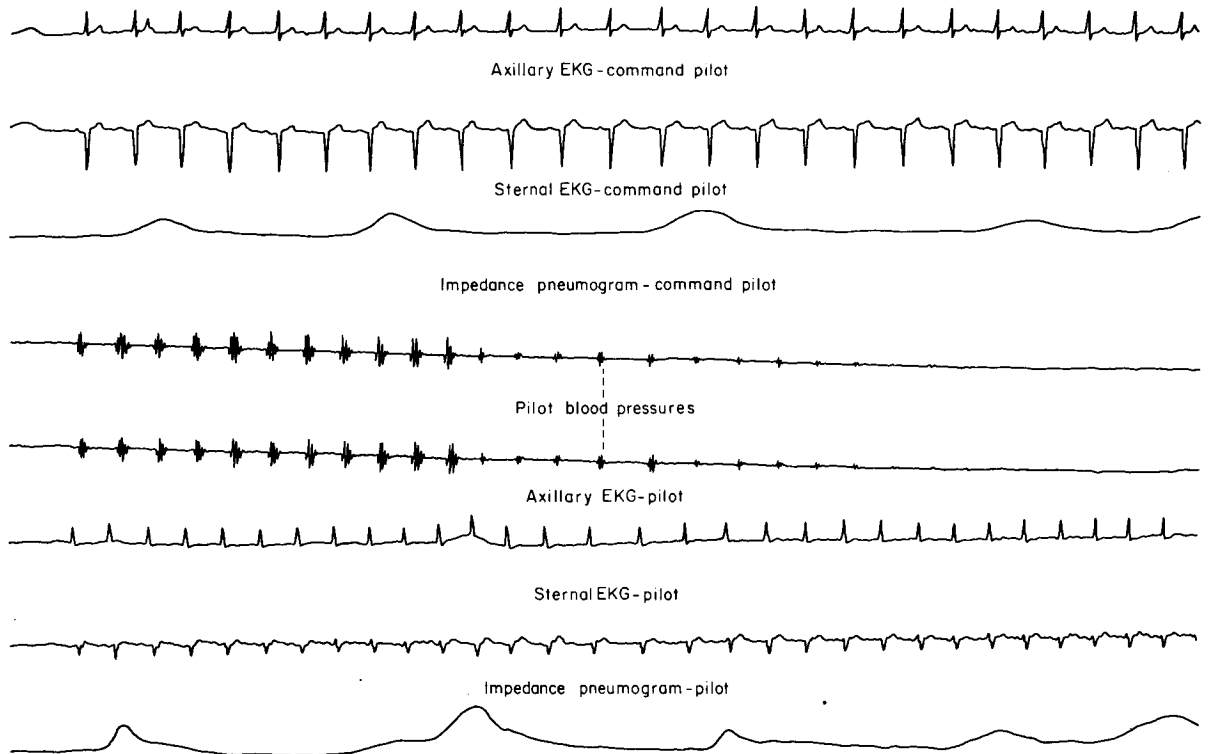
FIGURE 25–3.—Sample of biomedical data.

Preflight Exercise

The crews have used various forms of exercise to maintain a state of physical fitness in the preflight period. The peak of fitness attained has varied among the crewmembers, but they all have been in an excellent state of physical fitness. They have utilized running and various forms of activity in the crew-quarters gymnasium in order to maintain this state. Approximately 1 hour per day has been devoted to such activity.

Space-Flight Stresses

There has been a multiplicity of factors acting upon man in the space-flight environment. He is exposed to multiple stresses which may be summarized as: full pressure suit, confinement and restraint, 100 percent oxygen and 5-psia atmosphere, changing cabin pressure (launch and reentry), varying cabin and suit temperature, acceleration g-force, weightlessness, vibration, dehydration, flight-plan performance, sleep need, alertness need, changing illumination, and diminished food intake. Any one of these stresses will always be difficult to isolate. In

a sense, it could be said that this is of only limited interest, for the results always would represent the effects of man's exposure to the total space-flight environment. However, in attempting to examine the effects of a particular space-flight stress, such as weightlessness, it must be realized that the responses observed may indeed be complicated by other factors such as physical confinement, acceleration, dehydration, or the thermal environment.
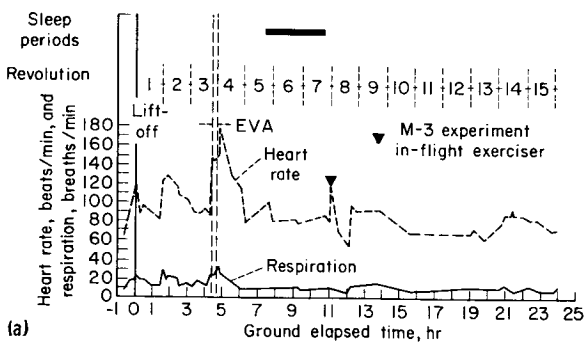
Heart Rate

On all missions, the peak elevations of heart rates have occurred at launch and reentry. The peak rates observed during the launch and reentry are shown in table 25–II. These detailed timeline plots of heart and respiratory rates demonstrate the peak responses associated with particular activities required by the flight plan, as was noted during the Mercury missions (fig. 25–4 (a) and (b)). As the mission durations have become longer, it has been necessary to compress the heart-rate data from the Gemini VII mission to the form shown in figure 25–5 (a) and (b). Such a plot demonstrates the di-
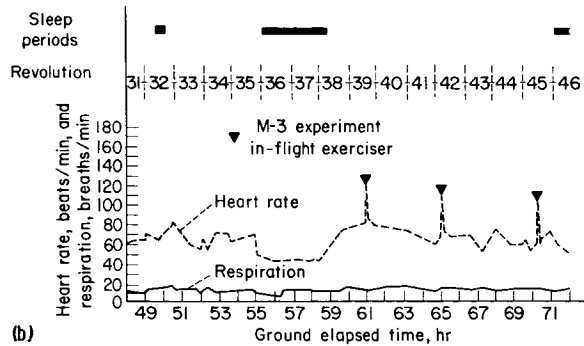
TABLE 25–II.—*Peak Heart Rates During Launch and Reentry*

Gemini mission	Peak rates during launch, beats per minute	Peak rates during reentry, beats per minute
III_____	152	165
	120	130
IV_____	148	140
	128	125
V_____	148	170
	155	178
VI–A_____	125	125
	150	140
VIII_____	152	180
	125	134

urnal cycles related to the nighttime and the normal sleep periods at Cape Kennedy, Fla. In general, it has been noted that there has been a decrease in the heart rate from the high levels at launch toward a rather stable, lower baseline rate during the midportion of the mission. This is altered at intervals since the heart has responded to demands of the inflight activities in a very normal manner throughout the mission. The rate appears to stabilize around the 36- to 48-hour period and remain at this lower level until two or three revolutions before retrofire. The anticipation and the activity associated with preparation for retrofire and reentry cause an increase in the heart rate for the remainder of the flight. The electrocardiogram has been very helpful in observing the response to the sleep periods when heart rates have frequently been observed in the forties and some in the high thirties. The graphing of such rates by mini-
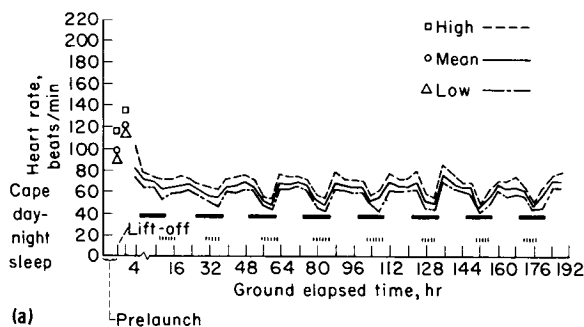

(b) From 48 to 72 hours ground elapsed time.
FIGURE 25–4.—Concluded.

mum, maximum, and mean has also been helpful in determining the quality of sleep. If the crewmen have awakened several times to check the condition of spacecraft controls and displays, there is a noted spread between the maximum and minimum rates.

During the extravehicular operation, both crewmen noted increased heart rates. The pilot had a heart rate of 140 beats per minute while standing in the open hatch, and this rate continued to climb during the extravehicular activity until it reached 178 beats per minute at spacecraft ingress. Future extravehicular operations will require careful attention to determine the length of time these elevated rates are sustained.

Electrocardiogram

The electrocardiogram has been observed on a real-time basis, with a series of detailed measurements being taken during the Gemini VII flight. The electrocardiogram has also been evaluated postflight, and the only abnormalities of note have been occasional, and very rare, pre-

(a) From lift-off to 24 hours ground elapsed time.
FIGURE 25–4.—Physiological measurements for Gemini IV pilot.

(a) From lift-off to 192 hours ground elapsed time.
FIGURE 25–5.—Physiological measurements for Gemini VII pilot.
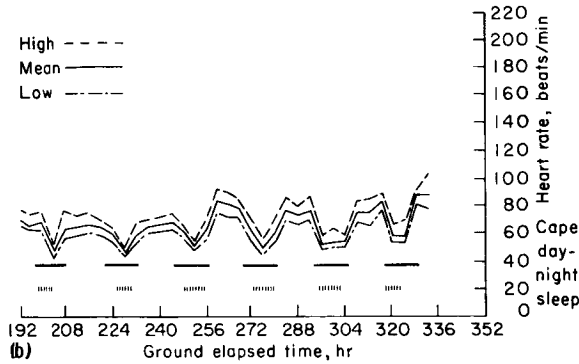
(b) From 192 to 352 hours ground elapsed time.
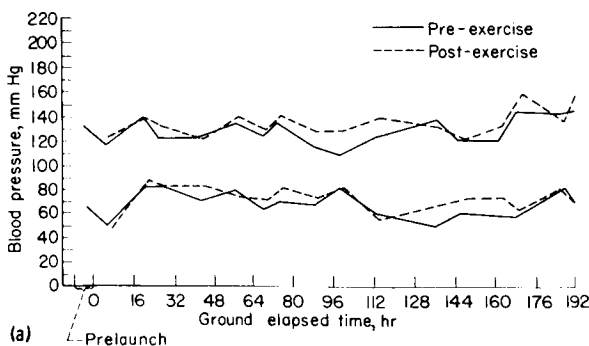FIGURE 25-5.—Concluded.

(b) From 192 to 384 hours ground elapsed time.
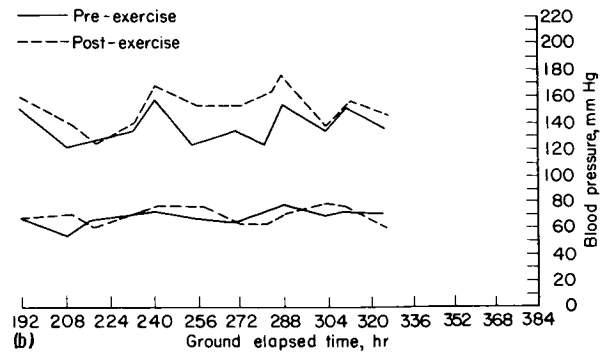FIGURE 25-6.—Concluded.

mature auricular and ventricular contractions. The detailed analyses have shown no significant changes in the duration of specific segments of the electrocardiogram which are not merely rate related. On each of the long-duration missions, a special experiment has involved observation of the relationship of the Q-wave to the onset of mechanical systole, as indicated by the phonocardiogram. These data, in general, have revealed no prolongation of this interval with an increase in the duration of space flight.

Blood Pressures

The blood pressure values were determined three times in each 24 hours during the 4- and 8-day missions, and two times each 24 hours on the 14-day mission. These determinations were made before and after exercise on the medical data passes. The only truly remarkable thing in all blood pressures to date has been the normalcy with a lack of significant increase or decrease with prolonged space flight (fig. 25-6 (a) and (b)). The blood pressures have varied

(a) From lift-off to 192 hours ground elapsed time.
FIGURE 25-6.—Blood pressure measurement.

with heart rate, as evidenced by the 201 over 90 blood pressure obtained after retrofire during one of the missions. This was accompanied by a heart rate of 160, however, and is felt to be entirely normal.

Some blood pressures of particular interest were those determined on the 4-day mission: (1) just after retrofire and while the crew was still in zero g; (2) just before the transition to two-point suspension on the main parachute, which places the crew at about a 45° back angle; (3) just after the transition to two-point suspension; and (4) with the spacecraft on the water and the crew in a sitting position. All of these pressures were in the same general range as the inflight blood pressures and were all certainly normal, demonstrating no evidence of hypotension.

Body Temperature

The oral thermistor was used with each medical data pass, and all body temperatures recorded have been within the normal range. Occasional spurious readings were noted on the oral thermistor when it got misplaced against the body, causing it to register.

Respiratory Rates

Respiratory rates during all of the long-duration missions have tended to vary normally along with heart rate. Hyperventilation has not occurred in flight.

Inflight Exercise

An exercise consisting of 30 pulls on a bungee cord has been utilized to evaluate cardiovascular response on all of these missions. No significant difference in the response to this

calibrated exercise load has been noted through the 14-day flight. In addition to these programed exercise response tests, the bungee cord has been utilized for additional exercise periods. Daily during the 14-day mission, the crew performed 10 minutes of exercise, including the use of the bungee cord for both the arms and the legs, and some isometric exercises. These 10-minute periods preceded each of the three eating periods.

Sleep

A great deal of difficulty was encountered in obtaining satisfactory sleep periods on the 4-day mission. Even though the flight plan was modified during the mission in order to allow extra time for sleep, it was apparent postflight that no long sleep period was obtained by either crewman. The longest consecutive sleep period appeared to be 4 hours, and the command pilot estimated that he did not get more than 7½ to 8 hours' good sleep in the entire 4 days. Factors contributing to this lack of sleep included: (1) the firing of the thrusters by the pilot who was awake; (2) the communications contacts, because the communications could not be completely turned off; and (3) the requirements of housekeeping and observing, which made it difficult to settle down to sleep. Also the responsibility felt by the crew tended to interfere with adequate sleep.

An attempt was made to remove a few of these variables on the 8-day mission and to program the sleep periods in conjunction with normal nighttime at Cape Kennedy. This required the command pilot to sleep from 6 p.m. until midnight eastern standard time, and the pilot to sleep from midnight until 6 a.m., each getting a 2-hour nap during the day. This program did not work out well due to flight-plan activities and the fact that the crew tended to retain their Cape Kennedy work-rest cycles with both crewmen falling asleep during the midnight to 6 a.m. Cape Kennedy nighttime period. The 8-day crew also commented that the spacecraft was so quiet that any communication or noise, such as removing items attached with Velcro, produced an arousal reaction.

On the 14-day flight, the flight plan was designed to allow the crew to sleep during hours which generally corresponded to nighttime at Cape Kennedy. There was a 10-hour period

established for this sleep (fig. 25-7), and it worked out very well with their normal schedule. In addition, both crewmen slept at the same time, thus obviating any arousal reactions from the actions of the other crewmember. The beginning of the scheduled rest and sleep period was altered to move it one-half hour earlier each night during the mission in order to allow the crew to be up and active throughout the series of passes across the southern United States. Neither crewman slept as soundly in orbit as he did on the earth, and this inflight observation was confirmed in the postflight debriefing. The pilot seemed to fall asleep more easily and could sleep more restfully than the command pilot. The command pilot felt that it was unnatural to sleep in a seated position, and he continued to awaken spontaneously during his sleep period and would monitor the cabin displays. He did become increasingly fatigued over a period of several days, then would sleep soundly and start his cycle of light, intermittent sleep to the point of fatigue all over again. The cabin was kept quite comfortable during the sleep periods by the use of the Polaroid screen and some foil from the food packs on the windows. The noise of the pneumatic pressure cuff for Experiment M-1 did interfere with sleep on both the 8- and 14-day missions. The crew of the 4-day flight were markedly fatigued following the mission. The 8-day crew were less so, and the 14-day crew the least fatigued of all. The 14-day crew did feel there was some irritability and loss of patience during the last 2 days of the mission, but they continued to be alert and sharp in their responses, and no evidence of performance decrement was noted.
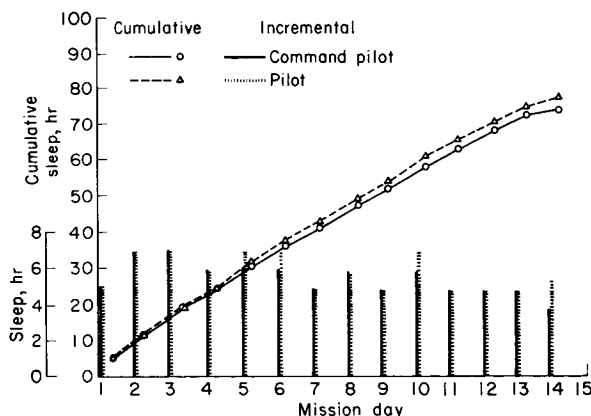

FIGURE 25-7.—Sleep data for Gemini VII flight crew.

Food

The diet has been controlled for a period of 5 to 7 days before flight and, in general, has been of a low residue. The Gemini VII crew were on a regulated calcium diet of a low-residue type for a period of 12 days before their 14-day mission. The inflight diet has consisted of freeze dehydrated and bite-size foods. A typical menu is shown in table 25–III. The crew are routinely tested with the inflight menu for a period of several days before final approval of the flight menu is given. On the 4-day flight, the crew were furnished a menu of 2500 calories per day to be eaten at a rate of four meals per day. They enjoyed the time that it took to prepare the food, and they ate all the food available for their use. They commented that they were hungry within 2 hours of ingesting a meal and that, within 4 hours after ingesting a meal, they felt a definite physiological need for the lift produced by food.

TABLE 25–III.—*Typical Gemini Menu*

[Days 2, 6, 10, and 14]

Meal A:	Calories
Grapefruit drink	83
Chicken and gravy	92
Beef sandwiches	268
Applesauce	165
Peanut cubes	297
	905
Meal B:	
Orange-grapefruit drink	83
Beef pot roast	119
Bacon and egg bites	206
Chocolate pudding	307
Strawberry cereal cubes	114
	829
Meal C:	
Potato soup	220
Shrimp cocktail	119
Date fruitcake	262
Orange drink	83
	684
Total calories	2418

These findings were in marked contrast to the 8-day mission where each crewmember was furnished three meals per day for a caloric value of 2750. Again these meals consisted of one juice, two rehydratable food items, and two bite-size items. The 8-day crew felt no real hunger, though they did feel a physiological lift from the ingestion of a meal. They ate very little of their bite-size food and subsisted principally on the rehydratable items. A post-flight review of the returned food revealed that the average caloric intake per day varied around 1000 calories for this crew. Approximately 2450 calories per day was prepared for the 14-day mission and including ample meals for 14⅔ days. Inflight and postflight analyses have revealed that this crew actually consumed about 2200 calories per day.

Water Intake

There has been an ample supply of potable water on all of these missions, consisting of approximately 6 pounds per man per day. Prior to the 4-day and 8-day missions, the water intake was estimated by calibrating a standard mouthful or gulp for each crewman; then, during the flight, the crew would report the water intake by such measurements. On the 4-day mission, the water intake was less than desired in the first 2 days of the mission but increased during the latter part of the flight, varying from 2.5 to 5.0 pounds in a 24-hour period. The crew were dehydrated in the postrecovery period. On the 8-day mission, the crew did much better on their water intake, averaging 5.2 to 5.8 pounds per 24 hours, and they returned in an adequately hydrated state.

For the 14-day mission, the water dispensing system was modified to include a mechanism whereby each activation of the water dispenser produced ½ ounce of water, and this activated a counter. The number of counts and the number of ounces of water were laboriously logged by the crew. It has been obvious that the crewmen must be reminded of their water intake, and when this is done they manage very well. The 14-day crew were well hydrated at the time of their recovery, and their daily water intake is presented in figure 25–8.

Waste Disposal

A urine collection device has been utilized on each of the Gemini missions and has been modified according to need and experience. On the 14-day flight, for the first time, the system permitted the collection of urine samples. Prior to this time, all of the urine was flushed overboard. The system shown in figure 25–9 al-
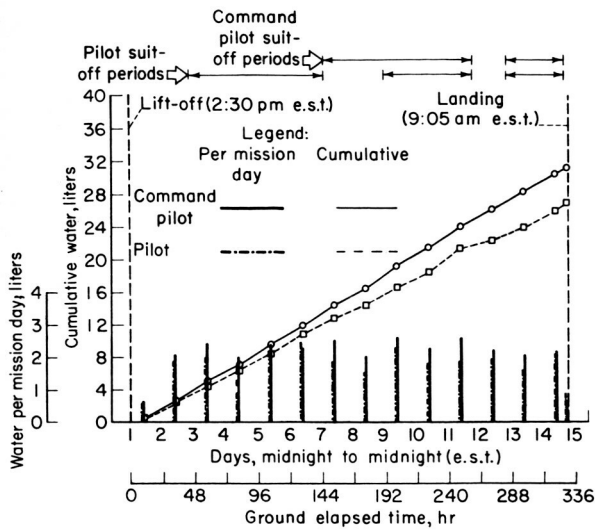
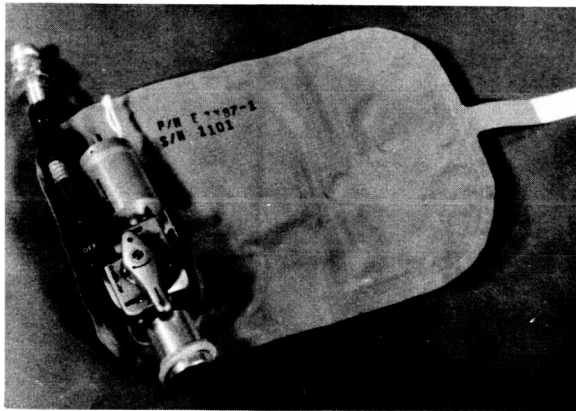FIGURE 25–8.—Water intake per day for Gemini VII flight crew.

FIGURE 25–9.—Urine collection device.

lowed for collection of a 75-cc sample and the dumping of the remainder of the urine overboard. The total urine volume could be obtained by the use of a tritium-dilution technique.
. The handling of fecal waste has been a bothersome inflight problem. Before the mission, the crews eat a low-residue diet, and, in addition, on the 8-day and 14-day missions, they have utilized oral and suppository Dulocolax for the last 2 days before flight. This has proved to be a very satisfactory method of preflight preparation. The fecal collection device is shown in figure 25–10.

The sticky surfaces of the bag opening can be positioned much easier if the crewman is out of the space suit, as occurred during the 14-day

flight. The system creates only a minimum amount of difficulty during inflight use and is an adequate method for the present missions. On the 14-day flight, the system worked very well and allowed the collection of all of the fecal specimens for use with the calcium-balance experiment.

Bowel habits have varied on each of the three long-duration missions, as might be expected. Figure 25–11 lists the defecations recorded for these three missions, and the longest inflight delay before defecation occurred was 6 days on the 14-day mission. The opportunity to measure urine volume on the 14-day flight has been of particular interest, as it had been anticipated a diuresis would occur early in the flight. Figure 25–12 shows the number of urinations per day and the urine volume as determined from the flowmeter utilized on the 14-day mission. The accuracy of these data will be compared with that from the tritium samples.
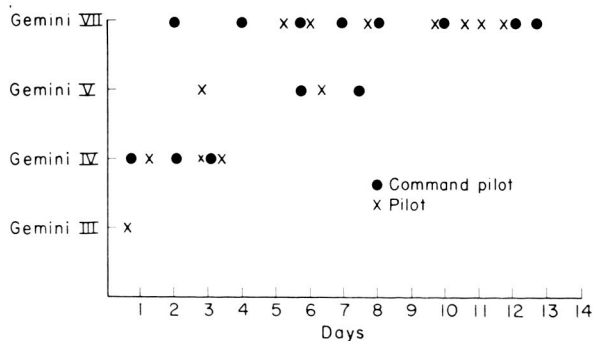

FIGURE 25–10.—Fecal bag.

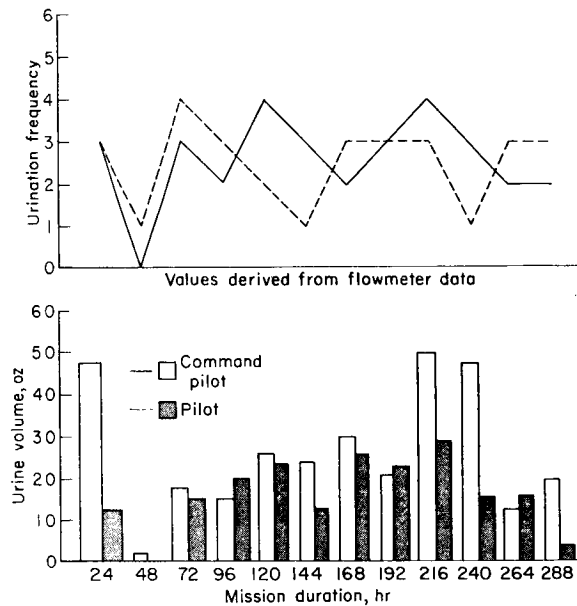FIGURE 25–11.—Inflight defecation frequency.

Medications

Medications in both injectable and tablet forms have been routinely provided on all flights. The basic policy has continued to be that a normal man is preferred and that drugs are used only if necessary. A list of the supplied drugs is shown in table 25–IV, and the medical kit is shown in figure 25–13. The injectors may be used through the suit, although to date none have been utilized. The only medication used thus far has been dexedrine, taken prior to reentry by the Gemini IV crew. The dexedrine was taken to insure an adequate state of alertness during this critical mission period. In spite of the minimal use of medications, they must be available on long-duration missions, and each crewmember must be pretested to any drug which may potentially be used. Such pretesting of all of the medications listed in table 25–IV has been carried out with each of the crews.

FIGURE 25–12.—Urine volume and urination frequency of Gemini VII flight crew.

TABLE 25–IV.—*Gemini VII Inflight Medical and Accessory Kits*

(a) Medical kit

Medication	Dose and form	Label	Quantity
Cyclizine HCl	50-mg tablets	Motion sickness	8
d-Amphetamine sulfate	5-mg tablets	Stimulant	8
APC (aspirin, phenacetin, and caffeine)	Tablets	APC	16
Meperidine HCl	100-mg tablets	Pain	4
Triprolidine HCl	2.5-mg tablets	} Decongestant	16
Pseudoephedrine HCl	60-mg tablets		
Diphenoxylate HCl	2.5-mg tablets	} Diarrhea	16
Atropine sulfate	0.25-mg tablets		
Tetracycline HCl	250-mg film-coated tablet	Antibiotic	16
Methylcellulose solution	15-cc in squeeze-dropper bottle	Eyedrops	1
Parenteral cyclizine	45-mg (0.9-cc in injector)	Motion sickness	2
Parenteral meperidine HCl	90-mg (0.9-cc in injector)	Pain	2

(b) Accessory kit

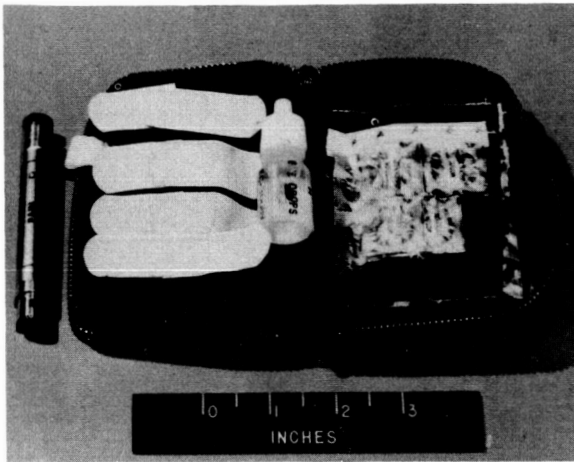| Item	Quantity
Skin cream (15-cc squeeze bottle)	2
Electrode paste (15-cc squeeze bottle)	1
Adhesive disks for sensors	12 for EKG, 3 for phonocardiogram leads
Adhesive tape	20 in.

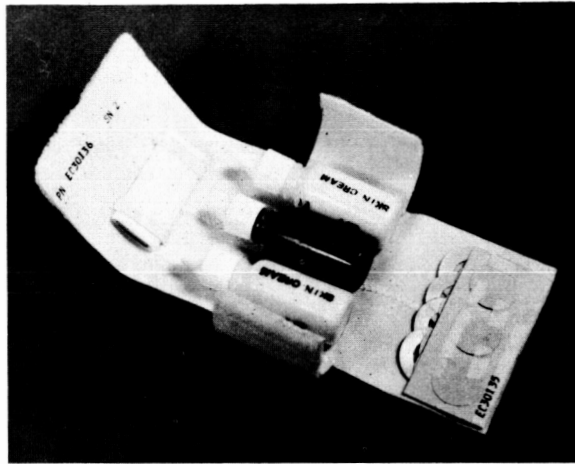FIGURE 25-13.—Medical kit carried onboard the spacecraft.

FIGURE 25-14.—Medical accessory kit carried onboard the spacecraft.

On the 14-day mission, a medical accessory kit, shown in figure 25-14, was carried to allow the reapplication of medical sensors should they be lost during the flight. The kit contained the sensor jelly, and the Stomaseal and Dermaseal tape for sensor application. In addition, the kit contained small plastic bottles filled with a skin lotion, which was a first-aid cream. During the 14-day mission, this cream was used by both crewmen to relieve the dryness of the nasal mucous membranes and was used occasionally on certain areas of the skin. During the mission, the lower sternal electrocardiogram sensor was replaced by both crewmen, and excellent data were obtained after replacement.

Psychology of Flight

Frequent questions are asked concerning the ability of the crewmembers to get along with one another for the long flight periods. Every effort is made to choose crewmembers who are compatible, but it is truly remarkable that none of the crews, including the long-duration crews, have had any inflight psychological difficulties that were evident to the ground monitors or that were discussed in postflight debriefings. They have had some normal concerns for the inherent risks of space flight. They were well prepared for the fact that 4, 8, and 14 days in space in such a confined environment as the Gemini spacecraft would not be an easy task. They had trained well, done everything humanly possible for themselves, and knew that everyone

connected with the program had done everything possible to assure their stay. There is some normal increased tension at lift-off and also prior to retrorocket firing. There was some normal psychological letdown when the Gemini VII crew saw the Gemini VI-A spacecraft depart after their rendezvous. However, the Gemini VII crew accepted this very well and immediately adjusted to the flight-plan activity.

A word should be said about overall crew performance from a medical point of view. The crews have performed in an exemplary manner during all flights. There has been no noted decrease in performance, and the fine control tasks such as reentry and, notably, the 11th-day rendezvous during the Gemini VII mission have been handled with excellent skill.

Additional Inflight Observations of Medical Importance

The crews have always been busy with flight-plan activity and have felt that their days were complete and full. The 14-day crew carried some books, occasionally read them in the pre-sleep period, and felt they were of value. Neither crewman completed a book. Music was provided over the high-frequency air-to-ground communications link to both the 8-day and the 14-day crews. They found this to be a welcome innovation in their flight-plan activity.

The crews have described a sensation of fullness in the head that occurred during the first 24 hours of the mission and then gradually disappeared. This feeling is similar to the increase of blood a person notes when hanging on parallel bars or when standing on his head. There was no pulsatile sensation in the head and no obvious reddening of the skin. The exact cause of this condition is unknown, but it may be related to an increase of blood in the chest area as a result of the readjustment of the circulation to the weightless state.

It should be emphasized that no crewmembers have had disorientation of any sort on any Gemini mission. The crews have adjusted very easily to the weightless environment and accepted readily the fact that objects will stay in position in midair or will float. There has been no difficulty in reaching various switches or other items in the spacecraft. They have moved their heads at will and have never noticed an aberrant sensation. They have always been oriented to the interior of the spacecraft and can orient themselves with relationship to the earth by rolling the spacecraft and finding the horizon through the window. During the extravehicular operation, the Gemini IV pilot oriented himself only by his relationship to the spacecraft during all of the maneuvers. He looked repeatedly at the sky and at the earth and had no sensations of disorientation or motion sickness at any time. The venting of hydrogen on the 8-day flight created some roll rates of the spacecraft that became of such magnitude that the crew preferred to cover the windows to stop the visual irritation of the rolling horizon. Covering the windows allowed them to wait for a longer period of time before having to damp the rates with thruster activity. At no time did they experience any disorientation. During the 14-day flight, the crew repeatedly moved their heads in various directions in order to try to create disorientation but to no avail. They also had tumble rates of 7° to 8° per second created by venting from the water boiler, and one time they performed a spin-dry maneuver to empty the water boiler, and this created roll rates of 10° per second. On both occasions they moved their heads freely and had no sensation of disorientation.

The crews of all three long-duration missions have noted an increased g-sensitivity at the time of retrofire and reentry. All the crews felt that they were experiencing several g when the g-meter was just beginning to register at reentry. However, when they reached the peak g-load, their sensations did not differ from their centrifuge experience.

Physical Examination

A series of physical examinations have been accomplished before each flight in order to determine the crewmembers' readiness for mission participation, and also after each flight to evaluate any possible changes in their physical condition. These examinations normally have been accomplished 8 to 10 days before launch, 2 days before launch, on launch morning, and immediately after the flight and have been concluded with daily observations for 5 to 10 days after recovery. These examinations thoroughly surveyed the various body systems. With the exception of items noted in this report, there have been no significant variations from the normal preflight baselines. The 14-day crew noted a heavy feeling in the arms and legs for several hours after recovery, and they related this to their return to a 1-g environment, at which time their limbs became sensitive to weight. In the zero-g condition, the crew had been aware of the ease in reaching switches and controls due to the lack of weight of the arms. The 8-day crew also reported some heaviness in the legs for several hours after landing. Both the 8-day and 14-day crews reported some muscle stiffness lasting for several days after recovery. This was particularly noted in the legs and was similar to the type of stiffness resulting from initial athletic activity after a long period of inactivity.

On all missions there has been minimum skin reaction surrounding sensor sites, and this local irritation has cleared rapidly. There have been a few small inclusion cysts near the sternal sensors. In preparing for the 8-day flight the crews bathed daily with hexachlorophene for approximately 10 days before the flight. In addition, the underwear was washed thoroughly in hexachlorophene, and attempts were made to keep it relatively free of bacteria until donning. The 14-day crew showered daily with a standard hexachlorophene-containing soap and also used Selsun shampoos for a 2-week period. Follow-

ing the 8-day and 14-day missions, the crewmembers' skin was in excellent condition. The 8-day flight crewmembers did have some dryness and scaling on the extremities and over the sensor sites, but, after using a skin lotion for several days, the condition cleared rapidly. The 14-day crewmembers' skin did not have any dryness and required no treatment postflight. After their flight, the 8-day crew had some marked dandruff and seborrheic lesions of the scalp which required treatment with Selsun for a period of time. The 14-day crew had virtually no dandruff in the postflight examination, nor was it a problem during flight.

The crew of the 14-day mission wore new lightweight space suits and, in addition, removed them for a portion of the flight. While significant physiological differences between the suited and unsuited crewman were difficult to determine, it was noted that the unsuited crewman exercised more vigorously, slept better, and had higher urine output because fluid was not being lost as perspiration. The excellent general condition of the crewmembers, particularly their skin condition, is to a large extent attributable to the unsuited operations.

Bacterial cultures were taken from each crewmember's throat and from several skin areas before and after the long-duration missions. The numbers of bacteria in the throat flora were reduced, and there was an increase in the fecal flora in the perineal areas. All fungal studies were negative. These revealed no significant difference in the complexity of the microflora. No significant transfer of organisms between crewmembers has been noted, and there has been no "locking in" of floral patterns through 14 days.

Postflight ear, nose, and throat examinations have consistently been negative, and caloric examinations before and after each flight have been normal. On each of the long-duration missions, the crews have reported nasal drying and stuffiness, and this has been evident by the nasal voice quality during voice communication with the surgeon at the Mission Control Center. This symptom has lasted varying amounts of time but has been most evident in the first few days of the mission. The negative postflight findings have been of interest in view of these inflight observations. The crews have reported

they found it necessary to clear their ears frequently in inflight. Some of this nasal and pharyngeal congestion has been noted in the long-duration space cabin simulator runs in a similar environment. It may be related to dryness, although the cabin humidity would not indicate this to be the case, or another cause might be the pure oxygen atmosphere in the cabin. It may also be related to a possible change in blood supply to the head and thorax as a result of circulatory adaptation to weightlessness.

The oral hygiene of the crewmembers has been checked closely before each flight and has been maintained inflight by the use of a dry toothbrush and a chewable dental gum. This technique provided excellent oral hygiene through the 14-day flight.

Weight

A postflight weight loss has been noted for each of the crewmembers; however, it has not increased with mission duration and has varied from 2.5 to 10 pounds. The majority of the loss has been replaced with fluid intake within the first 10 to 12 hours after landing. Table 25-V shows the weight loss and postflight gain recorded for the crewmen of the long-duration flights.

TABLE 25-V.—*Astronaut Weight Loss*

| Gemini mission	Command pilot weight loss, lb	Pilot weight loss, lb
III	3	3. 5
IV	4. 5	8. 5
V	7. 5	8. 5
VI-A	2. 5	8
VII	10	6

Hematology

Clinical laboratory hematologic studies have been conducted on all missions, and some interesting findings have been noted in the white-blood-cell counts. The changes are shown in figure 25-15 (a) and (b). It can be seen that on the 4-day flight there was a rather marked absolute increase in white blood cells, specifically neutrophiles, which returned to normal within 24 hours (though not shown in the figure). This finding was only minimally pres-

ent following the 8-day flight and was noted again following the 14-day flight. It very likely can be explained as the result of an epinephrine response. The red-cell counts show some post-flight reduction that tends to confirm the red-cell mass data to be discussed.

Urine and blood chemistry tests have been performed before and after each of the missions, and the results may be seen in tables 25–VI and 25–VII. The significant changes noted will be discussed in the experiments report.

Blood Volume

On each of the long-duration flights, plasma volume has been determined by the use of a technique utilizing radio-iodinated serum albumin. On the 4-day mission, the red-cell mass was calculated by utilizing the hematocrit determination. Analysis of the data caused some concern as to the validity of the hematocrit in view of the dehydration noted. The 4-day mission data showed a 7- and 15-percent decrease in the circulating blood volume for the two crewmembers, a 13-percent decrease in plasma volume, and an indication of a 12- and 13-percent decrease in red-cell mass, although it had not been directly measured. As a result of these findings, red cells were tagged with chromium 51 on the 8-day mission in order to get an accurate measurement of red-cell mass while continuing to utilize the radio-iodinated serum albumin technique for plasma volume. The
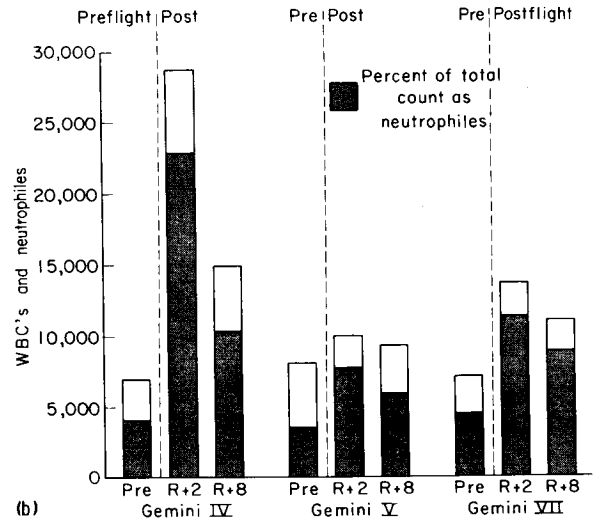
(b) Pilots.

FIGURE 25–15.—Concluded.

chromium-tagged red cells also provided a measure of red-cell survival time. At the completion of the 8-day mission, there was a 13-percent decrease in blood volume, a 4- to 8-percent decrease in plasma volume, and a 20-percent decrease in red-cell mass. These findings pointed to the possibility that the red-cell mass decrease might be incremental with the duration of exposure of the space-flight environment. The 14-day flight results show no change in the blood volume, a 4- and 15-percent increase in plasma volume, and a 7- and 19-percent decrease in red-cell mass for the two crewmembers. In addition to these findings, the red-cell survival time has been reduced. All of these results are summarized in figure 25–16. It can be concluded that the decrease in red-cell mass is not incremental with increased exposure to the space-flight environment. On the 14-day flight, the maintenance of total blood volume, by increasing plasma volume, and the weight loss noted indicated that some fluid loss occurred in the extracellular compartment but that the loss had been replaced by fluid intake after the flight. The detailed explanation of the decreased mass is unknown at the present time, and several factors, including the atmosphere, may be involved. This loss of red cells has not interfered with normal function and is generally equivalent to the blood withdrawn in a blood-bank donation, but the decrease occurs over a longer period of time, and this allows for adjustment.
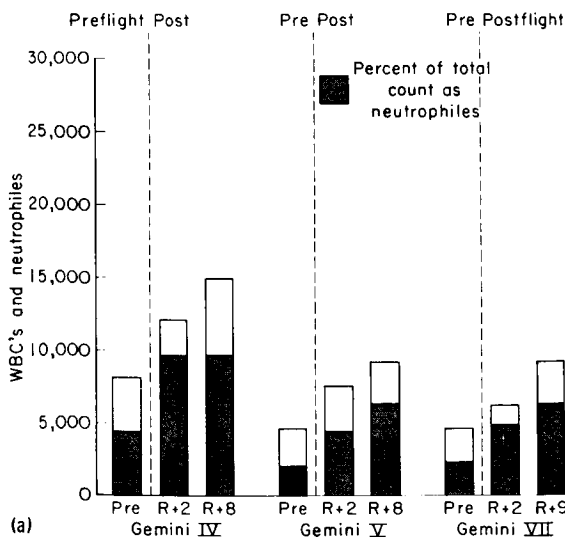
(a) Command pilots.

FIGURE 25–15.—White blood cell response.

TABLE 25–VI.—*Gemini VII Urine Chemistries*

[All dates 1965]

Determination	Command pilot Preflight Nov. 23 and Dec. 1	Command pilot Dec. 18 Measured	Percent of preflight	Command pilot Dec. 20 Measured	Percent of preflight	Command pilot Dec. 21 Measured	Percent of preflight	Pilot Preflight Nov. 23 and Dec. 1	Pilot Dec. 18 Measured	Percent of preflight	Pilot Dec. 20 Measured	Percent of preflight	Pilot Dec. 21 Measured	Percent of preflight
Sodium, meq/24 hr	143	95	66	182	127	150	105	150	76	51	94	63		
Potassium	71	118	166	93	131	90	127	70	60	86	89	127		
Chlorine	141	89	63	168	119	145	103	141	67	48	73	52		
Calcium, mg/24 hr	228	269	118	260	114	210	92	184	89	48	105	57		
Phosphate, mg/24 hr	1131	2133	188	936	83	978	86	1200	996	83	1345	112		
17-hydroxycorticosteriods	7.7	18.6	241	7.3	95	9.1	118	6.2	11.3	183	8.1	130	8.2	132
Epinephrine, µg/24 hr	7.8	16.4	210	(a)		(a)		10.2						
Norepinephrine	50.3	103.0	204	(a)		(a)		42.7						
Aldosterone, µg/24 hr	26	75	288			28	108	26	47	181			60	230
Creatine, mg/24 hr	2035	3297	162	1380	68	2070	102	2230	2003	90	2225	100		

a Not significant.

TABLE 25–VII.—*Gemini VII Blood Chemistry Studies for Command Pilot*

Determination	Preflight		Postflight			
	Nov. 24 and Nov. 25, 1965	Nov. 30 and Dec. 2, 1965	Dec. 18, 1965		Dec. 19, 1965	Dec. 20 and Dec. 21, 1965
			11:30 a.m., e.s.t.	6:20 p.m., e.s.t.		
Blood urea nitrogen, mg percent	19	16	16	20	25	18
Bilirubin, total mg percent	.4	.2	.3	----------	.3	.4
Alkaline phosphatase (B–L units)	1.7	2.0	1.7	----------	----------	----------
Sodium, meq/liter	147	146	138	140	144	143
Potassium, meq/liter	4.7	5.4	4.1	4.7	4.7	4.9
Chloride, meq/liter	103	103	100	102	103	106
Calcium, mg percent	9.0	9.2	8.6	9.2	9.0	9.2
Phosphate, mg percent	3.2	3.7	4.0	3.2	3.1	3.6
Glucose, mg/100 ml, nonfasting	71	90	98	----------	----------	----------
Albumen, g percent	4.6	4.73	5.16	----------	4.5	4.6
Alpha 1, g percent	.23	.26	.08	----------	----------	----------
Alpha 2, g percent	.40	.39	.40	----------	----------	----------
Beta, g percent	.63	.84	.72	----------	----------	----------
Gamma, g percent	1.03	.97	.72	----------	----------	----------
Total protein, g percent	6.9	7.2	7.1	7.6	7.0	7.1
Uric acid, mg percent	6.8	6.6	4.6	6.0	5.9	6.0

Tilt Studies

The first abnormal finding noted following manned space flight was the postflight orthostatic hypotension observed on the last two Mercury missions. Study of this phenomenon has been continued in order to develop a better appreciation of the physiological cost of manned space flight. A special saddle tilt table, shown in figure 25–17, has been used, and the tilt-table procedure has been monitored with electronic equipment providing automatic monitoring of blood pressure, electrocardiogram, heart rate, and respiration. The procedure consists of placing the crewman in a horizontal position for 5 minutes for stabilization, tilting to the 70° head-up position for 15 minutes, and then returning to the horizontal position for another 5 minutes. In addition to the usual blood pressure and pulse rate determinations at minute intervals, some mercury strain gages have been used to measure changes in the circumference of the calf. On the 4-day, 8-day, and 14-day missions there were no symptoms of faintness experienced by the crew at any time during the landing sequence or during the post-

landing operation. Abnormal tilt-table responses, when compared with the preflight baseline tilts, have been noted for a period of
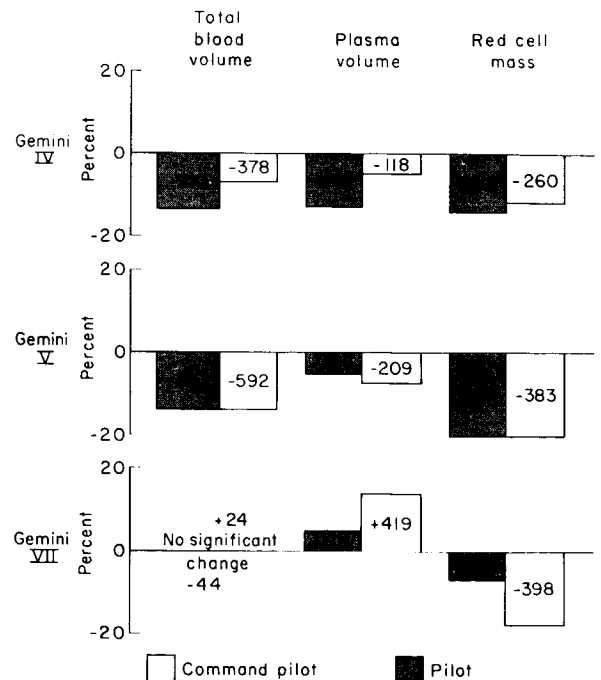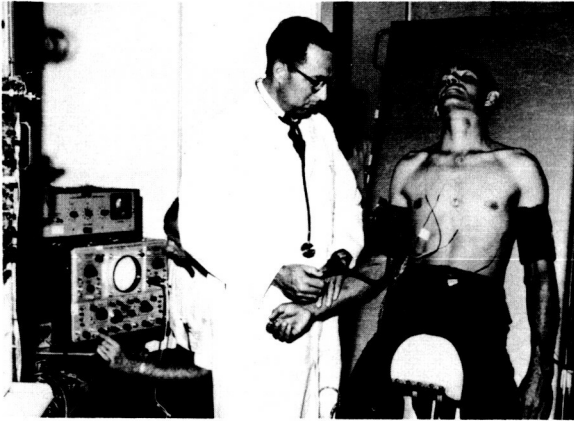

FIGURE 25–16.—Blood volume studies.

FIGURE 25–17.—Tilt-table test.

48 to 50 hours after landing. Typical initial postlanding tilt responses are graphed for the 4-day and 8-day mission crews in figures 25–18 through 25–21. A graph of the percentage increase in heart rate from baseline normal to that attained during the initial postflight tilt can be seen in figure 25–22. All of the data for Gemini III through VI–A fell roughly on a linear curve. The projection of this line for the 14-day mission data would lead one to expect very high heart rates or possible syncope. It was not believed this would occur. The tilt responses of the 14-day mission crew are shown in figures 25–23 and 25–24.

The response of the command pilot is not unlike that of previous crewmen, and the peak heart rate attained is more like that seen after 4 days of space flight. The tilt completed 24 hours after landing is virtually normal. The pilot's tilt at 1 hour after landing is a good example of individual variation, for he had a vagal response, and the heart rate, which had reached 128, dropped, as did the blood pressure, and the pilot was returned to the horizontal position at 11 minutes. Subsequent tilts were similar to previous flights, and the response was at baseline values in 50 hours. When these data are plotted on the curve in figure 25–22, it will be noted that they more closely resemble 4-day mission data. There has been no increase in the time necessary to return to the normal preflight tilt response, a 50-hour period, regardless of the duration of the flight. The strain-gage data generally confirm pooling of blood in the lower extremities during the period of roughly 50

hours that is required to readjust to the 1-g environment. The results of these studies may be seen in figure 25–25.

Bicycle Ergometry

In an effort to further assess the physiologic cost of manned space flight, an exercise capacity test was added for the 14-day mission. This test utilized an electronic bicycle ergometer pedaled at 60 to 70 revolutions per minute. The load was set at 50 watts for 3 minutes and increased by 15 watts during each minute. Heart rate, respiration rate, and blood pressure were recorded at rest and during the last 20 seconds of each minute during the test. Expired air was collected at several points during the test, which was carried to a heart rate of 180 beats per minute. Postflight results demonstrated a decrease in work tolerance, as measured by a decrease in time necessary to reach the end of the test, amounting to 19 percent on the command pilot and 26 percent on the pilot. There was also a reduction in physical competence measured as a decrease in oxygen uptake per kilogram of body weight during the final minute of the test.

Medical Experiments

Certain procedures have been considered of such importance that they have been designated operationally necessary and have been performed in the same manner on every mission. Other activities have been put into the realm of specific medical experiments in order to answer a particular question or to provide a particular bit of information. These investigations have been programed for specific flights. An attempt has been made to aim all of the medical investigations at those body systems which have indicated some change as a result of our earlier investigations. Thus, attempts are not being made to conduct wide surveys of body activity in the hope of finding some abnormality, but the investigations are aimed at specific targets. A careful evaluation is conducted on the findings from each flight, and a modification is made to the approach based upon this evaluation in both the operational and experimental areas. Table 25–VIII shows the medical experiments which have been conducted on the Gemini flights to date.
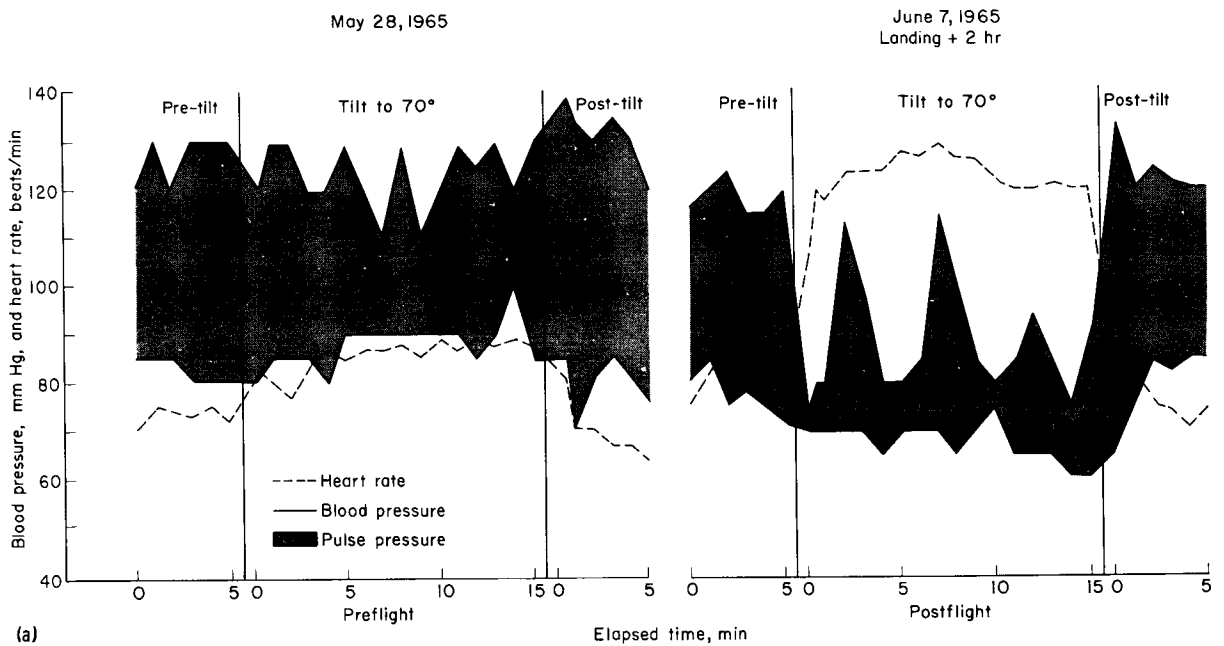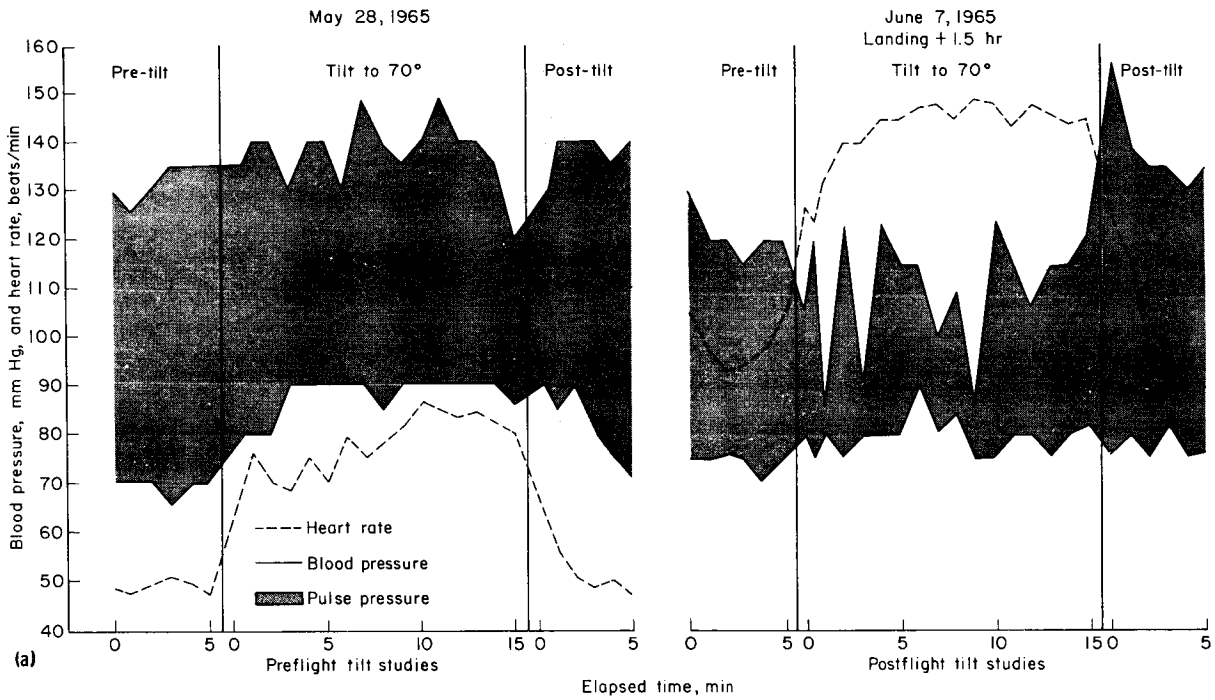
(a) Studies conducted preflight and at 2 hours after landing.

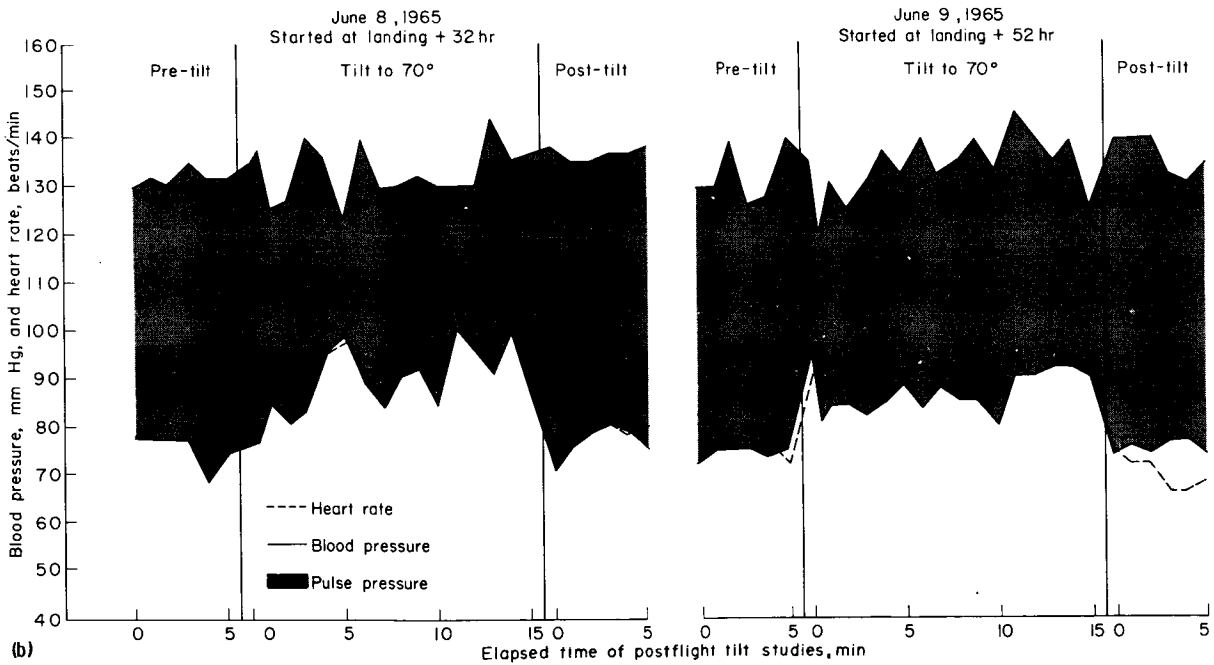FIGURE 25–18.—Tilt-table studies of Gemini IV command pilot.
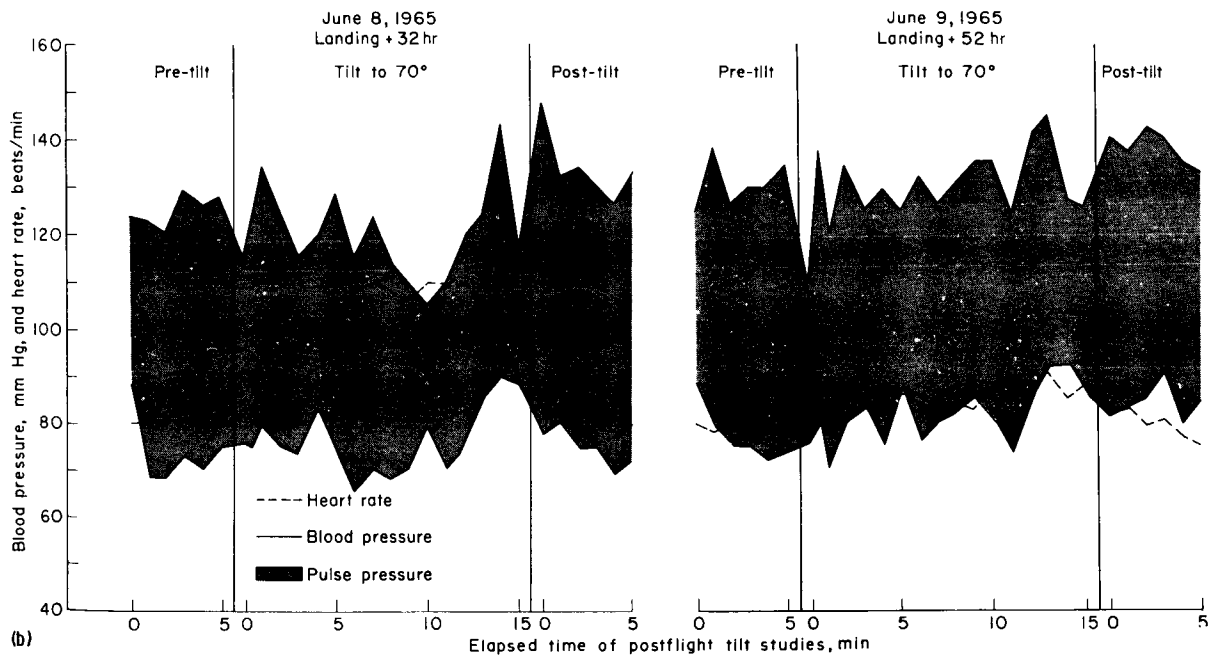
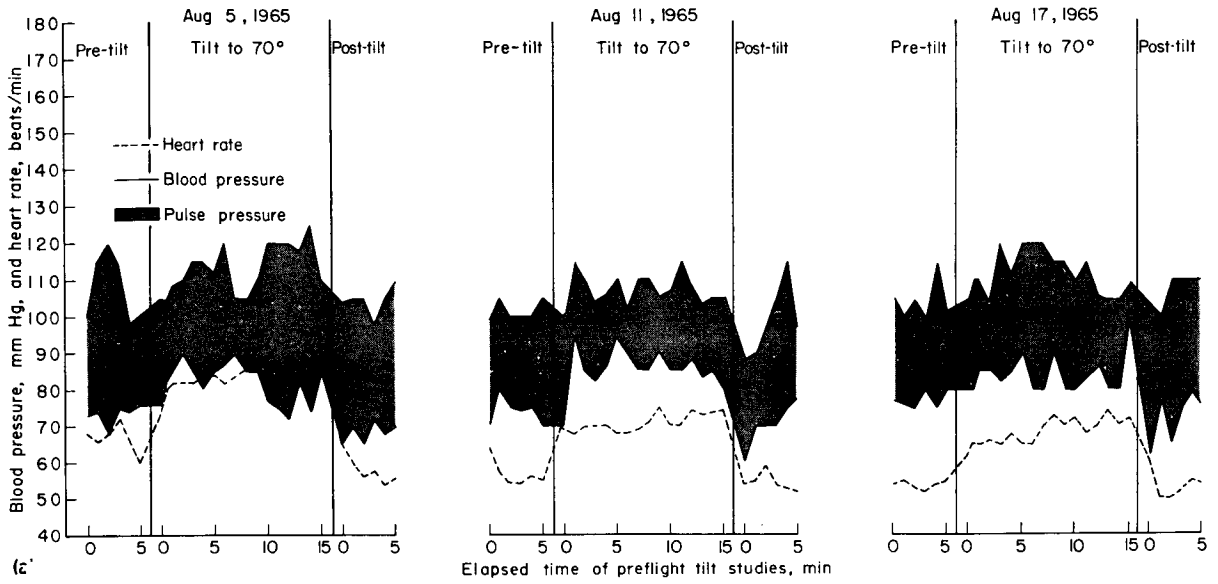(b) Studies conducted 32 hours and 52 hours after landing.

FIGURE 25–18.—Concluded.

(a) Studies conducted preflight and 1.5 hours after landing.

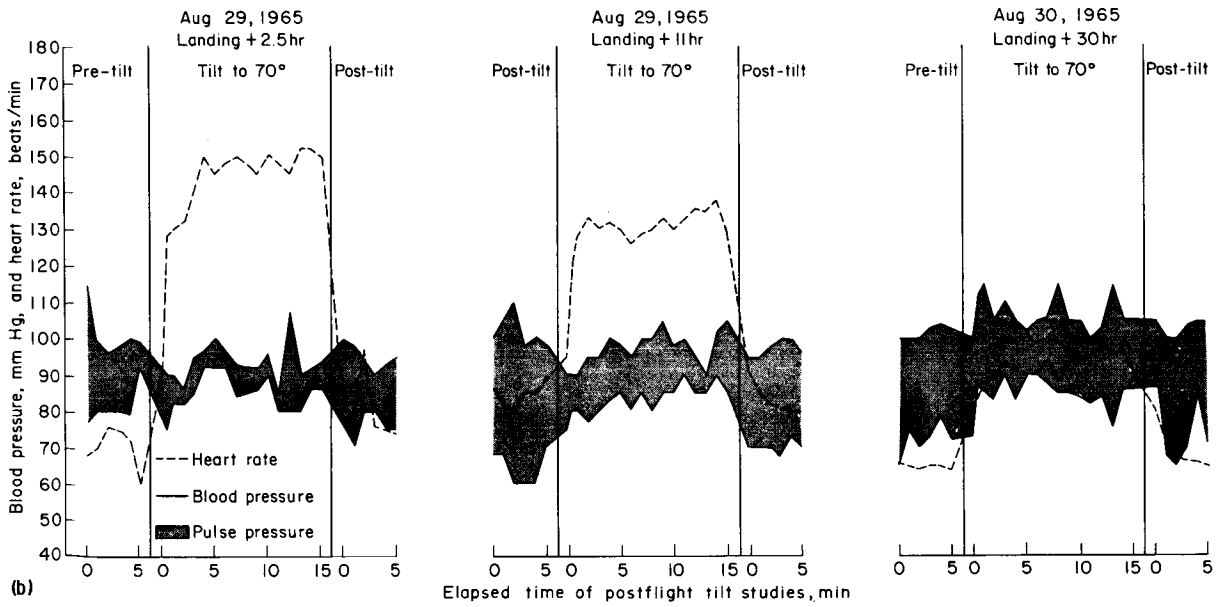FIGURE 25-19.—Tilt-table studies of Gemini IV pilot.

(b) Studies conducted 32 hours and 52 hours after landing.
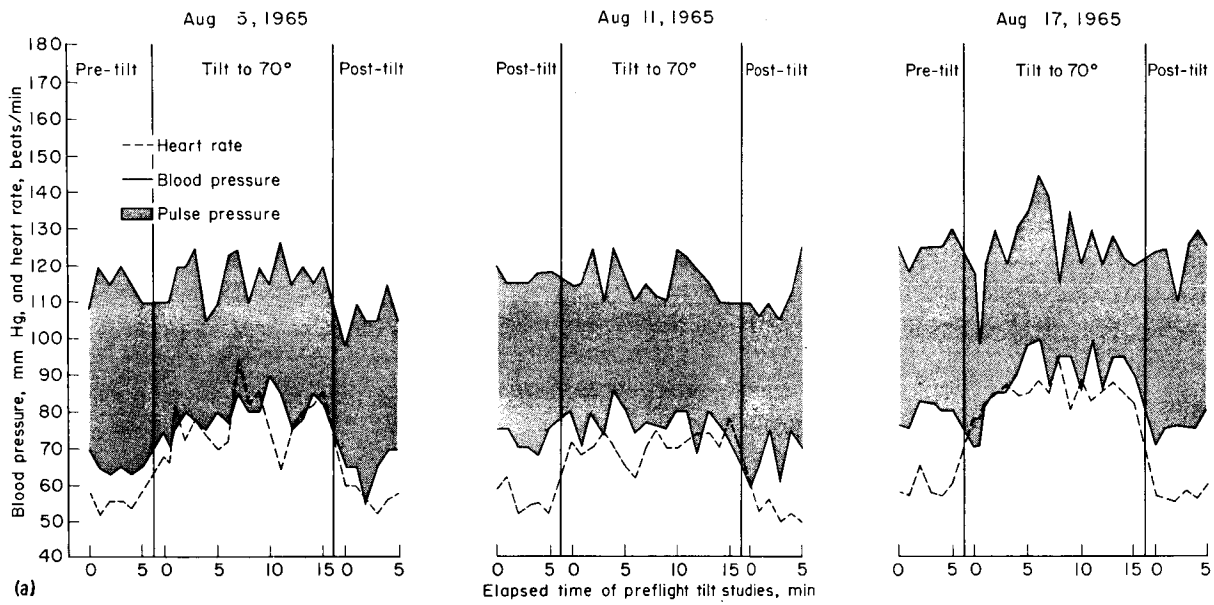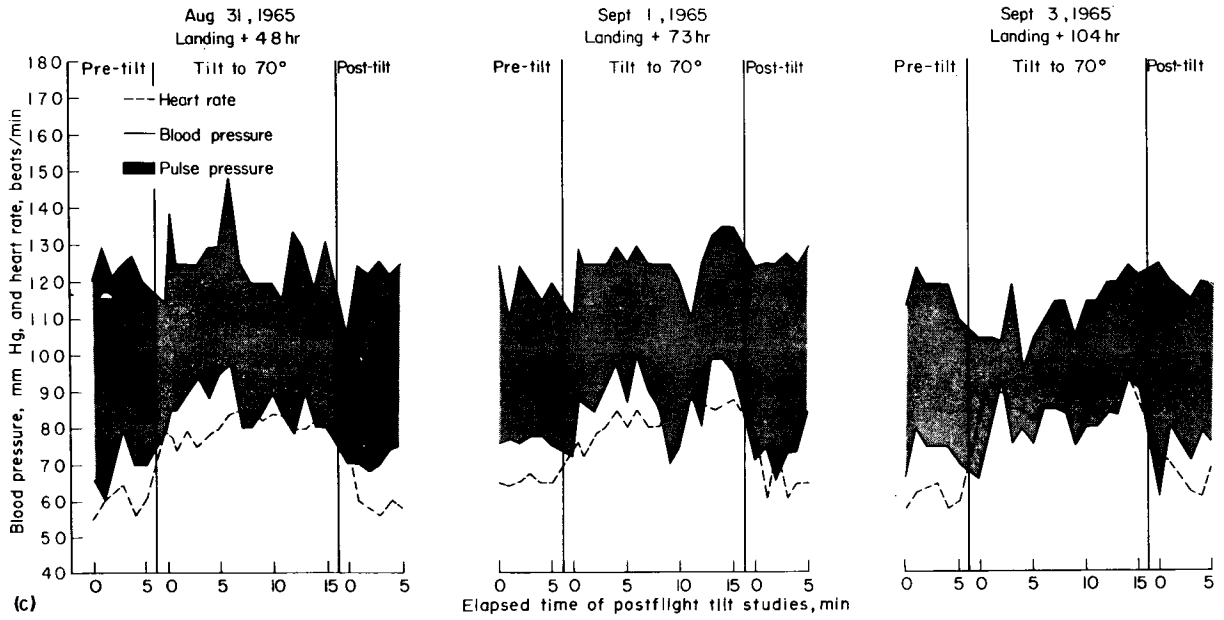
FIGURE 25-19.—Concluded.

(*a*) Preflight.

FIGURE 25–20.—Tilt-table studies of Gemini V command pilot.

(*b*) Postflight.

FIGURE 25–20.—Concluded.

(a) Preflight.

FIGURE 25–21.—Tilt-table studies of Gemini V pilot.
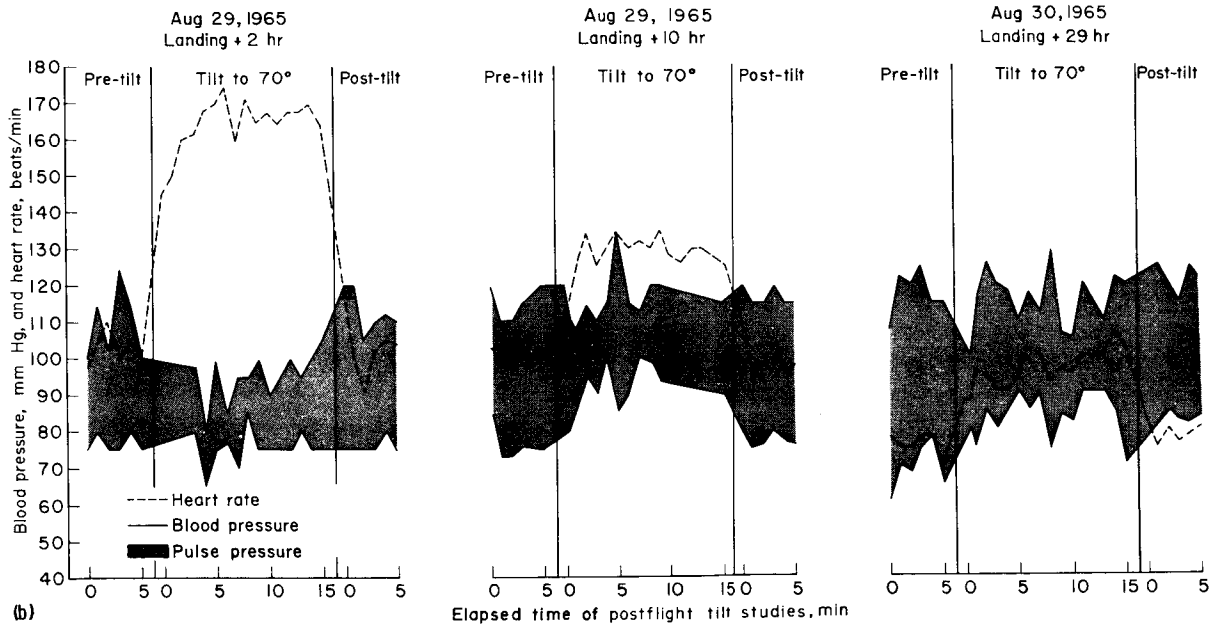
(b) Studies conducted at 2, 10, and 29 hours after landing.

FIGURE 25–21.—Continued.

(c) Studies conducted at 48, 73, and 104 hours after landing.
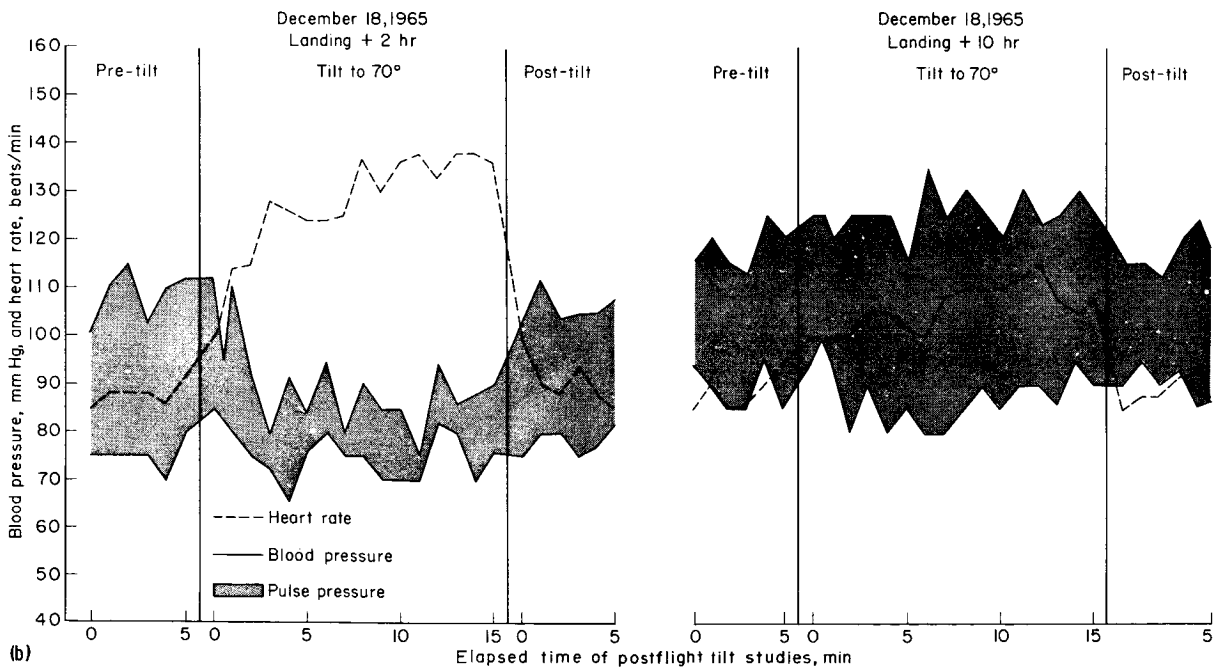
FIGURE 25-21.—Concluded.
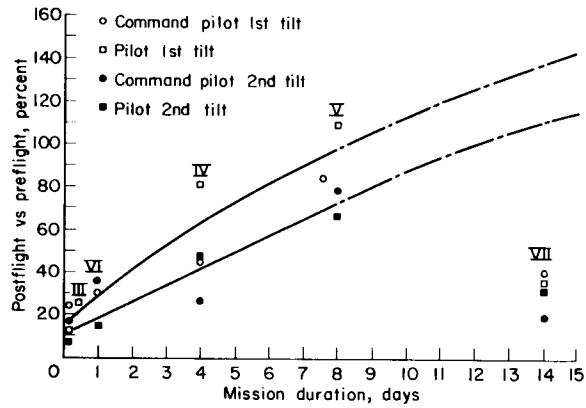
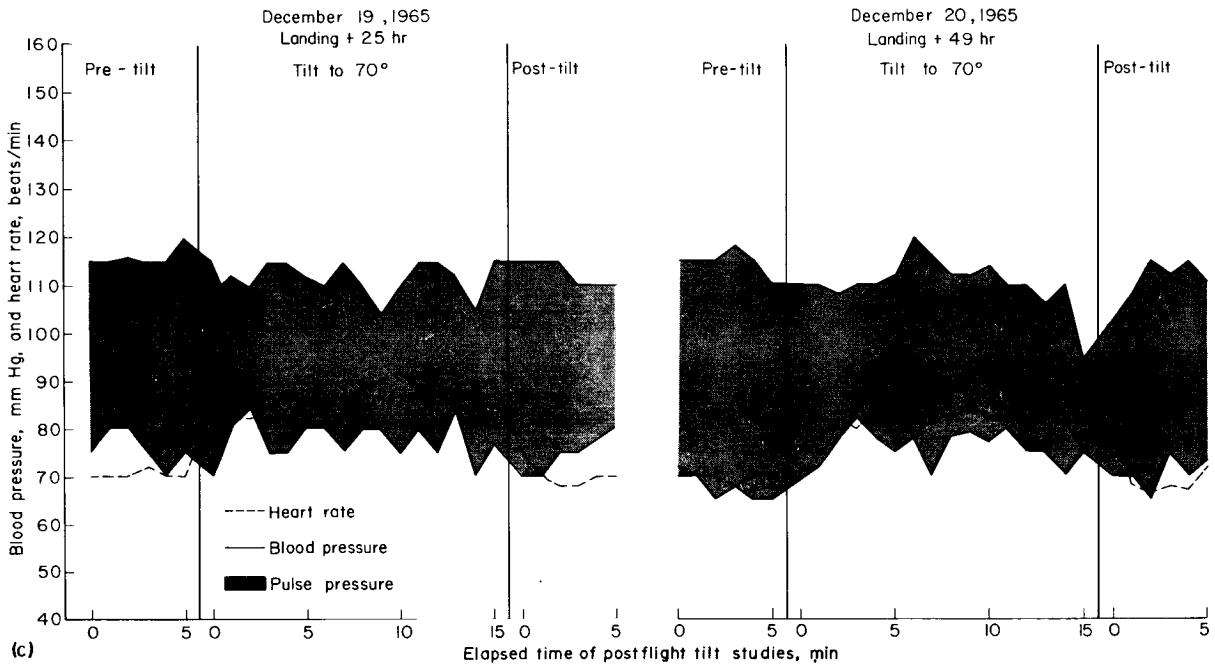FIGURE 25-22.—Heart-rate tilt response compared with mission duration.
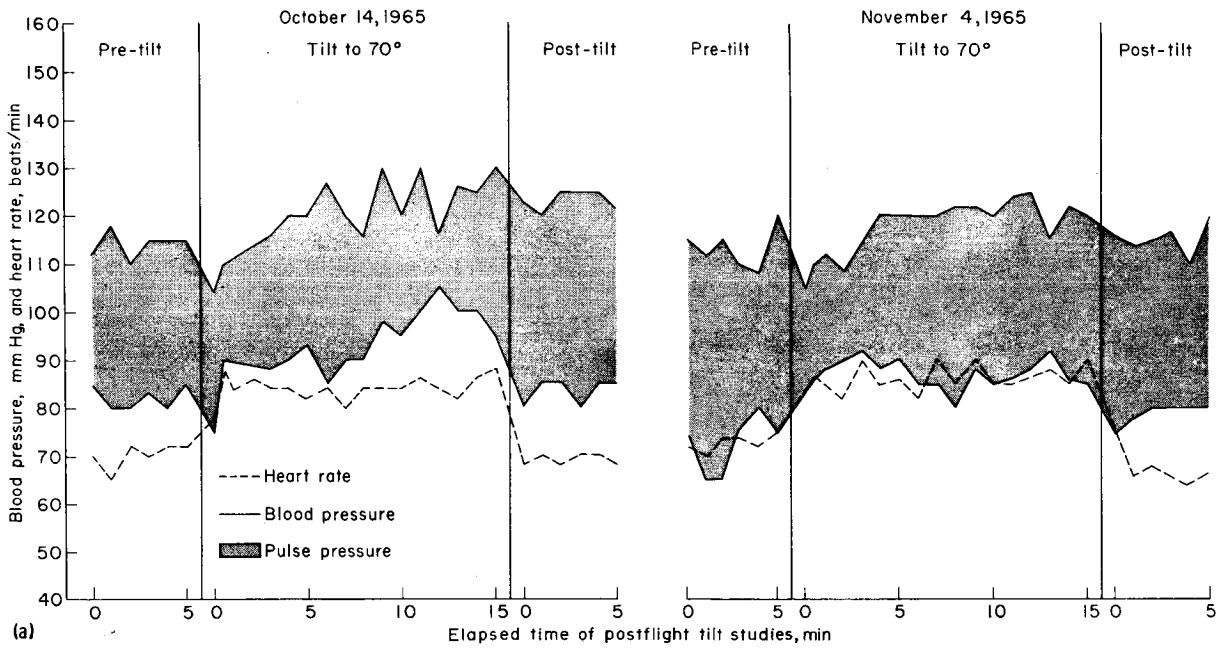
(a) Preflight.

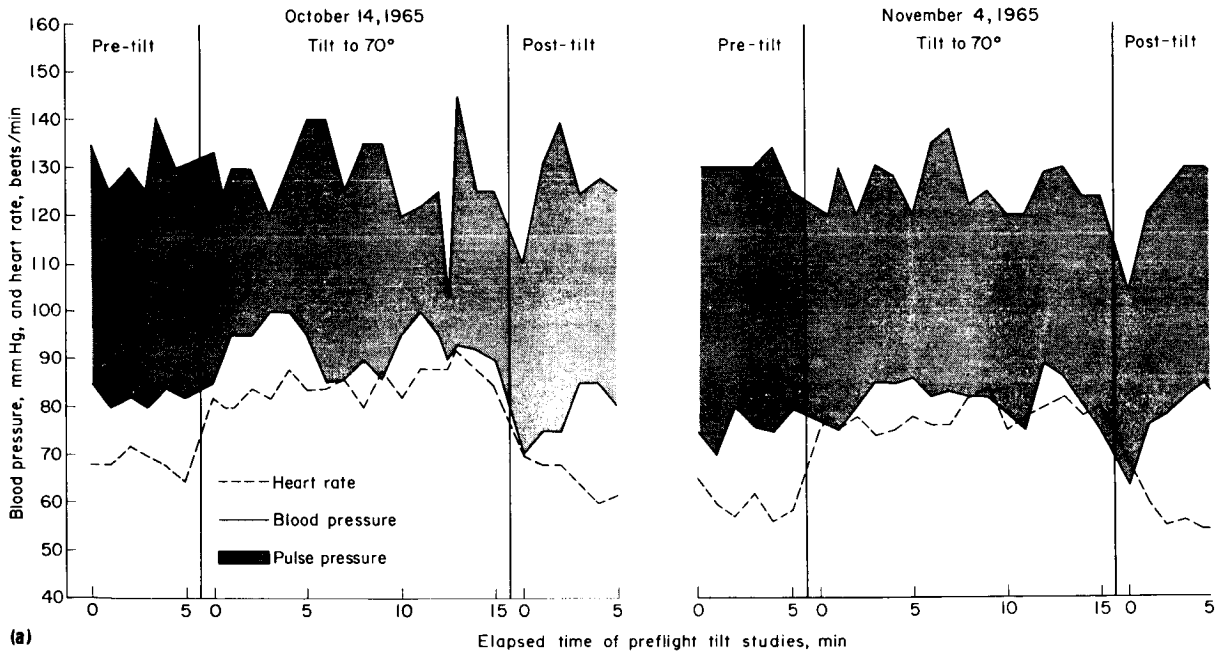FIGURE 25–23.—Tilt-table studies of Gemini VII command pilot.

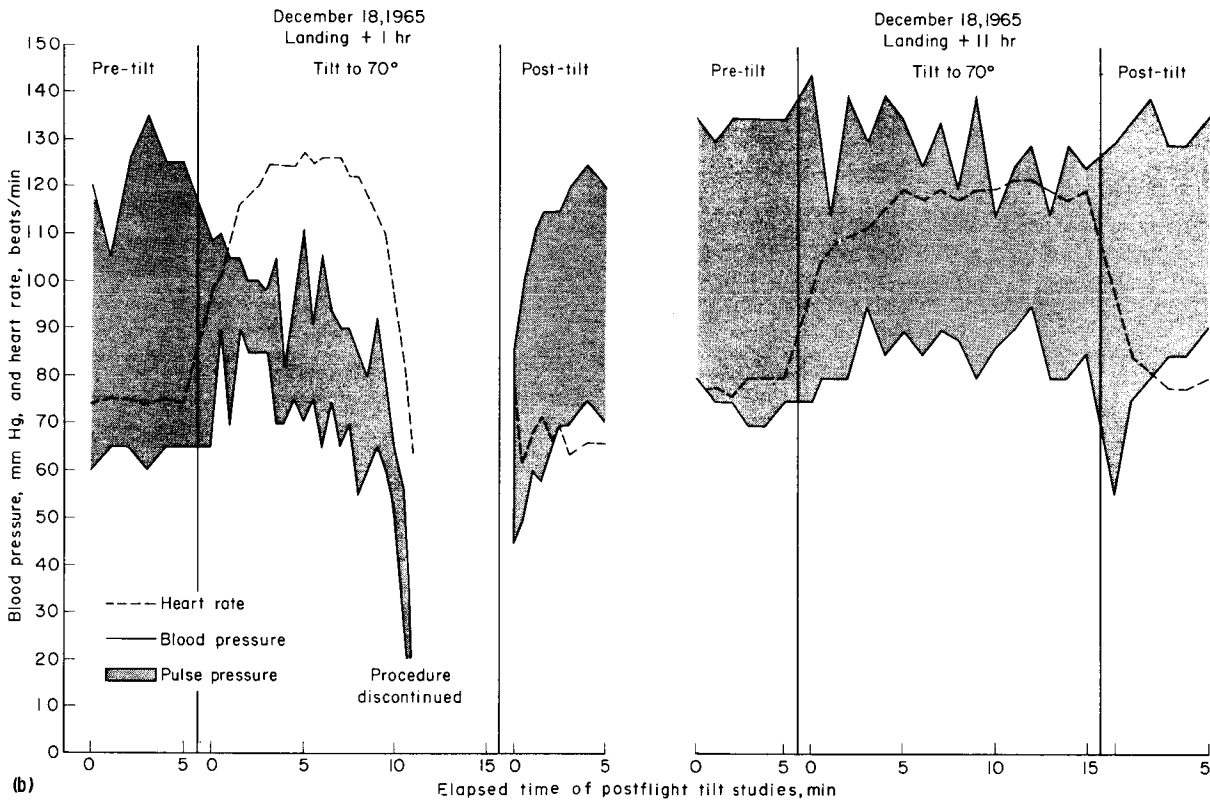(b) Studies conducted at 2 and 10 hours after landing.

FIGURE 25–23.—Continued.

(c) Studies conducted at 25 and 49 hours after landing.
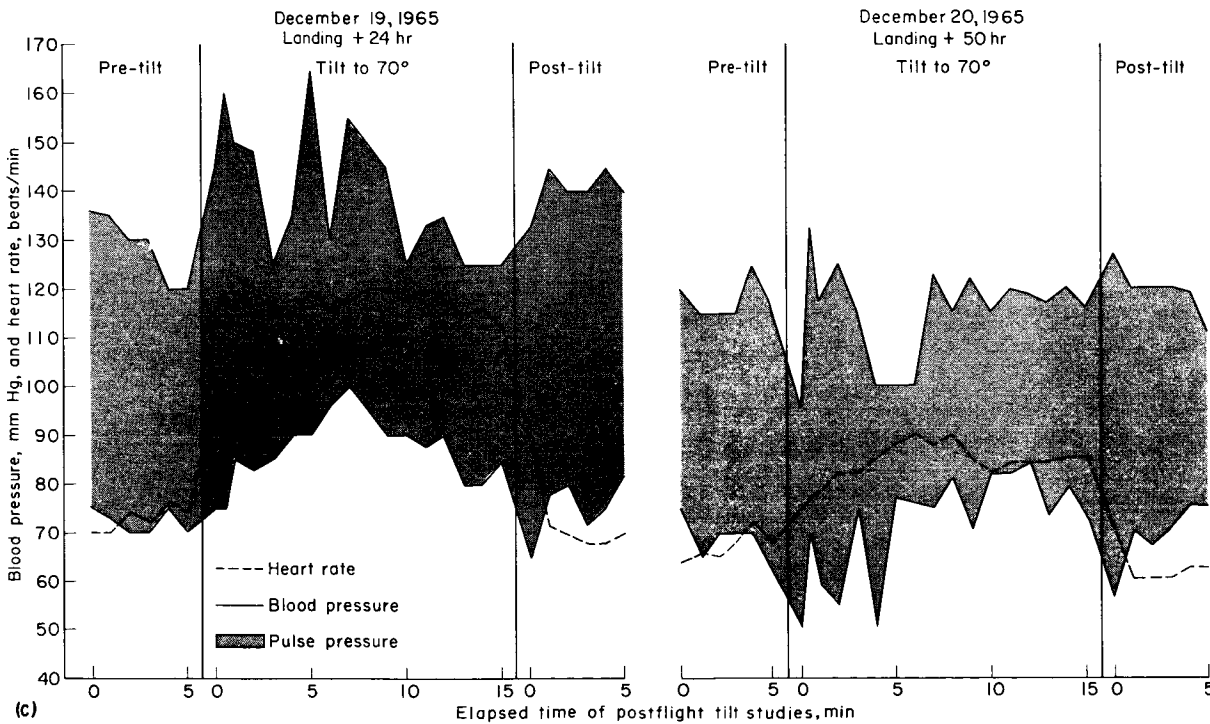
FIGURE 25–23.—Concluded.

(a) Preflight.

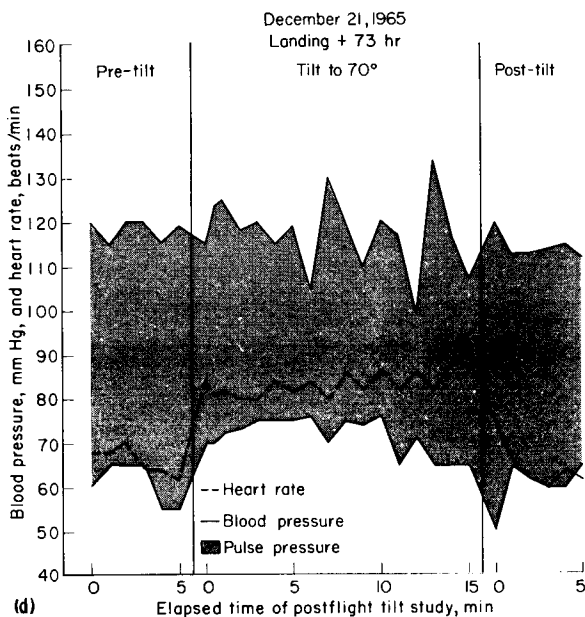FIGURE 25–24.—Tilt-table studies of Gemini VII pilot.

(b) Studies conducted at 1 and 11 hours after landing.

FIGURE 25–24.—Continued.

(c) Studies conducted at 24 and 50 hours after landing.

FIGURE 25–24.—Continued.

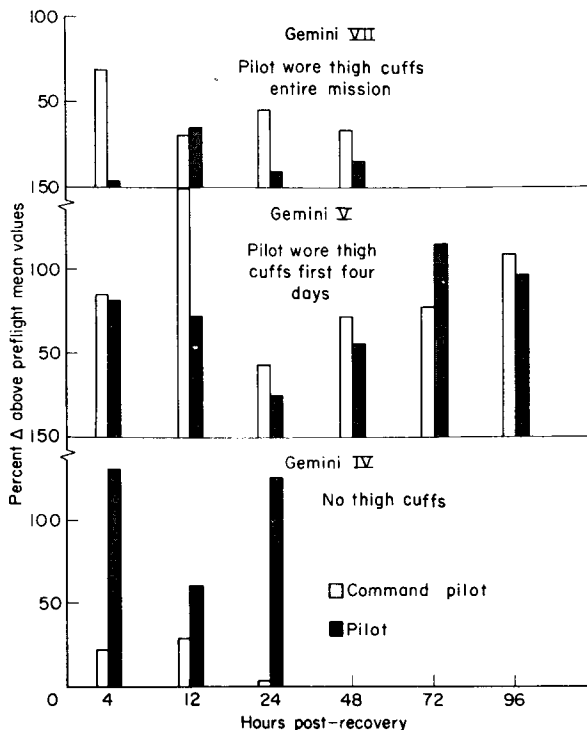(d) Study conducted at 73 hours after landing.

FIGURE 25-24.—Concluded.

FIGURE 25-25.—Leg volume changes during postflight tilt-table studies.

TABLE 25-VIII.—*Medical Experiments on Gemini Long-Duration Missions*

Code	Short title	Gemini IV, 4 days	Gemini V, 8 days	Gemini VII, 14 days
M-1	Cuffs		X	X
M-2	Tilt table	Include as medical operations procedure		
M-3	Exercise tolerance	X	X	X
M-4	Phonocardiogram		X	X
M-5	Body fluids			X
M-6	Bone densitometry	X	X	X
M-7	Calcium and nitrogen balance study			X
M-8	Sleep analysis			X
M-9	Otolith function		X	X

Radiation

The long-duration flights have confirmed previous observations that the flight crews are exposed to very low radiation dose levels at orbital altitudes. The body dosimeters on these missions have recorded only millirad doses which are at an insignificant level. The recorded doses may be seen in table 25-IX.

Concluding Remarks

A number of important medical observations during the Gemini flights have been made without compromising man's performance. It can

be stated with certainty that all crewmen have performed in an outstanding manner and have adjusted both psychologically and physiologically to the zero-g environment and then readjusted to a 1-g environment with no undue symptomatology being noted. Some of the findings noted do require further study, but it is felt that the experience gained through the 14-day Gemini VII mission provides great confidence in any crewman's ability to complete an 8-day lunar mission without any unforeseen psychological or physiological change. It also appears that man's responses can be projected into the future to allow 30-day exposures in larger spacecraft. The predictions thus far have been valid. Our outlook to the future is extremely optimistic, and man has shown his capability to fulfill a role as a vital, functional part of the spacecraft as he explores the universe.

TABLE 25–IX.—*Radiation Dosage on Gemini Long-Duration Missions*

[In millirads]

Mission	Command pilot	Pilot
Gemini IV [a]	38.5 ± 4.5	42.5 ± 4.7
	40.0 ± 4.2	45.7 ± 4.6
	42.5 ± 4.5	42.5 ± 4.5
	45.0 ± 4.5	69.3 ± 3.8
Gemini V [a]	190 ± 19	140 ± 14
	173 ± 17.3	172 ± 17.2
	183 ± 18.3	186 ± 18.6
	195 ± 19.5	172 ± 17.2
Gemini VII [b]	178 ± 10	98.8 ± 10
	105 ± 10	215 ± 15
	163 ± 10	151 ± 10

[a] Values are listed in sequence: left chest, right chest, thigh, and helmet.

[b] Values are listed in sequence: left chest, right chest, and thigh.