Chapter 25

SPACE MEDICINE

The origin of aviation medicine as a clinical discipline in the United States may be specified rather accurately by the Secretary of War's order to the Surgeon General, in 1912, to prepare a special examination for Aviation School candidates.

Thirty-six years later, *space medicine* was recognized as an entity by a symposium on the subject and, shortly thereafter, in 1949, by the creation of a Department of Space Medicine. Both events occurred at the School of Aviation Medicine at Randolph Air Force Base.

This is not to say that there was, in 1948, or is, even now, a clear delineation between aviation medicine and space medicine, particularly from the clinical point of view. Many, if not most, of the physiological problems of space flight are also the problems of aviation medicine. Some of these, such as the effects of cold, oxygen deprivation, and fear, had been identified as early as the 18th century through the balloon flights of Professor Jacques Charles, Dr. John Sheldon, and others. Reports by these aerialists of the anomalies of physiological response encountered in high altitude flight led to more scientific levels of reporting during the 19th century, when records of body responses during flight were kept in greater detail. Glaisher and Coxwell, for example, who reached almost 6 miles in altitude, reported, meticulously, their medical findings during their flight. In 1901, Professor A. Berson and Dr. R. J. Suring, equipped with special clothing, adequate oxygen, and devices designed for ready and reliable altitude control, became the first to reach the stratosphere. Knowledge gained from personal experience and from reports of earlier balloonists had well prepared them for this venture.

It is interesting to observe that some of the medical problems that were incidental to later high-altitude aircraft and space flight, were more the problems of the early balloonists than they were of the aviators in the pre-World War I days of powered flight.

The later balloon flights of Picard and Kipfer, Settle and Fordney, Anderson and Stevens, Simons, and Kittinger (102,800 feet) all provided more detail of the physical and physiological hazards of high altitudes, as did the powered flights of men like the US Army's Schroeder (33,113 feet) and Macready (38,704 feet), and the Navy's Soucek (43,166 feet) in 1930.

Since, from the point of view of the human organism, the dividing line between the earth's atmosphere and space is often considered to be about 43,000 feet in altitude, it will be apparent that space flight, in the broad definition, did occur long before the symposium at Randolph Air Force Base in 1948, and that those in the field of aviation medicine were interested in and worked on problems which were associated with these activities. However, space medicine, until the time of the Soviet's Vostok I, in 1961, remained, for the most part, a research-oriented discipline, and it was only with the advent of NASA's Project Mercury that it became a clinical entity in the United States.

Broadly, *space medicine,* as does its synonym "bioastronautics," *relates to the selection, support, and care of an astronaut and the life support of operations in space.* In a more specific operational definition, the purview of space medicine would include:

a. Providing the body of knowledge and the human standards required for the design and engineering of space vehicles intended for manned missions.

b. Providing the body of knowledge essential to the development and effective operation of crew-protective and life support systems.

c. Identifying and studying, through ground-based studies or in-flight experiments, space flight stresses and their psychophysiological effects.

d. Establishing the medical standards for the selection of astronauts and for their continuing medical care.

e. Providing the medical supervision, indoctrination, and experimental familiarization with aspects of the astronaut training program, such as centrifuge and chamber operations.

f. Providing the preflight medical preparation of the astronaut and the postflight medical observation and care.

g. Developing the medical protocol for the operational support of manned missions and providing the medical support at launching sites, tracking stations, and in recovery and rescue operations.

h. Evaluating the medical results of manned space missions.

i. Devising and developing means of increasing the body of biomedical knowledge, whether through experiment or analysis of flight medical data, to provide the basis for planning flights of extended duration and for estimating and providing for man's capability to function on planetary surfaces.

j. Devising and developing means of protecting the earth's atmosphere, population, and living resources from a possible back-contamination from extraterrestrial sources.

The final definition of space medicine, then, is that it is a discipline which, within the broad frame of preventive medicine, is concerned with the development of information and techniques to prepare man for adventures in space; the support of man during space and planetary exploration; and the protection of man and his terrestrial environment from the hazards of space. This chapter will consider the medical contributions to the achievement of manned space flight and the medical results of the manned space missions.

THE UNITED STATES MANNED SPACE FLIGHT PROGRAM

Studies, during the International Geophysical Year (1 July 1957 to 31 December 1959), indicate that there is no clearly defined point at which the earth's atmosphere may be said to end and space to begin.

The absence of a specific physical definition for space, however, imposes no restrictions in defining the medical aspects of space, for, as early as 1951, Strughold, Haber, *et al.*, suggested that the dividing line between the atmosphere and space occurs at different altitudes for different physiological functions. This, they referred to as *Space Equivalence* or the *Functional Border of Space*. Strughold's concept presents not only a meaningful frame of reference in which to work, but it also emphasizes the close relationship between aviation medicine and space medicine.

The United States manned space flight program was planned on an incremental basis, each flight extending somewhat the stresses experienced previously, or investigating new parameters. There were, therefore, short-duration flights before longer ones, single-man crews before multiman crews, and various other instances of increased activity and progressive application of experience and knowledge previously gained. The incremental progression is evidenced clearly not only in the different objectives of the major projects of Mercury, Gemini, and Apollo, but also in the objectives and planned sequence of events which identify the individual missions within a given project.

For all practical purposes, the manned space flight program in the United States began with Project Mercury, definitive efforts toward which were initiated in 1958. The activity under Project Mercury which established space medicine as a clinical entity rather than, solely, a research effort, was the medical selection of astronauts.

MEDICAL SELECTION OF ASTRONAUTS

By command decision, the first astronauts were to be chosen from among the military test pilots on active duty who volunteered their services and who were both homogeneous in terms of experience and highly motivated by a keen interest in the space program. Thus, they were to be a highly select group in the medical sense.

Men were selected in two phases. In the first phase, the records of all military test pilots were reviewed and screened in accordance with the basic criteria established, such as graduation from a test-pilot school, a minimum of 1,500 flying hours, qualification in high-performance jet aircraft, age not to exceed 39 years, and height not in excess of 71 inches. On the basis of the results of this screening, prospective candidates were reduced in number to 69. These candidates were, then, assembled in Washington DC, where they were interviewed, provided with technical details of the project, and given the opportunity to volunteer or decline. Medical records of those who volunteered were reviewed again in greater detail. In addition, psychiatric and psychological examinations were given these volunteers. Thirty-two were selected for the second phase of the selection process. Thirty-one completed the series of examinations. The second phase consisted of intensive medical examination at the Lovelace Clinic in Albuquerque, New Mexico, and psychological and stress testing at the Aerospace Medical Laboratory at Wright-Patterson Air Force Base.

Medical Examination

Basic to the medical examination were the medical and aviation histories. The former, in addition to the conventional medical and family history, included investigation into the attitude of the immediate family toward hazardous flying; the candidate's growth, development, and education; travel in areas where parasitic diseases were endemic; and tendency to disorders which precluded pressure inflation of the sinuses, lungs, or ears. The aviation history included information on total flying hours, war and peacetime military experiences, and operational experience with pressure suits.

The physical examination was conducted by flight surgeons, internists, and other appropriate specialists, including an ophthalmologist, otolaryngologist, neurologist, and cardiologist.

Laboratory tests conducted during the course of the examination are shown in table 25–1. Roentgenograms were made of the teeth, sinuses, thorax, esophagus, stomach, colon, and lumbosacral spine. Cineradiograms were made of the heart.

To estimate the candidate's general condition, physical competence measurements were made, including various vital capacity tests and a bicycle ergometer test under electrocardiograph monitoring. A summary of pertinent physiological data is provided in table 25–2.

Psychological and Stress Testing

The intent of the psychological tests administered at the Aerospace Medical Laboratory was to determine, on the one hand, personality and motivation and, on the other, intelligence and special aptitudes. A variety of standardized tests were used in both instances. Although the complete listing of tests will not be discussed here, it is interesting to note that the personality-motivation series included, in addition to such standard items as the Rorschach and Thematic Apperception Test, the Officer Effectiveness Inventory. The intelligence-special aptitudes group included the Air Force Qualification Test, the Navy's Aviation Qualification Test, the Wechsler Adult Scale, and a variety of analogies, comprehension, and spatial orientation tests.

The astronaut candidates were subjected to a large number of stress tests of both a psychological and physiological nature. These included the Harvard Step Test, a treadmill workload test, tilt-table test, and a cold-pressor test. Other stresses to which the candidates were exposed were noise, vibration, acceleration, isolation (3 hours in a dark, soundproof room), a simulated altitude

TABLE 25-1. LABORATORY TESTS (MERCURY ASTRONAUT SELECTION)

Test	Astronaut candidates (31)		Astronauts selected (7)	
	Mean	Range	Mean	Range
*Hemoglobin, gm/100 ml	16. 0	14. 5–17. 9	16. 6	14. 5–16. 2
Total circ. hemoglobin, gm	756. 5	565–1,127	857. 2	674–1,120
*Leukocytes, 1,000/mm³	8. 1	4. 7–15. 3	7. 7	5. 0–10. 0
*Sedimentation rate, mm/hr	5	0–32	4	2–6
*Cholesterol, mg/ml	225	150–320	238	184–280
*Sodium, meq/l	142	139–147	143	141–144
*Potassium, meq/l	4. 6	3. 4–5. 5	4. 7	4. 0–5. 5
*Chlorine, meq/l	105	103–110	10. 5	103–108
*Carbon dioxide, meq/l	26	22–30	26	23–30
*Sugar, mg/100 ml	102	84–112	100	88–108
*Protein bound iodine, μgm/100 ml	5. 8	4. 2–10. 4	5. 5	4. 9–6
*Bromsulphalein, % retention (45 min)	3	0–7	3	2–4
17-ketogenic steroids, mg/24 hr	19. 1	8. 8–29	18. 3	11. 1–23
17-ketosteroids, mg/24 hr	13. 7	8–22. 6	13. 3	9. 9–17. 5

*Fasting specimen.

TABLE 25-2. PHYSIOLOGICAL DATA (MERCURY ASTRONAUT SELECTION)

Test	Astronaut candidates (31)		Astronauts selected (7)	
	Mean	Range	Mean	Range
Height, cm	176	167–180	177	170–180
Weight, kg	73. 4	61–87	75. 3	70–87
Body surface area, m²	1. 9	1. 7–2. 1	1. 9	1. 8–2. 1
Lean body mass, kg	63. 9	55–71	66. 8	59–71
Total body potassium, gm	168. 6	142–204	175. 4	167–199
Total body water, liters	41. 3	36–47	41. 5	37–45
Blood volume, liters	4. 92	3. 33–6. 91	5. 40	4. 35–6. 91
Total circ. hemoglobin, gm	756. 5	565–1,127	857. 2	674–1,120
Total lung capacity, liters	6. 82	5. 36–8. 19	7. 02	6. 34–8. 02
Functional residual capacity, liters	3. 22	2. 25–4. 23	3. 41	2. 96–4. 23
Vital capacity, liters	5. 49	4. 35–6. 91	5. 54	5. 11–6. 02
Residual volume, liters	1. 32	0. 83–2. 00	1. 48	1. 13–2. 00
Maximum breathing capacity, liters	180	149–247	191	156–247
Nitrogen clearance equivalent	11. 1	9. 3–13. 0	10. 9	9. 2–12. 0
Final O_2 uptake during exercise, l/min	2. 41	1. 90–2. 84	2. 60	2. 07–2. 84

of 65,000 feet in an MC-1 partial pressure suit, and a complex behavior simulator.

The final evaluation of the candidates, made jointly by representatives of the Aerospace Medical Laboratory, the Lovelace Clinic, and medical and technical activities in NASA, resulted in the selection of seven astronauts.

With the exception of the requirement that the candidate be a test pilot and qualified in high-performance aircraft, selection criteria, standards, and techniques for Gemini and Apollo astronauts varied only slightly from those originally established.

MEDICAL SUPPORT OF FLIGHT AND RECOVERY OPERATIONS

A significant aspect of a manned space flight mission is the medical support of flight and recovery operations. The group that provides this support serve:

a. As aeromedical monitors, assigned to network tracking stations, to observe the physiological condition of the astronaut during flight.

b. At the launch site to provide emergency surgical support in the event of an incident.

c. On recovery vessels to provide immediate medical assistance in the event of an emergency during recovery.

d. At advanced medical units in high probability landing areas.

e. At the launch site to assist in preflight medical preparations.

f. As medical flight controllers at the Mission Control Center to determine whether the astronaut is capable of continuing a mission from a physiological point of view.

These needs are met by flight surgeons and other medical specialists, nurses, dietitians, and medical technicians, the majority of which are military personnel. Further support, in the form of medical specialty teams, has been provided by the Wilford Hall USAF Hospital, Lackland AFB, the US Naval Hospital, Portsmouth, Va., the Walter Reed Army Hospital, Washington, DC, and the Tripler General Hospital, Honolulu.

Medical Monitoring

Since the safety and welfare of the astronaut, both in training and flight, comprise a basic doctrine within the philosophy of the United States manned space flight program, the possibility of a requirement for a medical decision during flight is evident. Logically, it follows that there would be a necessity for means by which to observe physiological responses during flight, sources of evaluation, and a point of medical decision concerning continuation of the mission.

The continuous monitoring of physiological data taken from a pilot during a test flight is a relatively recent concept. In fact, at the time Project Mercury was to be undertaken, suitable techniques for reliably measuring the desired physiological parameters for prolonged flight were not readily available. Therefore, in the interest of flight safety, it was decided, at the beginning of the Mercury series, to attempt to monitor body temperature, chest movement, and heart action. The standards for devising techniques to accomplish this objective required that the sensors and equipment be comfortable, reliable, compatible with other spacecraft systems, and not interfere with the astronaut's primary mission.

The physiological parameters monitored and the changes and problems with respect to sensors can be summarized as follows: In the Mercury missions, body temperature was monitored with a rectal thermistor. This procedure was later modified, using an oral thermistor. The range of the thermistor was also changed to permit it to record suit-outlet temperature when it was in the stowed position on the right ear muff.

At first, respiration was measured by an indirect method, using a linear potentiometer and carbon-impregnated rubber. Early in the program, this method was changed to a thermistor kept at 200° F and placed on the microphone pedestal in the helmet. Since neither of these methods gave reliable respiration traces during flight, another method was employed during the last two Mercury missions, using the impedance pneumograph.

Electrocardiographic electrodes were of a low impedance to match the spacecraft amplifier. They were required to record during body movements and to stay effective during flight durations of over 30 hours. The electrodes functioned well and gave very good information on cardiac rate and rhythm. The value of having two leads of electrocardiograph, even though they differed from the standard clinical leads, was shown repeatedly. This allowed easier determination of artifacts and was most helpful in determining the valid sounds on the blood-pressure trace by comparison with the remaining ECG lead. The electrode paste was changed from 30% calcium chloride in water mixed with bentonite, to a combination of carboxypolymethylene in Ringer's solution. The 10 times isotonic Ringer solution not only retained the necessary conductivity and low impedance required, but also afforded decreased skin irritation after prolonged contact.

In 1958, the obtaining of blood pressures in flight was considered and then delayed, as no satisfactory system was available. Definitive work began about the time of the first manned suborbital Mercury flight, and the automatic system which used the unidirectional microphone and cuff was developed for use in the orbital flights. This system without the automatic feature was used on the first manned orbital mission. During the second manned orbital mission, all of the in-flight blood pressures obtained were elevated, and an extensive postflight evaluation program was undertaken. It was determined that the cause of these elevations was most likely instrumentation error resulting from the necessity for very careful gain settings matched to the individual astronaut along with the cuff and microphone. A great deal of preflight calibration and matching of these settings was done prior to the last two missions, and in both instances, excellent blood-pressure tracings were obtained.

Voice transmissions can be a very valuable source of monitoring information. Normal flight reports and answers to queries have been used for evaluating the pilot. In addition to normal reports, verifying the actual comfort level was valuable in determining the importance of temperature readings obtained by way of telemetry. In-flight photography and, in later missions, television views of the astronaut were used as additional data sources. In early experience, both of these sources proved to be of little value in the medical monitoring of the astronaut because of poor camera positioning and varying lighting conditions resulting from the operational situation.

The value of the comparison of multiple physiological parameters and their correlation with environmental data has been proven repeatedly. Abnormal or lost values attributed to instrumentation difficulty have been obtained frequently, but it has been found that interpretation of the astronaut's physiological condition could be made by the use of the parameters remaining or the correlation of those remaining with environmental data.

Flight experience thus far has shown that a satisfactory amount of information on current astronaut status can be obtained with the use of such basic vital signs or viability measures.

Considerable experience in the medical flight control of an orbiting astronaut was obtained through the use of range simulations and the actual flights. It was apparent that the development of mission rules to aid in flight control was necessary in the medical area, just as it was in the many engineering areas, and definite number-value cutoffs for various medical parameters were established early in the program. Gradually, the rules were made less specific. Consequently, the evaluation and judgment of the medical flight controller became the prime determinants in making a decision. The condition of the astronaut, which was determined by voice and interrogation rather than by physical parameters alone, became a key factor in the medical decision to continue or terminate the mission.

Recovery

The medical support of mission recovery

operations must fulfill two basic requirements:

a. Provide prompt, optimum medical care for the astronaut, if necessary, upon his retrieval from the spacecraft.

b. Conduct an early medical evaluation of the astronaut's postflight condition.

It is considered essential to establish a medical capability for any circumstance under which recovery could occur. The general concept is to provide the best care as fast as possible. Original plans were necessarily based on anticipation of the direst situation possible.

The extent to which medical care can be effectively administered to the astronaut during the recovery operation is governed, to a large degree, by the physical circumstances under which recovery occurs. Medical support at the different recovery areas varies according to the area potential for administration of competent medical treatment. The most extensive medical support is concentrated in the areas where descent to earth by the astronaut is most probable.

Access times for the various recovery areas were established to provide medically acceptable time periods that would afford the astronaut reasonable protection. These time periods were based upon accumulated knowledge of human survival, need for medical attention, and reaction to physiologic stress.

One of the basic changes in philosophy occurring during the program concerned the medical care of the astronaut. In the early missions, the emphasis was on bringing medical aid to the site of recovery. In the later missions, provisions were made to return the astronaut to definitive medical care centers as required.

Medical support is provided for three basic categories:

(1) Rapid crew egress and launch-complex rescue capability during the late countdown and early phases of powered flight.

(2) Positive short-time recovery capability throughout all phases of powered flight and landing at the end of each orbital pass.

(3) Reduced capability in support of an unplanned landing along the orbital track.

In the launch-site area, this support includes a medical-specialty team consisting of a general surgeon, an anesthesiologist, surgical technicians and nurses, a thoracic surgeon, an orthopedic surgeon, a neurosurgeon, an internist, a radiologist, a pathologist, a urologist, a plastic surgeon, and supporting technicians. In the early missions, this team was deployed to Cape Kennedy to be available when needed at the Cape or in the recovery area, to which they were transported by aircraft. For the last two Mercury missions, a team was activated at Tripler General Hospital, Hawaii, to cover the Pacific area as well. When it became obvious that there were large numbers of highly trained physicians who were merely waiting out the mission in a deployed state and, more than likely, would not be used, the conclusion was reached that specialty teams could be maintained on standby at Stateside hospitals and easily flown to the Cape or a recovery site.

Other launch-site support is provided by a point team consisting of a flight surgeon and scuba-equipped pararescue personnel, airborne in a helicopter. Medical technicians, capable of rendering first aid care, are also available in Lighter Amphibious Resupply Cargo (LARC) vehicles and in small water jet boats. A surgeon and an anesthesiologist, along with their supporting personnel, are stationed in a blockhouse at Cape Kennedy to serve as the first echelon of resuscitative medical care in the event of an emergency. Physicians are stationed throughout the recovery areas in the Atlantic and Pacific, aboard destroyers and aircraft carriers. In the early missions, each vessel was assigned a team comprising a surgeon, anesthesiologist, and medical technician, along with a supporting medical equipment chest, necessary for evaluation and medical or surgical care. As confidence was gained in the operations, the number and distribution of medical personnel were modified.

Postflight medical data is collected at the earliest opportunity. Immediately after the hatch is opened, an extension cord for the biomedical cable may be attached to the astronaut's biosensor plug and blood-pressure fitting, and connected to the spacecraft onboard recorder to record blood pressures and ECG before, during, and after egress. This system is extremely effective in deriving egress data.

The postflight activities of the pilot of Mercury-Atlas 9, the fourth manned orbital mission, are shown in table 25-3, as an example of the medical procedures observed.

PHYSIOLOGICAL RESPONSES IN SPACE FLIGHT

The United States manned space flight program has included three projects: Mercury, Gemini, and Apollo (see figure 25-1).

The first of these was Mercury. Its objective was to place a man into orbit and return him safely to earth. This objective was accomplished in February 1962, in a mission which extended over a period of 4 hours and 55 minutes (see table 25-4).

The second project, Gemini, was an essential interim program directed toward achievement of the national objective of landing a man on the moon and returning him safely to earth. The Gemini program was a logical follow-on program after Mercury which minimized time and expense and was designed to subject two men and necessary supporting equipment to long-duration flights, thus, accumulating the experience and knowledge necessary for trips to the moon and beyond (see table 25-5). A specific objective was to achieve rendezvous and docking with another orbiting vehicle and maneuver the combined spacecraft (a key element of the approach selected for the lunar project). The major medical objectives were the accumulation of experience with the effects of weightlessness and the physiological reactions of crew members during

TABLE 25-3. POSTFLIGHT ACTIVITIES, MA-9

Date, 1963	Time, local Midway [a]	Activity
May 16	12:25 p.m.	Landing.
	12:55 p.m.	Spacecraft on deck.
	1:09 p.m.	Blood pressure, recumbent in spacecraft.
	1:12 p.m.	Egress and blood pressure standing.
	1:15 p.m.	Physical examination begun in recovery ship sick bay.
	1:45 p.m.	First tilt table procedure.
	3:00 p.m.	Examination completed.
	3:30 p.m.	First postflight urination.
	3:42 p.m.	Second tilt table procedure.
	4:10 p.m.	First postflight meal.
	5:45 p.m.	First postflight bowel movement.
	7:11 p.m.	Third tilt table procedure.
	9:30 p.m.	To bed.
May 17	7:00 a.m.	Awakened.
	7:40 a.m.	Fourth tilt table procedure and brief medical examination.
	8:00 a.m.	Breakfast.
	9:00 to 11:00 a.m.	Self-debriefing.
	2:00 to 5:00 p.m.	Technical debriefing.
	7:00 to 9:00 p.m.	Medical debriefing.
May 18	1:00 p.m.	Left recovery ship.
May 20	9:00 a.m. e.s.t.	Comprehensive postflight medical examination at Patrick Air Force Base, Fla.

[a] To convert times to e.s.t., add 6 hours.

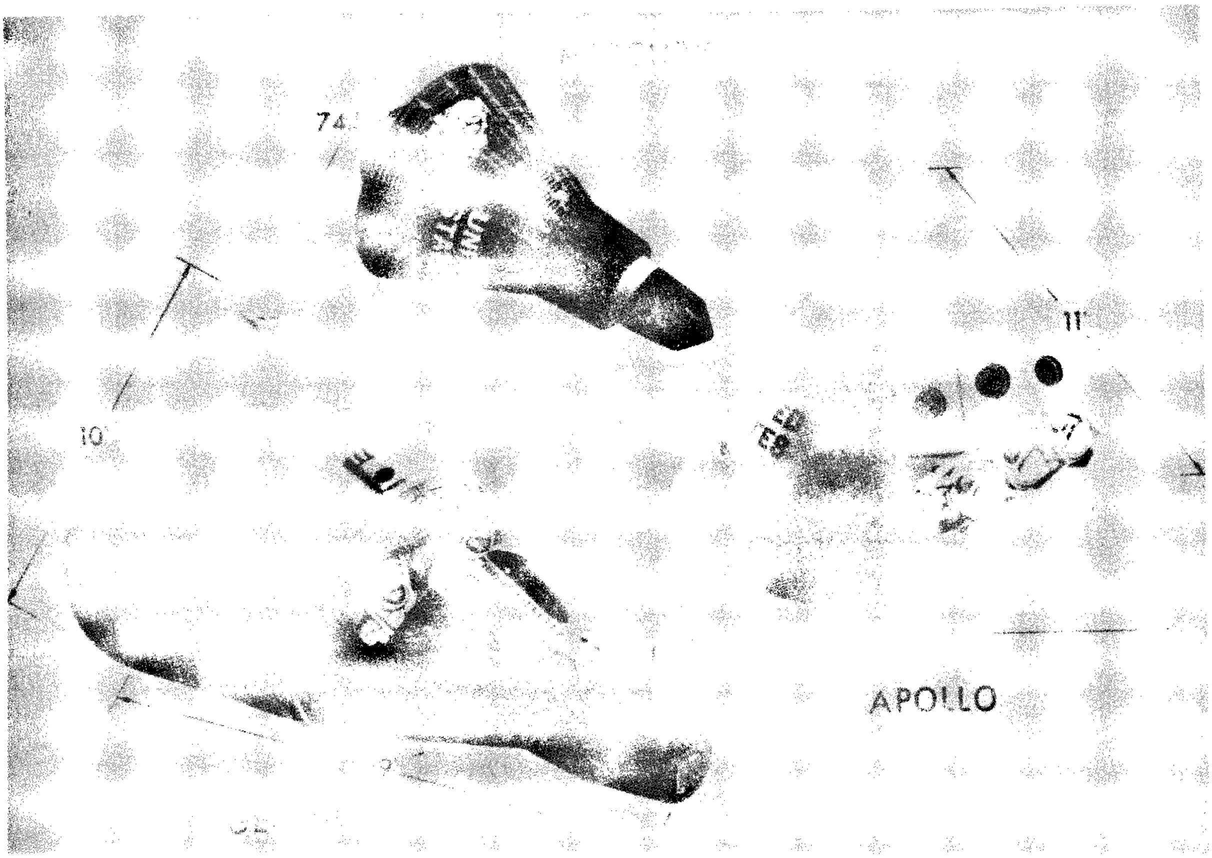


Figure 25–1. US Manned Flights.

long-duration missions, and the compilation of medical data necessary for planning missions in later programs. The Gemini spacecraft was, in many ways, a two-man orbiting laboratory through which knowledge of and experience in the space environment were increased considerably. The Gemini series was terminated with the flight of Gemini 12.

The third planned project is Apollo which has the objectives of lunar landing and exploration, using a three-man crew.

Before the first manned orbital flights, many predictions were made concerning the possible adverse effects of space flight. Since weightlessness was the one unknown factor that could not be duplicated exactly in a laboratory situation on the ground, some effect on almost every body system was predicted. These were anticipated on the basis of known influences of gravity on certain body systems, on the knowledge of effects of disease phenomena, and within the context of ground-based research and clinical observation. Vestibular and proprioceptive disturbances were anticipated not only on a theoretical basis, but also as a result of the reported appearance of symptoms in the case of Major Gheman Titov, the Russian Cosmonaut, during his 17.5 orbit flight in 1961. Since the cardiovascular system is markedly influenced by gravity, disturbances in the weightless condition were expected. On the basis of ground-based research in sensory deprivation, there was some expectation of hallucinations. The possibility of impairment of crew performance due to disturbance of circadian rhythm was also considered. None of these was significant in Mercury. However, the Mercury experience did define physiological problem areas on a more realistic basis.

TABLE 25-4. MERCURY MANNED FLIGHT SUMMARY

Mission *	Launch Date	Flight Duration # HR:MIN:SEC	Basic Test Objectives
MR-3...Manned	5 May 1961	00:15:22	Suborbital flight; familiarize man with space flight; evaluate response and S/C control.
MR-4...Manned	21 Jul 1961	00:15:37	Suborbital flight; same as MR-3.
MA-4...Unmanned	13 Sep 1961	01:49:20	One-pass orbital flight; same as MA-3.
MA-5...Unmanned	29 Nov 1961	03:20:59	Three-pass orbital flight; qualify all systems, network, for orbital flight recovery.
MA-6...Manned	20 Feb 1962	04:55:23	Three-pass orbital flight; evaluate effects on and performance of astronaut in space; astronaut's evaluation of S/C and support.
MA-7...Manned	24 May 1962	04:56:05	Three-pass orbital flight; same as MA-6; evaluate S/C modifications and network.
MA-8...Manned	3 Oct 1962	09:13:11	Six-pass orbital flight; same as MA-6 and MA-7 except for extended duration.
MA-9...Manned	15 May 1963	34:19:49	Twenty-two pass orbital flight; evaluate effects on man of up to 1 day in space; verify man as primary S/C system.

* MR - Mercury-Redstone Launch Vehicle; MA - Mercury-Atlas Launch Vehicle

\# Duration measured from lift-off to landing

TABLE 25-5. GEMINI MANNED FLIGHT SUMMARY

Mission	Launch Date	Duration *	Base Test Objectives
Gemini 3	23 Mar 1965	4 hours	Manned qualification of Gemini Spacecraft.
Gemini 4	3 Jun 1965	4 days	EVA and systems performance for 4 days.
Gemini 5	21 Aug 1965	8 days	Long-duration flight, rendezvous radar capability.
Gemini 7	4 Dec 1965	14 days	2-week duration flight, evaluation "shirt-sleeve" environment, controlled re-entry.
Gemini 6A	15 Dec 1965	1 day	On-time launch procedures, closed-loop rendezvous.
Gemini 8	16 Mar 1966	10 hours	Rendezvous and docking, controlled re-entry, parking.
Gemini 9A	3 Jun 1966	3 days	Rendezvous and docking, extravehicular activity.
Gemini 10	18 Jul 1966	3 days	Rendezvous and docking, extravehicular activity, experiments.
Gemini 11	12 Sep 1966	3 days	First revolution rendezvous and docking, docking practice, tethered vehicle test, automatic re-entry.
Gemini 12	11 Nov 1966	4 days	Rendezvous and docking, docking practice, station-keeping exercise, maneuvers.

* Approximate

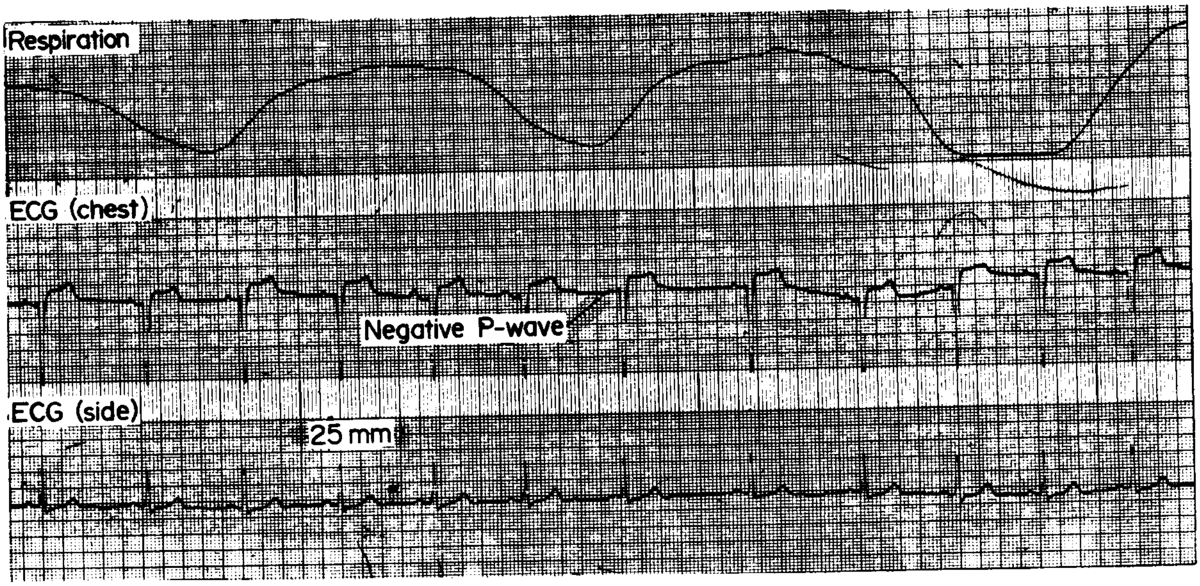
In studying the physiological responses of man in space flight, it is important to remember that there are multiple stresses acting upon him, thus complicating the analysis of any given response. Man must undergo a number of stresses in reaching, staying in, and departing the orbital environment. These stresses may include such factors as the full pressure suit, confinement and restraint, 100% oxygen and 5-psia atmosphere, changing cabin pressure (launch and reentry), varying cabin and suit temperatures, 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; however, in a sense, it could be said that this fact is only of limited interest, for the results would always represent the effects of man's exposure to the total space flight environment. 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.

In considering the physiological responses in space flight, it is necessary to have a detailed in-flight event history since peak physiological responses are closely related to critical in-flight events. This meaningful relationship is well demonstrated by pulse rate responses during flight (see table 25-6). Peak pulse rates during a launch phase usually occurred at sustainer-engine cutoff. This peak value in Mercury ranged from 96 to 162 beats per minute. The peak rates obtained on reentry ranged from 104 to 184 beats per minute. This usually occurred immediately after obtaining peak reentry acceleration, or on drogue parachute deployment. Pulse rates obtained during weightless flight varied from 50 to 60 beats per minute during the sleep periods to 80 to 100 beats per minute during the normal wakeful periods. Elevated rates during weightless flight were usually related to flight-plan activity. Respiratory rates ranged from 30 to 40 breaths per minute at sustainer-engine cutoff, from 8 to 20 breaths per minute during weightless flight, and from 20 to 32 breaths per minute at reentry. Changes noted in electrocardiograms included alterations in the pacemaker activity with wandering pacemakers and aberrant rhythm, including atrioventricular nodal beats and rhythm, premature atrial and ventricular contractions, sinus bradycardia, atrial rhythm, and atrioventricular contraction (see figures 25-2 and 25-3). All of these "abnormalities" can be considered normal physiological responses when related to the dynamic situation in which they were encountered.

Considerable progress was made in acquiring medical data and in understanding man's physiological and psychological reactions in the space environment during the relatively short time the Mercury and Gemini programs were in being. In May of 1963, it was predicted that man could live and work in a space environment for at least four days, as long as adequate life support was provided. A 14-day mission and additional flights followed which provided both rendezvous and extravehicular activity experience. At the end of 1966, 19 men had been exposed to a total weightless experience of about 1900 man-hours. Three astronauts had flown both single and dual-crew vehicles, and four had flown twice in the Gemini capsule. A comparison of data on the seven persons twice exposed to space flight reveals that, while this experience does alter some of the mental attitudes and performance, it

TABLE 25-6. PULSE RATES

Mission	SECO (Peak)	Weightlessness (Range)	Re-entry (Peak)
MR-3	138	108 to 125	132
MR-4	162	150 to 160	171
MA-6	114	88 to 114	134
MA-7	96	60 to 94	104
MA-8	112	56 to 121	104
MA-9	144	50 to 60 (sleep) 80 to 100 (awake)	184



This sample illustrates one of the frequent occurrences of sinus arrhythmia with wandering pacemaker. The Negative P-wave in this record suggests inverse depolarization from the atrioventricular node. Similar changes were observed before launch. (Recorder speed 25 mm/sec.)

Figure 25-2. MA-9. Sample of Biosensor Record at a Range Station.

appears to have little effect on physiologic response.

The in-flight medical results of the manned space flight missions through Gemini are summarized in the following paragraphs.

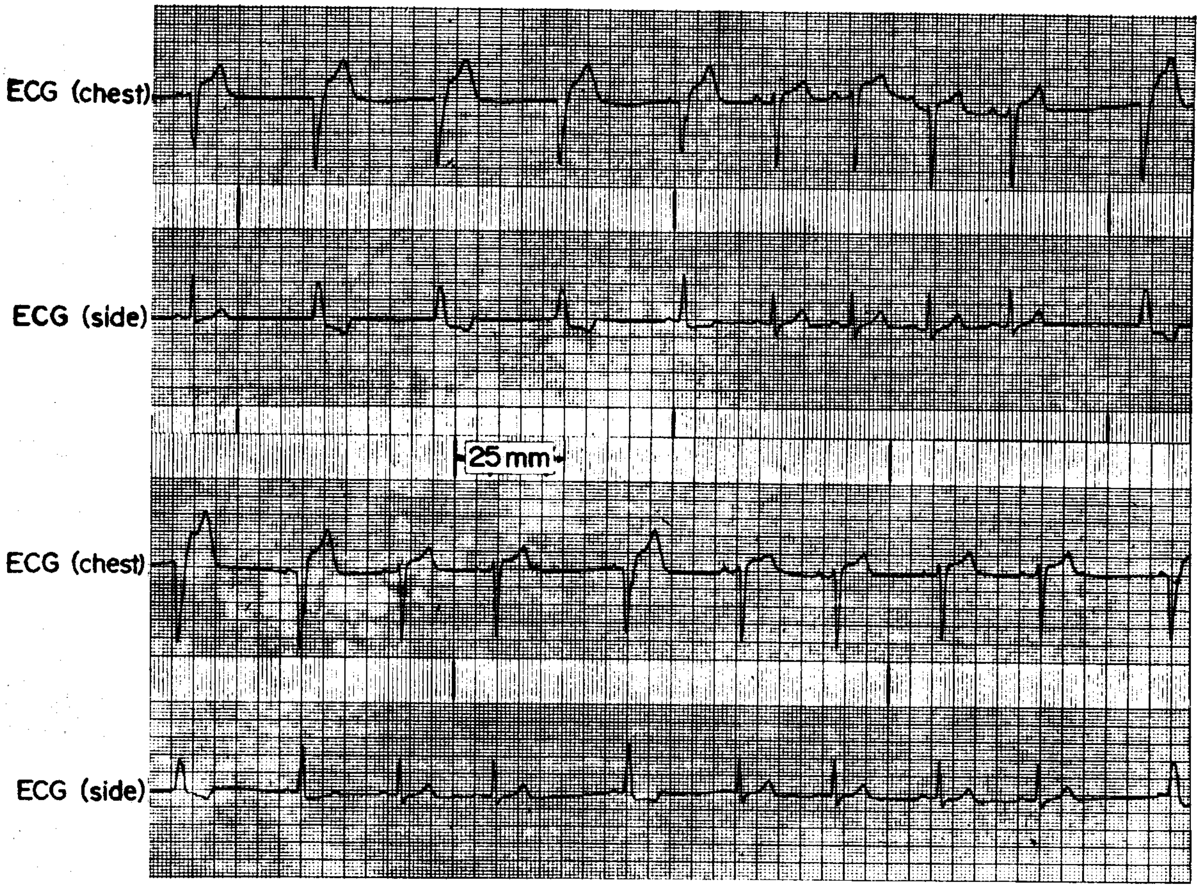
Central Nervous System

Psychological tests as distinct entities unrelated to in-flight tasks were not conducted. Instead, the high quality of performance on all missions served to described the adequacy of functioning of the central nervous system. This was illustrated during launch, rendezvous and docking, extravehicular activities, and the many accurate landings and recoveries. There was no evidence, either inflight or postflight, of any psychological abnormalities.

The EEG was used to evaluate sleep during the 14-day mission. A total of 54 hours and 43 minutes of interpretable EEG data was obtained. Variations in the depth of sleep from Stage 1 to the deep sleep in Stage 4 were noted in both in-flight and ground-based data.

Numerous observations reported by the crews involved in-flight sightings and descriptions of ground views. The actual determination of visual acuity was made in flight as well as in preflight and postflight examinations. All of these tests have supported the statement that *vision is not adversely affected during weightless flight.*

As previously noted, there had been much conjecture concerning vestibular changes in a weightless environment. In contrast to the data reported by the Russians, no evidence of altered vestibular function in flight was observed. Preflight and postflight caloric vestibular function studies and special studies of the otolith response revealed no significant changes. There were ample motions of the head in flight and during roll rates with the spacecraft, but there was never any vertigo or disorientation noted, even during the extravehicular activity when there was an occasional loss of all visual references. Several crewmen reported a feeling of fullness in the head similar in character to the fullness experienced when one



Recorder speed 25 mm/sec.

Figure 25-3. MA-9. Sample Record Illustrating Nodal Beats Occurring During Cancelled Launch Countdown.

is turned upside down. It is probable that this sensation resulted from altered distribution of blood in the weightless state. The lack of in-flight vestibular symptoms is interesting in view of the fact that a number of astronauts developed motion sickness while in the spacecraft on the water.

Skin

In spite of the moisture attendant to space suit operations, the skin remained in remarkably good condition through 14 days of space flight. Following the 8-day flight, some drying of the skin was noted during the immediate postflight period, but this was easily treated with lotion. There were no infections and there was only minimal reaction around the sensor sites. Dandruff was an occasional problem, easily controlled with preflight and postflight medication.

Eye, Ear, Nose and Throat

Two in-flight incidents of rather severe eye irritation occurred. One was the result of exposure to lithium hydroxide in the suit circuit. The other was not explained. In a few instances, a postflight conjunctival irritation which lasted only a few hours, was noted. The latter condition was attributed to the oxygen environment. Some nasal stuffiness occurred during the early portion of the flight, normally, the first 2 or 3 days. This nasal congestion was also related to the 100% oxygen environment and was usually self-limited. On occasion, the condition was treated locally or by oral medication.

The Respiratory System

Preflight and postflight X-rays failed to reveal any atelectasis. Pulmonary function studies before and after the 14-day mission revealed no alteration. Although no specific difficulties or symptomatology involving the respiratory system were evident, some rather high respiratory rates during heavy work loads in the extravehicular activity were present. Respiratory rates during all of the long-duration missions tended to vary normally, along with heart rate. The hyperventilation syndrome did not occur in flight.

The Cardiovascular System

The cardiovascular system was the first of the major body systems to show physiologic change following flight. Peak heart rates were observed at launch and at reentry, normally reaching higher levels during the reentry period. The midportions of all missions were characterized by more stable heart rates at lower levels with adequate response to physical demands.

Electrocardiograms were studied in detail throughout all missions. The only abnormalities of note during the Gemini program were very rare, premature auricular and ventricular contractions. There were no significant changes in the duration of specific segments of the electrocardiogram.

The only truly remarkable thing in all blood pressures, to date, has been the lack of significant increase or decrease with prolonged space flight. Blood pressure data obtained in the Gemini program showed that systolic and diastolic values remained within the envelope of normality throughout 14 days of space flight.

Cardiac cycle data were derived through synchronous phonocardiographic and electrocardiographic monitoring. Wide fluctuations in the duration of the cardiac cycle, but within physiological limits, were observed throughout these missions. Fluctuations in the duration of electromechanical systole correlated closely with changes in heart rate. Stable values were observed for electromechanical delay (onset of QRS to onset of first heart sound) throughout the missions, with shorter values observed during the intervals of peak heart rates recorded during lift-off, reentry, and extravehicular activity. The higher values observed for the duration of systole and for electromechanical delay in certain astronauts suggest a preponderance of cholinergic influences (vagal tone). An increase in sympathetic tone (adrenergic reaction) was generally observed during lift-off, reentry, and in the few hours preceding reentry.

In Mercury, postflight tilt tests demonstrated the presence of moderate orthostatic hypotension, with far greater heart rates required to maintain effective cardiovascular function (see figures 25–4 and 25–5). Compensation was achieved, however, and the pilot did not develop even near-syncope. Contributing stress factors, including heat, the effect of prolonged confinement, dehydration, fatigue, and a possible effect of weightlessness *per se*, are thought to be the principal elements responsible for this change.

In contrast, orthostatism resulting from any Gemini mission was detectable only by means of passive tilt-table provocation (see figure 25–6). Tilt-table procedures were monitored with electronic equipment providing automatic monitoring of blood pressure, electrocardiogram, heart rate, and respiration. The procedure consisted 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 were used to measure changes in the circumference of the calf. On the 4-day, 8-day, and 14-day missions, no symptoms of faintness were experienced by the crew at any time during the landing sequence or during the post-landing operation. There was 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 gen-

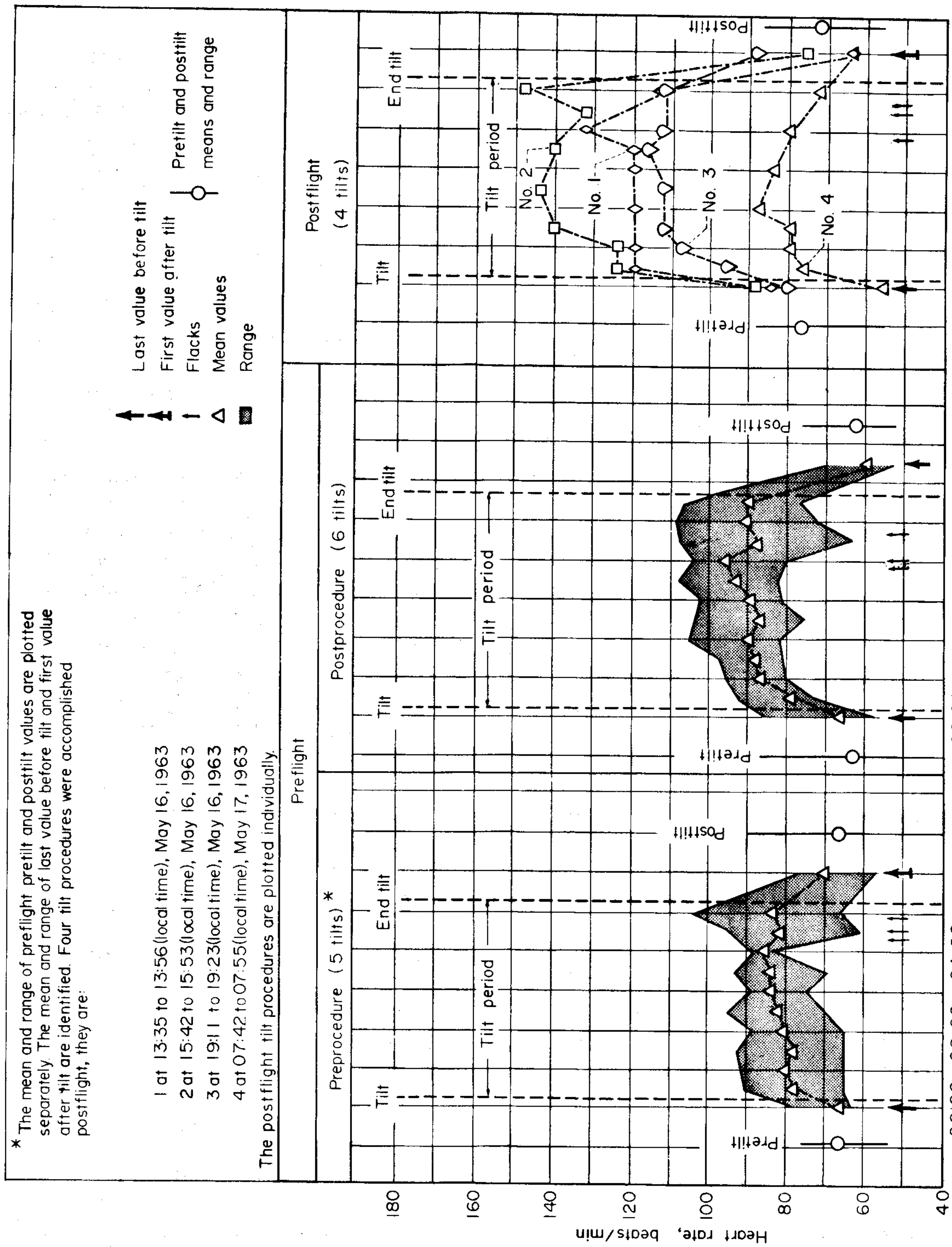


Figure 25-4. MA-9. Tilt Studies, Heart Rate Responses.

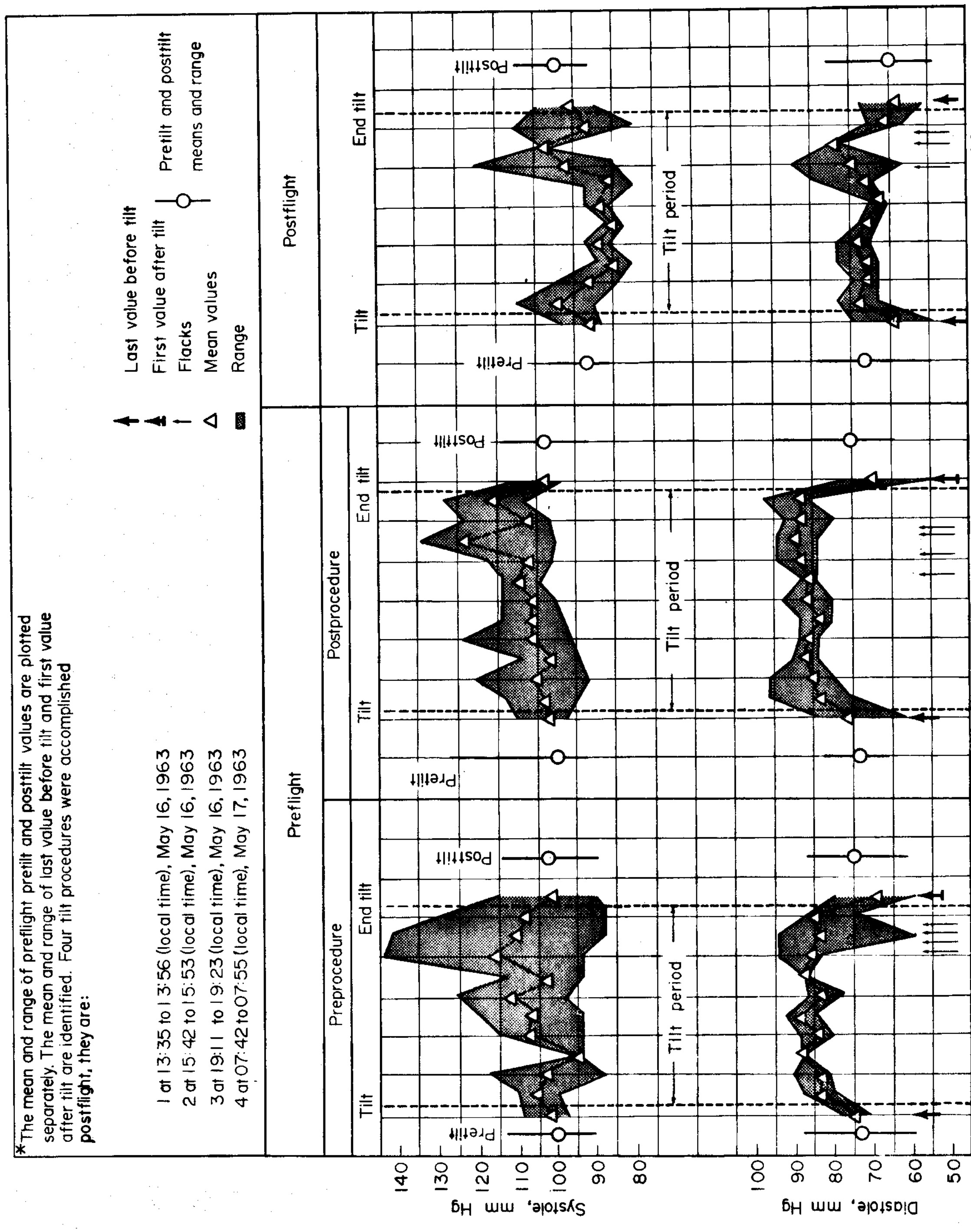


Figure 25-5. MA-9. Blood Pressure Responses.

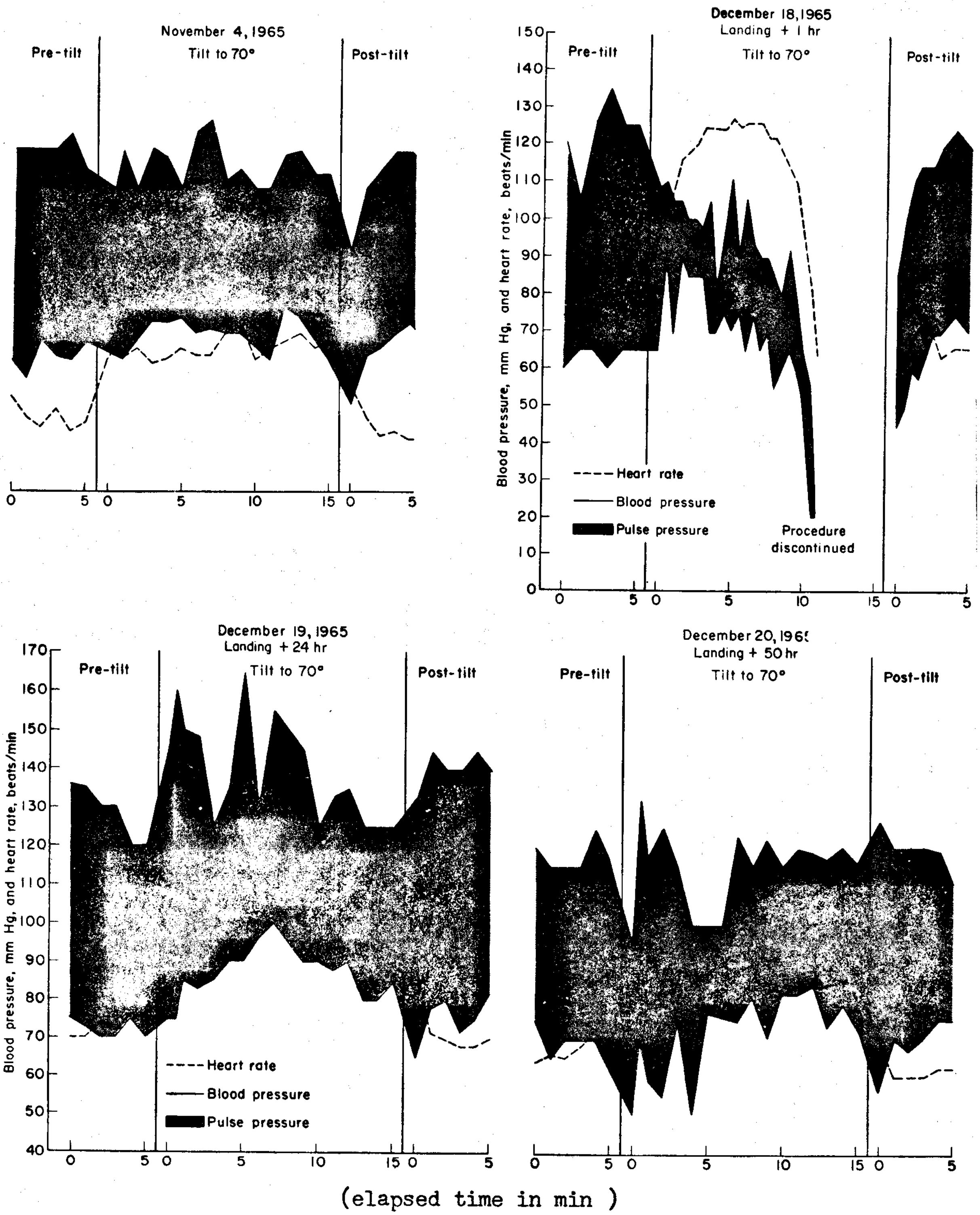


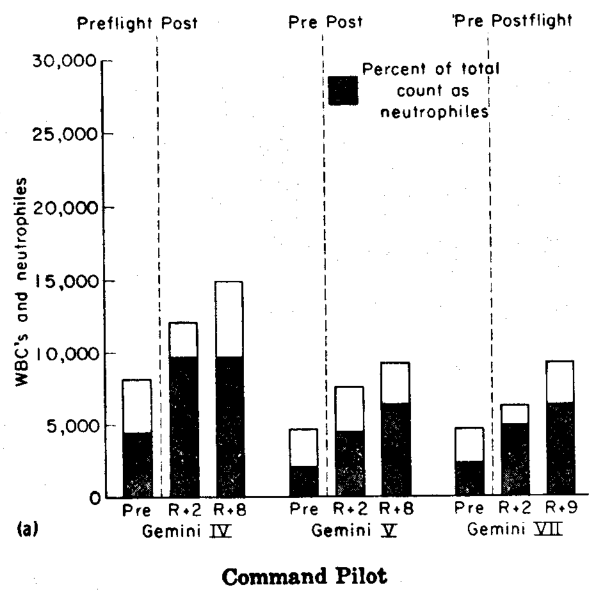
Figure 25–6. Tilt-Table Studies of Gemini 7 Pilot.

erally confirmed pooling of blood in the lower extremities during the period of, roughly, 50 hours that was required to readjust to the 1 G environment.

Blood Volume

On each of the long-duration flights, plasma volume was determined by the use of a technique using radioiodinated serum albumin. On the 4-day mission, red-cell mass was calculated by using 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 a 15% decrease in the circulating blood volume for the two crewmembers, a 13% decrease in plasma volume, and an indication of a 12% and a 13% 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 to get an accurate measurement of red-cell mass while continuing to use the radioiodinated serum albumin technique for plasma volume. The 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% decrease in blood volume, a 4% to 8% decrease in plasma volume, and a 20% 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 showed no change in the blood volume, a 4% and a 15% increase in plasma volume, and a 7% and a 19% decrease in red-cell mass for the two crewmembers. In addition, the red-cell survival time was reduced. These results are summarized in figures 25-7 and 25-8. 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 a 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 loss of red cells had not interfered with normal function and was generally equivalent to the blood withdrawn in a blood bank donation, but the decrease occurred for a longer time, thus allowing for adjustment.

The detailed explanation of the decreased mass is unknown at the present time, but



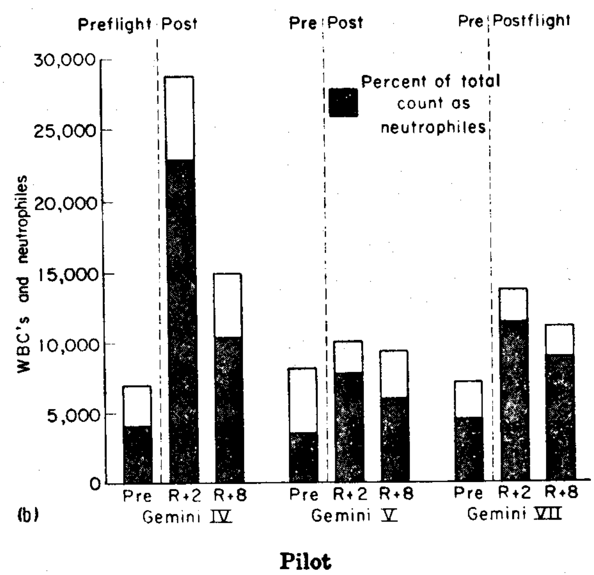


Figure 25-7. White Blood Cell Response.

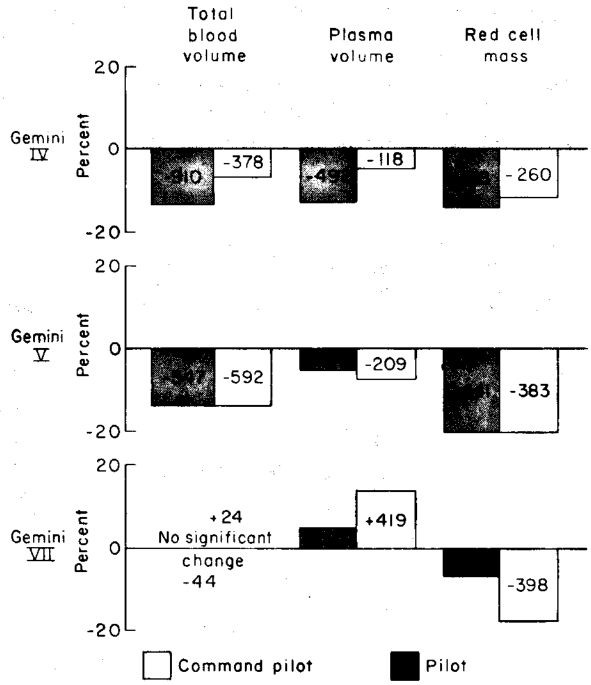


Figure 25-8. Blood Volume Studies.

several factors may underlie the red cell destruction. The variables which must be considered as possible causative factors are hyperoxia (*i.e.,* 166 mm O_2 at the alveolar membrane), lack of inert diluent gas (*i.e.,* nitrogen), relative immobility of the crew, dietary factors, and weightlessness. Of the factors stated, only increased oxygen tension, immobility and dietary factors are well known to influence the erythron. Dietary considerations may be of considerable importance, but no definite incriminations can be levied against the flight diet at this point. Immobility is effective in reducing red-cell mass by curtailing erythrocyte production; however, all flight observations support hemolysis as the significant event. Although not demonstrated by any previous studies, it is possible that weightlessness is a contributing factor in the hemolysis observed. Altered hemodynamics, resulting in hemostasis, could inflict a pre-lytic lesion on the erythrocytes involved and thereby result in the cell's premature demise. The role of a diluent gas (nitrogen) is not well understood; however, there has been shown a significant reduction in hematologic and neurologic toxicity in animals exposed to high pO_2 when an "inert" gas is present. Therefore, the absence of an "inert" atmospheric diluent could be significant at the hyperoxic levels encountered within the Gemini spacecraft.

Of all the mechanisms stated, oxygen has the greatest proven potential as a hemolytic agent. It has several documented deleterious effects on red-cell plasma membranes and metabolic functions, any combination of which could be operative within a Gemini spacecraft.

Biochemical Aspects

The analysis of urine and plasma has been used as an indication of astronaut physiological status preflight, in-flight, and postflight. Analyses of the results obtained in all three phases of the 14-day Gemini 7 flight were performed (see tables 25-7 and 25-8).

As expected, since a prime function of the homeostatic mechanisms of the body is to maintain the composition of blood and extracellular fluid as nearly constant as possible, significant changes in plasma were not observed. Pooled samples of flight urine indicated a slight reduction in the output of sodium during flight. This was associated with some increase in aldosterone excretion. Postflight, there was a marked retention of sodium. Chloride excretion paralleled the sodium excretion, and potassium excretion during flight appeared depressed and, in all but one instance, was depressed immediately postflight. This depression was observed in both the total 24-hour output and the minute output. The antidiuretic hormone appeared elevated in only the first postflight sample of the Gemini 7 pilot.

Calcium, magnesium, phosphate, and hydroxyproline were measured in plasma and in urine obtained preflight, in-flight, and postflight, as a continuing evaluation of the effects of space flight on bone demineralization. Following the 14-day flight, postflight plasma samples showed a marked increase in the bound hydroxyproline, while larger quantities of calcium were excreted later in the

TABLE 25-7. GEMINI 7 COMMAND PILOT PLASMA ANALYSIS (1965)

Components	Preflight		Postflight			
	Nov. 25	Dec. 2	Dec. 18 (1130 hr)	Dec. 18 (1820 hr)	Dec. 19	Dec. 21
Sodium, meq/liter	147	146	138	140	144	143
Potassium, meq/liter	4.7	5.4	4.1	4.7	4.7	4.9
Chlorine, meq/liter	103	103	100	102	103	106
Phosphate, mg, percent	3.2	3.7	4.0	4.2	3.1	3.6
Calcium, mg, percent	9.0	9.2	8.6	9.2	9.0	9.2
Urea nitrogen, mg, percent	19	16	16	20	25	18
Uric acid, mg, percent	6.8	6.6	4.6	6.0	5.9	6.0
Total protein, g, percent	7.3	7.4	6.8	7.6	7.0	7.1
Albumin, g, percent	4.7	4.9	4.2	QNS	4.5	4.6
17-OH corticosteroids, micrograms per 100 ml	18.8	----------	28.3	16.0	----------	----------
Hydroxyproline, micromilligrams per ml:						
Free	.008	.007	.010	.011	----------	----------
Bound	.131	.146	1.51	.185	----------	----------
Total	.139	.153	.161	.196	----------	----------

TABLE 25-8. GEMINI 7 COMMAND PILOT URINALYSIS (1965)

Components	Preflight		Postflight	
	Nov. 23	Dec. 1	Dec. 18	Dec. 21
Chlorine, meq	144	148	61	145
Calcium, mg	254	266	310	268
Uric acid, g	.96	.95	1.20	1.07
Total volume, ml	2920	3235	2160	3690
Sodium, meq	141	146	64	133
Potassium, meq	93.0	79	73	106
Phosphate, g	1.13	1.16	1.72	1.12
17-hydroxycorticosteroids	6.9	8.76	13.69	9.28
Total nitrogen, g	19.2	22.6	30.9	20.5
Urea nitrogen, g	18.1	18.5	26.6	18.7
Hydroxyproline, mg	48.74	37.0	65.4	39.9
Creatinine, g	2.11	2.11	2.86	1.80

flight than during the early phases of the flight, findings consistent with a change in bone structure.

Gastrointestinal System

The design and fabrication of foods for consumption during space flights imposed unique technological considerations. The volume of space food per man-day varied in the Gemini mission from 130 to 162 cubic inches (2131 cc to 2656 cc). Menus were made up of approximately 50 to 60% rehydratables (foods requiring the addition of water prior to ingestion), requiring food-packaging permitting both a method for rehydration and dispensing of food in zero G. The remaining foods were bite-size. About 50% of both the rehydratable and bite-size foods were freeze-dried products; the remaining were other types of dried or low-moisture foods, some of which were compressed. A typical menu had an approximate calorie distribution of 17% protein, 32% fat and 51% carbohydrate. Total calories provided and eaten per day varied from flight to flight. Although weight loss occurred on all missions, the amount of weight loss did not increase with mission duration.

Gastrointestinal-tract function on all missions was normal and there was no evidence of excess nutrient losses due to poor food digestibility during flight. Before the missions, the crews ate a low-residue diet and, in addition, on all flights, beginning with the Gemini 5 mission, oral and suppository laxatives were used during the last 2 days before flight. Figure 25-9 illustrates the in-flight defecation frequency. On the shorter EVA missions, crew preparation generally allowed them to avoid defecation in flight.

Genitourinary System

Difficulties involving the genitourinary system were not encountered during any of the missions. Urination occurred normally, both in-flight and postflight, and there was no evidence of renal calculi (see figure 25-10).

Musculoskeletal System

To date, the information available on bone and muscle metabolism as affected by space flight is limited to a very few subjects under varying dietary intakes and multiple flight stresses.

The bone demineralization (percent change in density) which occurred in the os calcis and phalanx 5-2 during the 14-day flight and under equivalent periods of bed rest with analogous intake of calcium, was definitely less in the 14-day flight, where calcium intake approached 1,000 mgs per day and the crew exercised routinely (see table 25-9). In all instances, the data on the bones examined indicates a negative change, and the

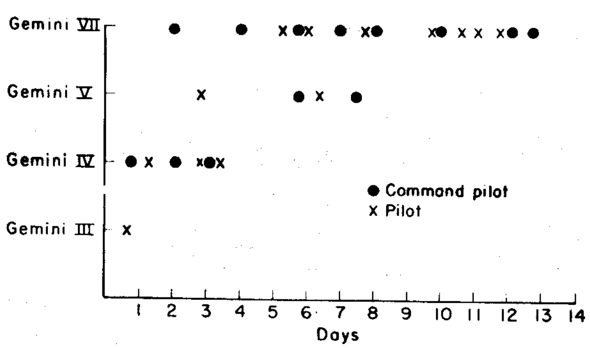


Figure 25-9. In-Flight Defecation Frequency.

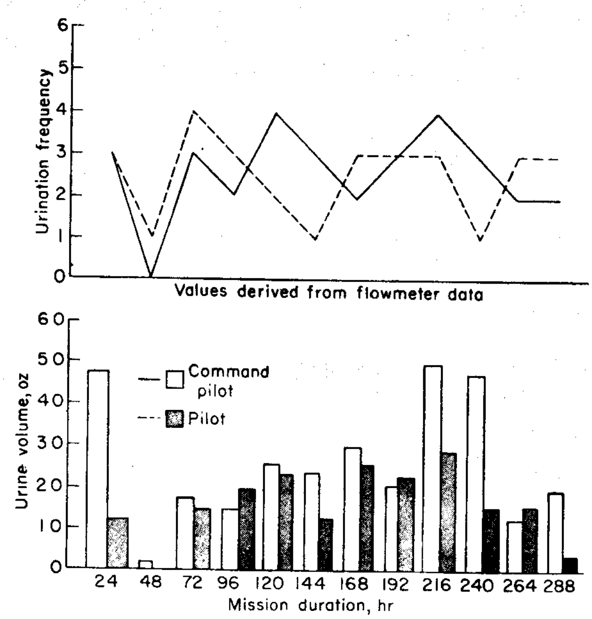


Figure 25-10. Urine Volume and Urination Frequency of Gemini 7 Flight Crew.

TABLE 25-9. COMPARISON OF BONE DENSITY CHANGES IN GEMINI 7 CREW WITH BEDREST SUBJECTS ON SIMILAR DIETS FOR 14 DAYS

	Gemini VII crew		TWU bedrest subjects
	Command pilot	Pilot	
Mean calcium daily intake (estimated), grams	1.00	1.00	(1) 0.931 (2) 1.021 (3) 1.034 (4) 1.020 (5) 0.930
Change in conventional section of os calcis in bone mass (calibration wedge equivalency), percent	−2.91	−2.84	(1) −3.46 (2) −3.56 (3) −5.79 (4) −5.11 (5) −5.86
Change in bone mass of hand phalanx 5-2, percent	−6.78	−7.83	(1) −1.57 (2) −1.00 (3) −0.44 (4) −0.96 (5) −1.27

calcium-balance data collected on Gemini 7 verifies a negative-balance trend. None of the changes is pathological, but they do indicate that ameliorative methods for use during flights of longer duration need to be examined.

It is interesting to note the differences in bone-mass change occurring in the several flights (see table 25-10). It is probable that the superior findings in the os calcis during the 14-day Gemini 7 flight could be attributed to a number of factors, among them the following: the crewmembers of this mission ate a far higher proportion of the diet prepared for them than did those of Gemini 4 and Gemini 5; had isometric and isotonic exercises daily for prespecified periods of time; used an exerciser routinely; and slept for longer periods of time.

Medication

Medications in both injectable and tablet form were routinely provided on all flights. The basic policy has continued to be that drugs are to be used only if necessary. A list of the supplied drugs is shown in table 25-11. The injectors may be used through the suit, although, to date, none has been utilized. Various drugs were used for symptomatic treatment of minor complaints, but the only significant medication used was d-amphetamine, taken prior to reentry by the Gemini 4 crew. This drug was taken to insure an adequate state of alertness during the 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 with any drug that may be used. Pretesting of all of the medications listed was carried out on each of the crews.

The medical results of the United States manned space flight efforts have been gratifying. Not only has new knowledge been acquired, but this knowledge has, in turn, generated confidence and assurance in the role of man in Apollo and future space exploration programs.

Crewmembers experienced no disorientation on any Gemini mission. The crews adjusted very easily to the weightless environ-

TABLE 25-10. COMPARISON OF BONE DENSITY CHANGES IN CREWMEN OF GEMINI 4, GEMINI 5, AND GEMINI 7 DURING SPACE FLIGHT

Position of anatomical site evaluated	Change in bone mass,[a] percent	
	Command pilot	Pilot
Conventional os calcis scan:		
Gemini IV	−7.80	−10.27
Gemini V	−15.10	−8.90
Gemini VII	−2.91	−2.84
Multiple os calcis scans:		
Gemini IV	−6.82	−9.25
Gemini V	−10.31	−8.90
Gemini VII	−2.46	−2.54
Hand phalanx 5-2 scans:		
Gemini IV	−11.85	−6.24
Gemini V	−23.20	−16.97
Gemini VII	−6.78	−7.83
Hand phalanx 4-2 scans:		
Gemini IV	([b])	([b])
Gemini V	−9.98	−11.37
Gemini VII	−6.55	−3.82

[a] Based on X-ray absorbency of calibration wedge.
[b] Not done on this flight.

ment and accepted readily the fact that objects will stay in position in midair or will float. There was no difficulty in reaching various switches or other items in the spacecraft. The crewmen moved their heads at will and noticed no aberrant sensations. They were always oriented to the interior of the spacecraft and could orient themselves in relation to the earth by rolling the spacecraft and finding the horizon through the window. During the extravehicular operations, the pilot oriented himself by his relationship to the spacecraft in all of the maneuvers. Looking repeatedly at the sky and the earth, he had no sensations of disorientation or motion sickness. 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, thus allowing them to wait a longer time before damping the rates with thruster activity. During the 14-day flight, the crew repeatedly moved their heads in various directions 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; one time, they performed a spin-dry maneuver to empty the water boiler, which 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 noted an increased G-sensitivity at the time of retrofire and reentry. All felt that they were experiencing several Gs when the G-meter was just beginning to register at reentry. However, when the peak G-load was reached, their sensations did not differ from their centrifuge experience.

The crews described a sensation of fullness in the head that occurred during the first 24 hours of the mission and then gradually disappeared. This feeling was 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.

An early problem of concern was the question of the ability of the crewmembers to get along with one another for the long flight periods. Every effort was made to choose crewmembers who were compatible. It is truly remarkable that none of the crews, including the long-duration crews, had any in-flight psychological difficulties that were evident to the ground monitors or that were discussed in postflight debriefings. They had some normal concerns for the inherent risks of space flight. There was some expected increased tension at lift-off and prior to retrorocket firing; also, a normal psychological letdown when the Gemini 7 crew saw the Gemini 6A spacecraft depart after their rendezvous. However, the Gemini 7 crew ac-

TABLE 25-11. GEMINI 7 IN-FLIGHT 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.

TABLE 25-12. 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.

cepted this very well and immediately adjusted to the flight-plan activity.

From a medical point of view, over-all crew performance was exemplary during all flights. There was no decrease in performance noted, and the fine control tasks, such as reentry and, notably, the 11th-day rendezvous during the Gemini 7 mission, were handled with skill.

The long-duration flights confirmed previous observations that the flight crews were exposed to very low radiation-dose levels at orbital altitudes. The body dosimeters on these missions recorded only millirad doses which were at an insignificant level. The recorded doses are shown in table 25-12.

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Director of Administrative Services

Summary of Revised, Deleted, or Added Material

This pamphlet contains major revisions of chapters from the Flight Surgeon's Manual pertaining to the following: Aerospace Medicine Program (chap 1); Effects of Decreased Partial Pressure of Oxygen, Decreased Barometric Pressure, Accelerative Forces, and Temperature (chaps 2 thru 5); Otolaryngologic Aspects—Barometric Pressure Changes (chap 6); Noise, Problems of the Eye, Psychiatric Disorders, Dental Problems, Drugs, Fatigue, and Nutrition (chaps 7 thru 13); Aviation Pathology, Aircraft Accident Prevention and Investigation, Emergency Egress, and Rescue and Recovery (chaps 14 thru 17); Pressure Suits (chap 18); Aeromedical Evacuation (chap 19); Military Public Health and Occupational Medicine (chaps 20 and 21); Water Control (chap 22); Control of Arthropods and Rodents (chap 23); Disaster Preparedness for Nuclear, Biological and Chemical Operations (chap 24); Space Medicine (chap 25). It does not contain the following topics from the Flight Surgeon's Manual: Epidemiology; Specific Diseases; Immunizations; Aircraft, Field and Food Service Sanitation; Medical Service Organization, Personnel, Research, Intelligence, Materiel, Treatment Facilities, Training, and Administrative and Operational Procedures.