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

By Charles A. Berry, M.D.
Chief of Center Medical Programs
Manned Spacecraft Center

D. O. Coons, M.D., Chief
Center Medical Office
Manned Spacecraft Center

A. D. Catterson, M.D.
Center Medical Office
Manned Spacecraft Center

G. Fred Kelly, M.D.
Center Medical Office
Manned Spacecraft Center

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 one-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 in 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 are listed in table 24-I, and 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 is summarized in table 24-II. 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 sort of limit to man's exposure. The reported Russian experiences strengthened this possiblity. 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 3-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 United States manned space-flight missions are summarized in table 24-III.

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

These Gemini mission operations are complex and require a great deal of 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 started at the time of the original selection of the astronauts and 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 have 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.

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 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 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 24-1. A sample of the telemetered data, as received at the Mission Control Center, is shown in figure 24-2. These data were taken near the end of the 14-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 Center. If requested, the medical data from the ships can be transmitted immediately after each spacecraft pass. The combined Gemini VI-A and VII missions 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 possiblity 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. As yet 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 on 100 percent oxygen for at least 2 hours prior to launch. No difficulty has been experienced with this procedure.

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 crew members 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, as summarized in table 24-IV and the particular effects of 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 the 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 Gemini flights are shown in table 24-V. 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. 24-3). As the mission durations have become longer, it has been necessary to compress the heart rate data to the form shown in figure 24-4 from the Gemini VII mission. Such a plot demonstrates the diurnal cycles related to the night time and the normal sleep periods at Cape Kennedy, Florida. 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 mid-portion 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 2 or 3 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 into the high thirties. The graphing of such rates by minimum, 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 crewman noted increased heart rates. The pilot had a heart rate of 140 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, premature 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 duration of space flight.

Blood Pressures

The blood pressure values were determined three times in each 24 hours during the 4-day 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. 24-5). The blood pressures have varied 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 transition to two-point, 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 would get 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 inflight.

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 7.5 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 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 program the sleep periods in conjunction with normal night time 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 night time 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 night time at Cape Kennedy. There was a 10-hour period established for this sleep (fig. 24-6) 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 crew member. 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 does on the earth and our inflight observations were 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 he 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-day and 14-day missions. The crew of the 4-day flight was markedly fatigued following the mission. The 8-day crew was 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.

Food

The diet has been controlled for a period of 5 to 7 days preflight and, in general, has been of a low residue. The Gemini VII crew were on a regulated calcium diet of 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 24-VI. 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 was furnished a menu of 2500 calories per day to be eaten at a rate of 4 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. These findings were in marked contrast to the 8-day mission where each crew member was furnished 3 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 postflight 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 included ample meals for $14\frac{2}{3}$ days. Inflight and postflight analyses have revealed that this crew actually consumed about 2200 calories per day.

Water Intake

There has been an ample water supply on all of these missions consisting of approximately 6 pounds per man per day of potable water. 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 one-half 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 24-7.

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 24-8 allowed for collection of a 75cc 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 24-9.

The sticky surfaces of the bag opening can be positioned much easier if the crewmen is out of the space suit as occurred during the 14-day flight. The system does create only a minimum amount of difficulty during use inflight 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 Experiment M-7.

Bowel habits have varied on each of three long-duration missions, as might be expected. Figure 24-10 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 24-11 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.

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 24-VII and the medical kit is shown in figure 24-12. The injectors may be used through the suit, though to date none have been utilized. The only medication used thus far has been dexedrine taken prior to reentry by the Gemini IV crew. This 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 crew member must be pretested to any drug which may be potentially used. Such pretesting of all of the medications listed in table 24-VII has been carried out with each of the crews.

On the 14-day mission, a sensor repair kit, shown in figure 24-13, 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 crew members to get along with one another for the long flight periods. Every effort is made to choose crew members who are compatible, but it is truly remarkable that none of the crews, including the long-duration crews, have had any inflight psychological difficulties 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 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 presleep period, and felt they were of value. In neither instance were the books completed. 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 crew members 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 mid-air 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 manuevers. 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 and create disorientation but to no avail. They also had tumble rates of 7 to 8 degrees 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's 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 crew members 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 one-g environment at which time their limbs became sensitive to weight. In 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 the 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. Following the 8-day and 14-day missions, the crew members skin was in excellent condition. The 8-day flight crew members 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 crew members 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 crew members, in particular, their skin condition, is, to a large extent attributable to the unsuited operations.

Bacterial cultures were taken from each crew member's throat and 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.

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 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 crew members 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 crew members; however, it has not increased with mission duration and has averaged 7 to 8 pounds. The majority of the loss has been replaced with fluid intake within the first 10 to 12 hours after landing. Table 24-VIII shows the weight loss and postflight gain recorded for the crewmen of the long-duration flights.

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 24-14. 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. This finding was only minimally present following the 8-day flight and was noted again following the 14-day flight. It most likely can be explained as due to an epinephine response. The red-cell counts show some postflight 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 24-IX and 24-X. The significant changes noted will be discussed with Experiment M-5.

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 7 and 15 percent decrease in the circulating blood volume for the two crew members, and 13 percent decrease in plasma volume, and an indication of 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 chromium-tagged red cells also provided a measure of red-cell survival time. At the completion of the 8-day mission, there was 13 percent decrease in blood volume, 4 to 8 percent decrease in plasma volume and 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 spaceflight environment. The 14-day flight results show no change in the blood volume, 4 and 15 percent increase in plasma volume and 7 and 19 percent decrease in red-cell mass for the two crew members. In addition to these findings, the red-cell survival time has been reduced. All of these results are summarized in figure 24-15. 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.

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 24-16 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-degree, 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 postlanding operation. Abnormal tilt table responses, when compared with the preflight baseline tilts, have been noted for a period of 48 to 50 hours after landing. Typical initial postlanding tilt responses are graphed for the 4-day and 8-day mission crews in figures 24-17, through 24-20. 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 24-21. 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 24-22 and 24-23.

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 beautiful 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 24-21, 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, 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 one-g environment. The results of these studies may be seen in figure 24-24.

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 24-XI shows the medical experiments which have been conducted on the Gemini flights to date.

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 24-XII.

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 one-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 crewmen'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 24-I

PREDICTED WEIGHTLESS EFFECTS

- ANOREXIA
- NAUSEA
- DISORIENTATION
- SLEEPINESS
- SLEEPLESSNESS
- FATIGUE
- RESTLESSNESS
- EUPHORIA
- HALLUCINATIONS
- DECREASED g TOLERANCE
- G. I. DISTURBANCE
- URINARY RETENTION
- DIURESIS
- MUSCULAR INCOORDINATION
- MUSCLE ATROPHY
- DEMINERALIZATION OF BONES

TABLE 24-II

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POST MERCURY MEDICAL STATUS

NO PROBLEM

- LAUNCH AND REENTRY ACCELERATION
- SPACECRAFT CONTROL
- PSYCHOMOTOR PERFORMANCE
- EATING AND DRINKING
- ORIENTATION
- URINATION

REMAINING PROBLEMS

- DEFECATION
- SLEEP
- ORTHOSTATIC HYPOTENSION

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TABLE 24-III

UNITED STATES' MANNED SPACEFLIGHTS

ASTRONAUTS	LAUNCH DATES	DURATION
SHEPARD	5-5-61	15 MIN
GRISSOM	7-21-61	15 MIN
GLENN	2-20-62	4 HRS 56 MIN
CARPENTER	5-24-62	4 HRS 56 MIN
SCHIRRA	10-3-62	9 HRS 14 MIN
COOPER	5-15-63	34 HRS 20 MIN
GRISSOM YOUNG	3-3-65	4 HRS 52 MIN
MC DIVITT WHITE	6-3-65	96 HRS 56 MIN
COOPER CONRAD	8-21-65	190 HRS 56 MIN
BORMAN LOVELL	12-4-65	330 HRS 35 MIN
SCHIRRA STAFFORD	12-15-65	25 HRS 51 MIN

TABLE 24-IV

SPACE FLIGHT STRESSES

FULL PRESSURE SUIT
CONFINEMENT AND RESTRAINT
100% OXYGEN 5 psi ATMOSPHERE
CHANGING CABIN PRESSURE (LAUNCH AND ENTRY)
VARYING CABIN AND SUIT TEMPERATURE
ACCELERATION-G FORCE
WEIGHTLESSNESS
VIBRATION
DEHYDRATION
FLIGHT PLAN PERFORMANCE
SLEEP NEED
ALERTNESS NEED
CHANGING ILLUMINATION
DIMINISHED FOOD INTAKE

TABLE 24-V

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GEMINI

PEAK HEART RATES, BEATS/MIN

FLIGHT	LAUNCH	REENTRY
GEMINI III	152 120	165 130
GEMINI IV	148 128	140 125
GEMINI V	148 155	170 178
GEMINI VI	125 150	125 140
GEMINI VII	152 125	180 134

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TABLE 24-VI

TYPICAL GEMINI MENU

DAYS 2, 6, 10 & 14

	CALORIES
MEAL A	
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

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TABLE 24-VII
GEMINI VII INFLIGHT MEDICAL AND ACCESSORY KITS

MEDICAL KIT			
MEDICATION	DOSE AND FORM	LABEL	QUANTITY
CYCLIZINE HC1	50 mg TABLETS	MOTION SICKNESS	8
d-AMPHETAMINE SULFATE	5 mg TABLETS	STIMULANT	8
APC (ASPIRIN, PHENACETIN, AND CAFFEINE)	TABLETS	APC	16
MEPERIDINE HC1	100 mg TABLETS	PAIN	4
TRIPROLIDINE HC1 PSEUDOEPHEDRINE HC1	2.5 mg 60 mg TABLETS	DECONGESTANT	16
DIPHENOXYLATE HC1 ATROPINE SULFATE	2.5 mg 0.25 mg TABLETS	DIARRHEA	16
TETRACYCLINE HC1	250 mg FILM-COATED TABLET	ANTIBIOTIC	16
METHYLCELLULOSE SOLUTION	15cc IN SQUEEZE DROPPER BOTTLE	EYEDROPS	1
PARENTERAL CYCLIZINE	45 mg (0.9cc IN INJECTOR)	MOTION SICKNESS	2
PARENTERAL MEPERIDINE HC1	90 mg (0.9cc IN INJECTOR)	PAIN	2

ACCESSORY KIT	
ITEM	QUANTITY
SKIN CREAM (15cc SQUEEZE BOTTLE)	2
ELECTRODE PASTE (15cc SQUEEZE BOTTLE)	1
ADHESIVE DISCS FOR SENSORS	12 FOR EKG, 3 FOR PHONOCARDIOGRAM LEADS
ADHESIVE TAPE	20 IN.

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TABLE 24-VIII

ASTRONAUT BODY WEIGHTS IN LBS

FLIGHT	COMMAND PILOT	PILOT
GEMINI III	PREFLIGHT 158 POSTFLIGHT 155 1/4 (-2 3/4)	PREFLIGHT 165 POSTFLIGHT 161 1/2 (-3 1/2)
GEMINI IV	PREFLIGHT 156 1/2 POSTFLIGHT 152 (-4 1/2)	PREFLIGHT 173 POSTFLIGHT 164 1/2 (-8 1/2)
GEMINI V	PREFLIGHT 152 POSTFLIGHT 144 5/8 (-7 3/8)	PREFLIGHT 154 POSTFLIGHT 145 1/2 (-8 1/2)
GEMINI VI	PREFLIGHT 176 1/4 POSTFLIGHT 174 (-2 3/8)	PREFLIGHT 171 POSTFLIGHT 162 7/10 (-8 3/10)
GEMINI VII	PREFLIGHT 162 1/2 POSTFLIGHT 152 1/2 (-10)	PREFLIGHT 169 1/2 POSTFLIGHT 163 1/5 (-6 3/10)

TABLE 24-IX (a)

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GEMINI VII URINE CHEMISTRIES

COMMAND PILOT

DETERMINATION	PREFLIGHT	← POSTFLIGHT		→
DATE, 1965	11/23+12/1	12/18	12/20	12/21
$Na^+ \frac{meg}{24\ HRS}$	143	95 (66%)*	182 (127%)	150 (105%)
K^+	71	118 (166%)	93 (131%)	90 (127%)
Cl^-	141	89 (63%)	168 (119%)	145 (103%)
$Ca^{++} \frac{mg}{24\ HRS}$	228	269 (118%)	260 (114%)	210 (92%)
$PO_4^{\equiv}$	1131	2133 (188%)	936 (83%)	978 (86%)
17OHCS	7.7	18.6 (241%)	7.3 (95%)	9.1 (118%)
$Epi \frac{ug}{24\ HRS}$	7.8	16.4 (210%)	N S	N S
Nor Epi	50.3	103.0 (204%)	N S	N S
ALDOSTERONE ug/24 HRS	26	75 (288%)		28 (108%)
$CREAT, \frac{mg}{24\ HRS}$	2035	3297 (162%)	1380 (68%)	2070 (102%)

*PERCENT OF PREFLIGHT VALUE

TABLE 24-IX (b)

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GEMINI VII URINE CHEMISTRIES
PILOT

DETERMINATION	PREFLIGHT	POSTFLIGHT		
DATE, 1965	11/23+12/1	12/18	12/20	12/21
Na^+ $\frac{meg}{24\ HRS}$	150	76 (51%)	94 (63%)	
K^+	70	60 (86%)	89 (127%)	
Cl^-	141	67 (48%)	73 (52%)	
Ca^{++} $\frac{mg}{24\ HRS}$	184	89 (48%)	105 (57%)	
$PO_4^{\equiv}$	1200	996 (83%)	1345 (112%)	
17OHCS	6.2	11.3 (183%)	8.1 (130%)	8.2 (132%)
Epi $\frac{ug}{24\ HRS}$	10.2			
Nor Epi	42.7			
ALDOSTERONE ug/24 HRS	26	47 (181%)		60 (230%)
CREAT, $\frac{mg}{24\ HRS}$	2230	2003 (90%)	2225 (100%)	

TABLE 24-X

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GEMINI VII BLOOD CHEMISTRY STUDIES

COMMAND PILOT

DETERMINATION	PREFLIGHT		POSTFLIGHT			
DATE, 1965	NOV 24 AND NOV 25	NOV 30 AND DEC 2	DEC 18 11:30 A M E S T	DEC 18 18:20 A M E S T	DEC 19	DEC 20 AND DEC 21
BLOOD UREA NITROGEN (BUN) mg PERCENT	19	16	16	20	25	18
BILIRUBIN, TOTAL mg PERCENT	0.4	0.2	0.3	—	0.3	0.4
ALKALINE PHOSPHATASE (B-L UNITS)	1.7	2.0	1.7	—	—	—
17-OH CORTICOSTEROIDS, mg PERCENT						
SODIUM, m Eq/l	147	146	138	140	144	143
POTASSIUM, m Eq/l	4.7	5.4	4.1	4.7	4.7	4.9
CHLORIDE, m Eq/l	103	103	100	102	103	106
CALCIUM, mgms PERCENT	9.0	9.2	8.6	9.2	9.0	9.2
PHOSPATE, mgm PERCENT	3.2	3.7	4.0	3.2	3.1	3.6
GLUCOSE, mgm/100 ml, NON-FASTING	71	90	98	—	—	
ALBUMEN, gm PERCENT	4.6	4.73	5.16	—	4.5	4.6
ALPHA 1, gm PERCENT	0.23	0.26	0.08	—	—	—
ALPHA 2, gm PERCENT	0.40	0.39	0.40	—	—	—
BETA, gm PERCENT	0.63	0.84	0.72	—	—	—
GAMMA, gm PERCENT	1.03	0.97	0.72	—	—	—
TOTAL PROTEIN, gm PERCENT	6.9	7.2	7.1	7.6	7.0	7.1
URIC ACID, mgm PERCENT	6.8	6.6	4.6	6.0	5.9	6.0

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TABLE 24-XI

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 MED OPS 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 & NITROGEN BALANCE STUDY			X
M-8	SLEEP ANALYSIS			X
M-9	OTOLITH FUNCTION		X	X

TABLE 24-XII (a)

NASA-S-66-1712 FEB 17

RADIATION DOSAGE ON GEMINI LONG-DURATION MISSIONS IN M RAD

GEMINI IV

COMMAND PILOT	PILOT
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

COMMAND PILOT	PILOT
190 ± 19	140 ± 14
173 ± 17.3	172 ± 17.2
183 ± 18.3	186 ± 18.6
195 ± 19.5	172 ± 17.2

*VALUES ARE LISTED IN SEQUENCE:
LEFT CHEST, RIGHT CHEST, THIGH, AND HELMET

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TABLE 24-XII (b)

RADIATION DOSAGE ON GEMINI LONG-DURATION MISSIONS IN M RAD

GEMINI VII

COMMAND PILOT	PILOT
178±10	98.8±10
105±10	215 ±15
163±10	151 ±10

* VALUES ARE LISTED IN SEQUENCE :
LEFT CHEST, RIGHT CHEST, THIGH

FIGURE 24-1

BIOSENSOR HARNESS AND SIGNAL CONDITIONERS

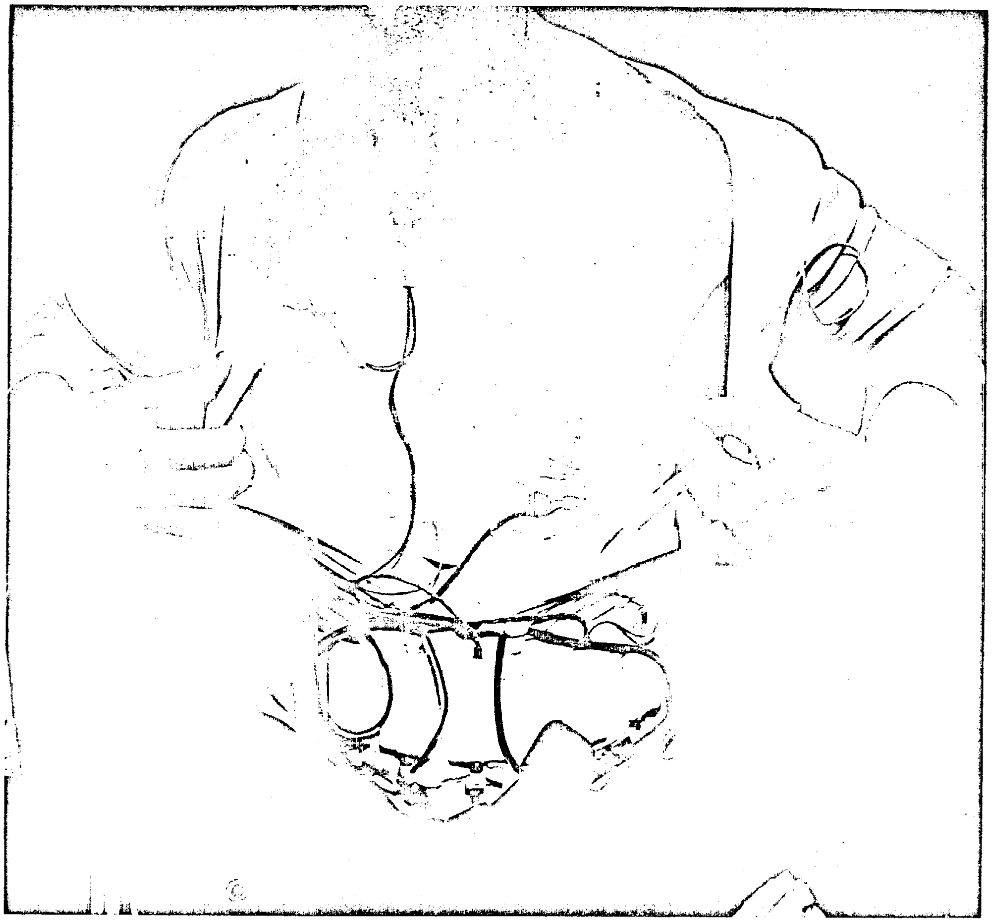


FIGURE 24-2

NASA-S-66-1772 FEB 18

SAMPLE OF BIOMEDICAL DATA

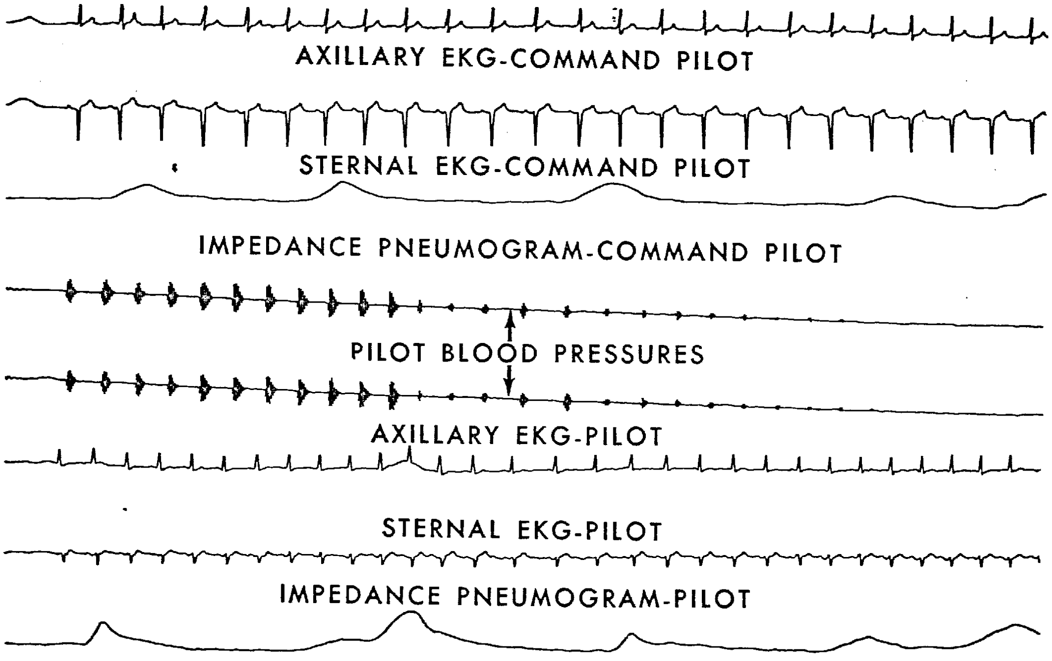


FIGURE 24-3 (a)

NASA-S-66-1770 FEB 18

GEMINI IV
PHYSIOLOGICAL MEASUREMENTS
PILOT

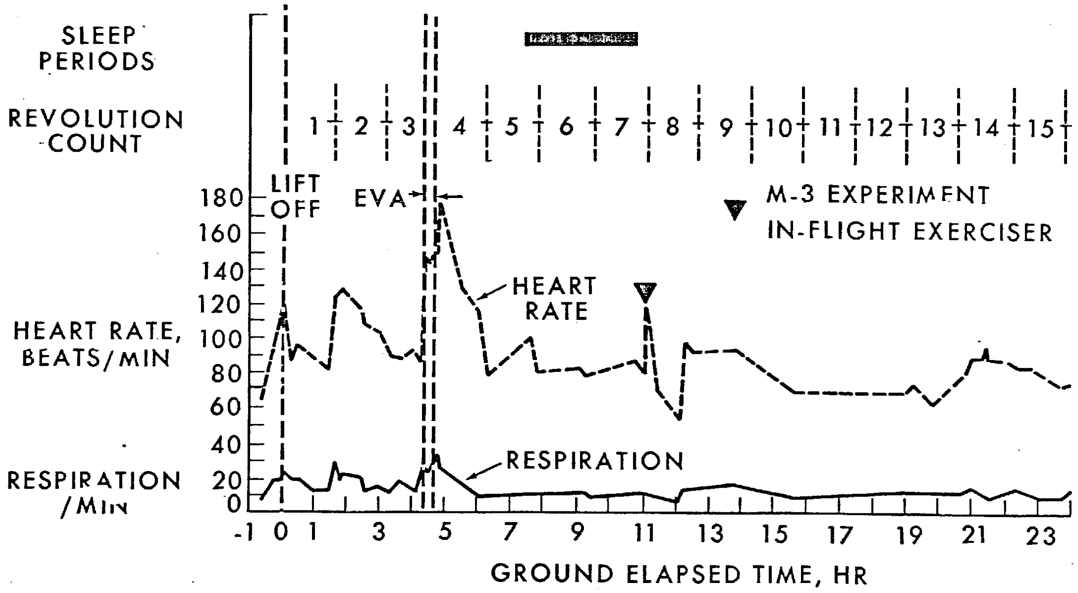


FIGURE 24-3 (b)

NASA-S-66-1769 FEB 18

GEMINI IV

PHYSIOLOGICAL MEASUREMENTS (CON'T)

PILOT

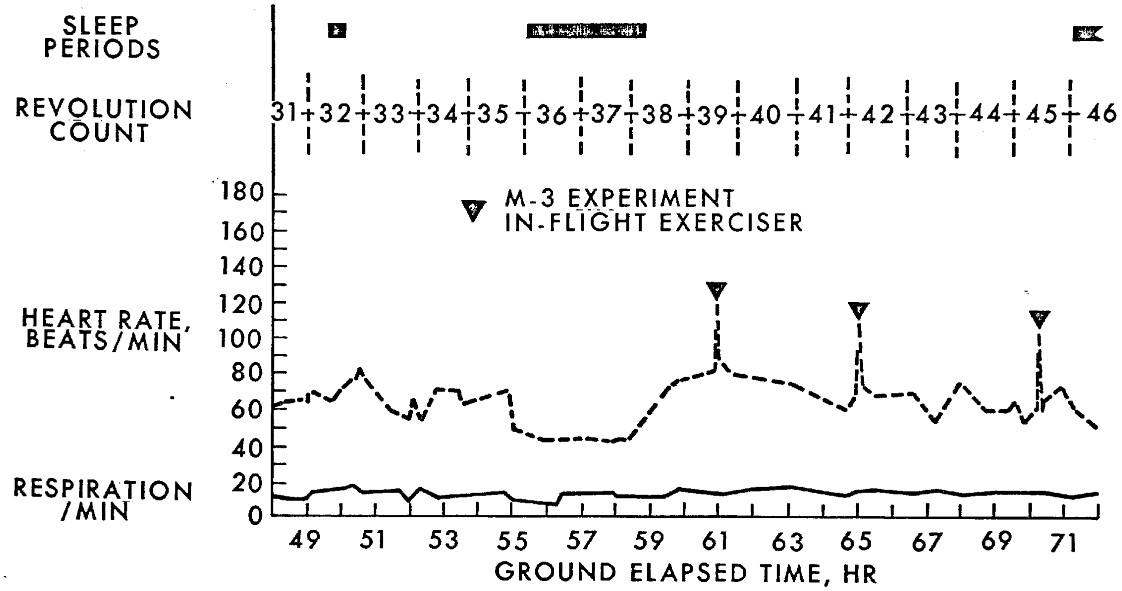


FIGURE 24-4 (a)

NASA-S-66-1765 FEB 18

GEMINI VII

PHYSIOLOGICAL MEASURMENTS

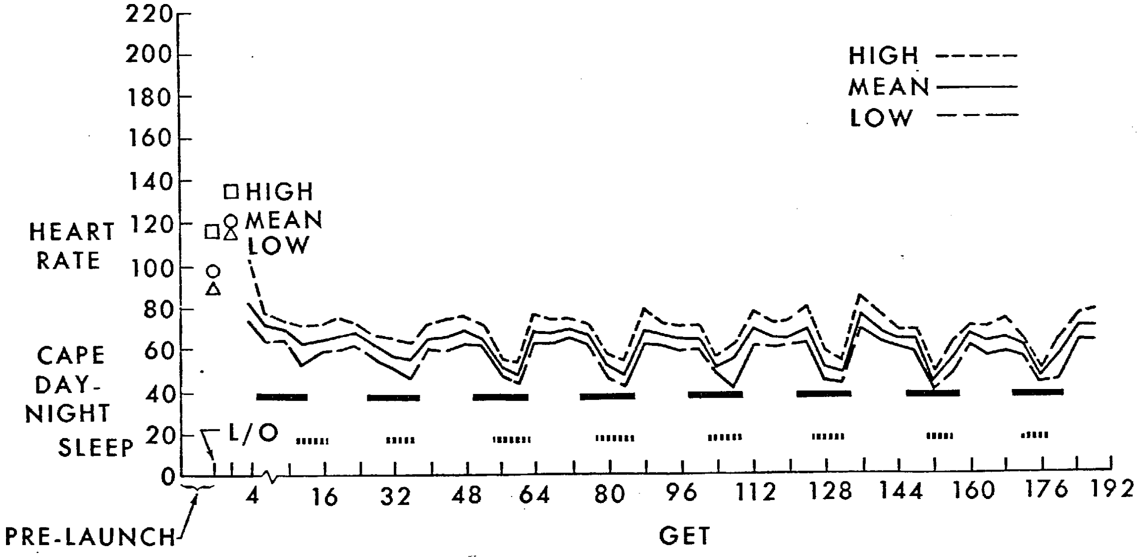


FIGURE 24-4 (b)

NASA-S-66-1780 FEB 18

GEMINI VII

PHYSIOLOGICAL MEASUREMENTS

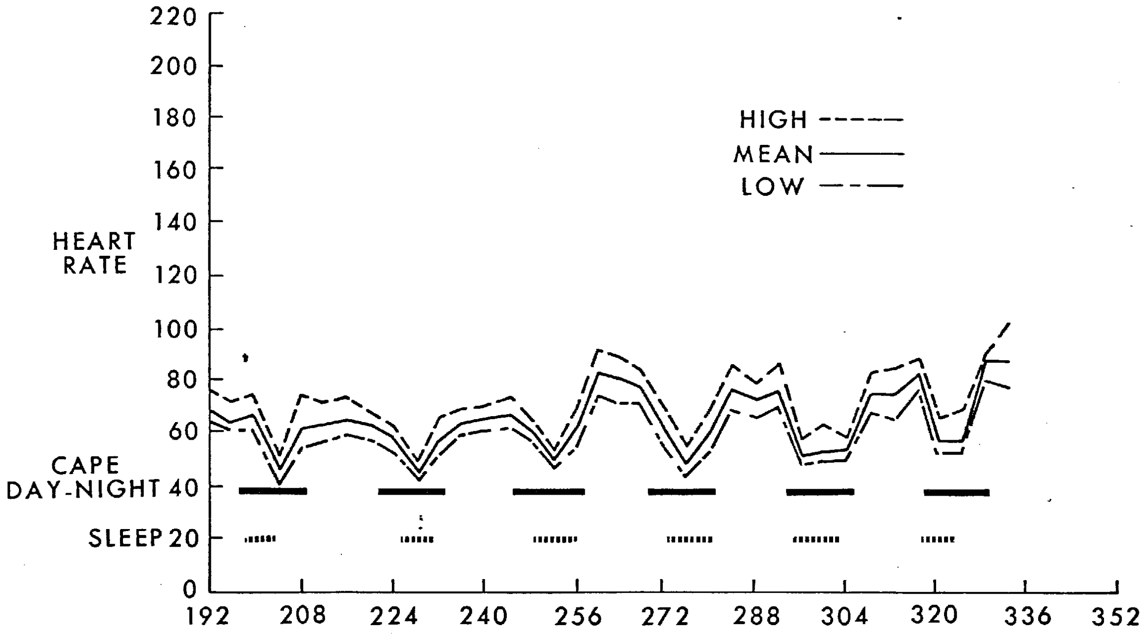


FIGURE 24-5

NASA-S-65-12592A

GEMINI VII
COMMAND PILOT BLOOD PRESSURE

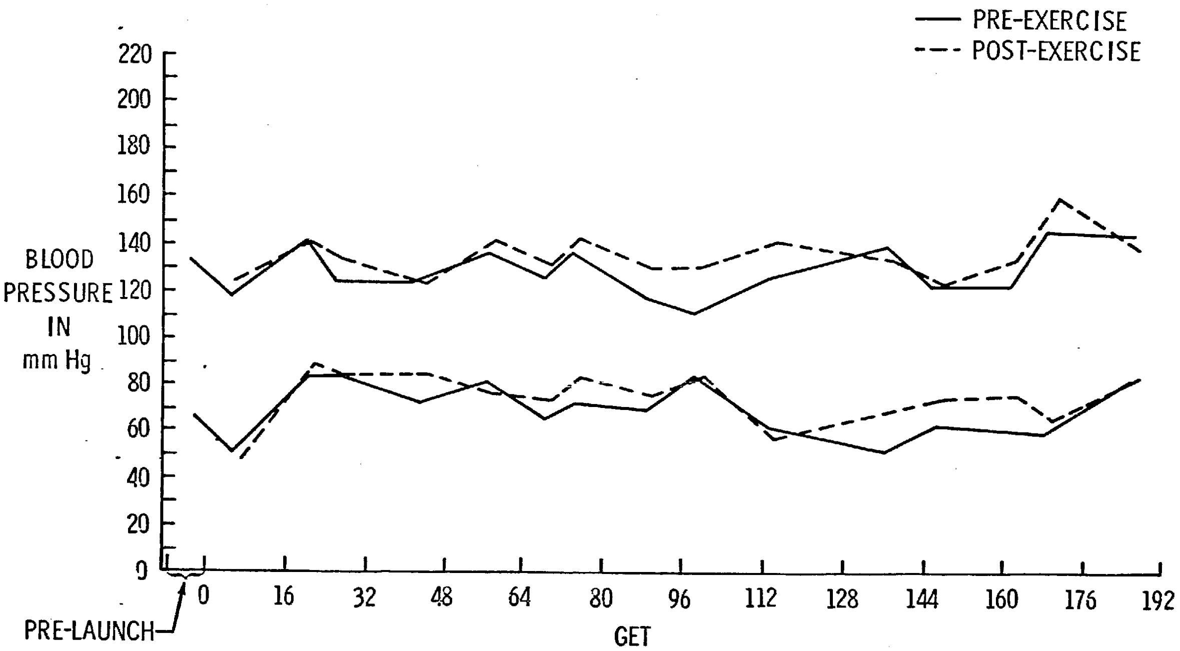


FIGURE 24-6

NASA-S-66-1773 FEB 18

GEMINI VII SLEEP DATA

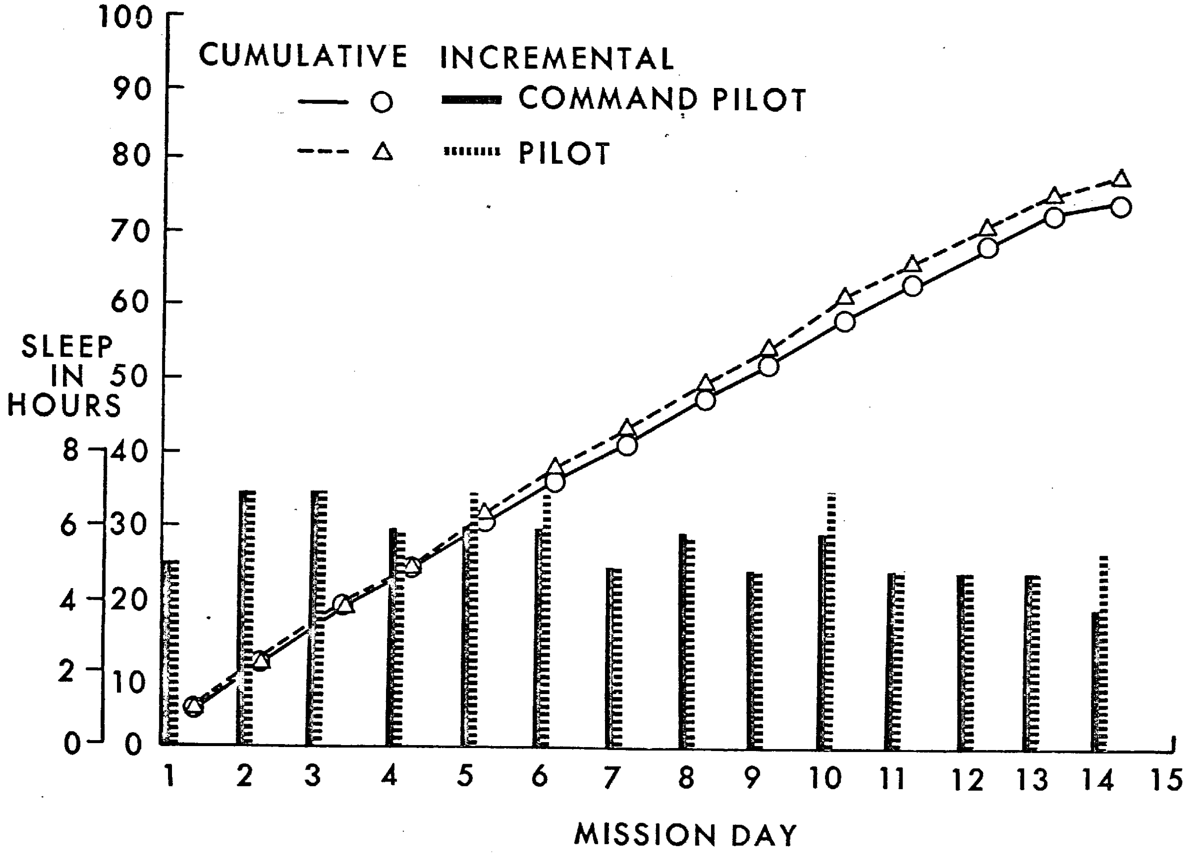


FIGURE 24-7

NASA-S-66-1764 FEB 18

GEMINI VII

WATER INTAKE VS MISSION DAY

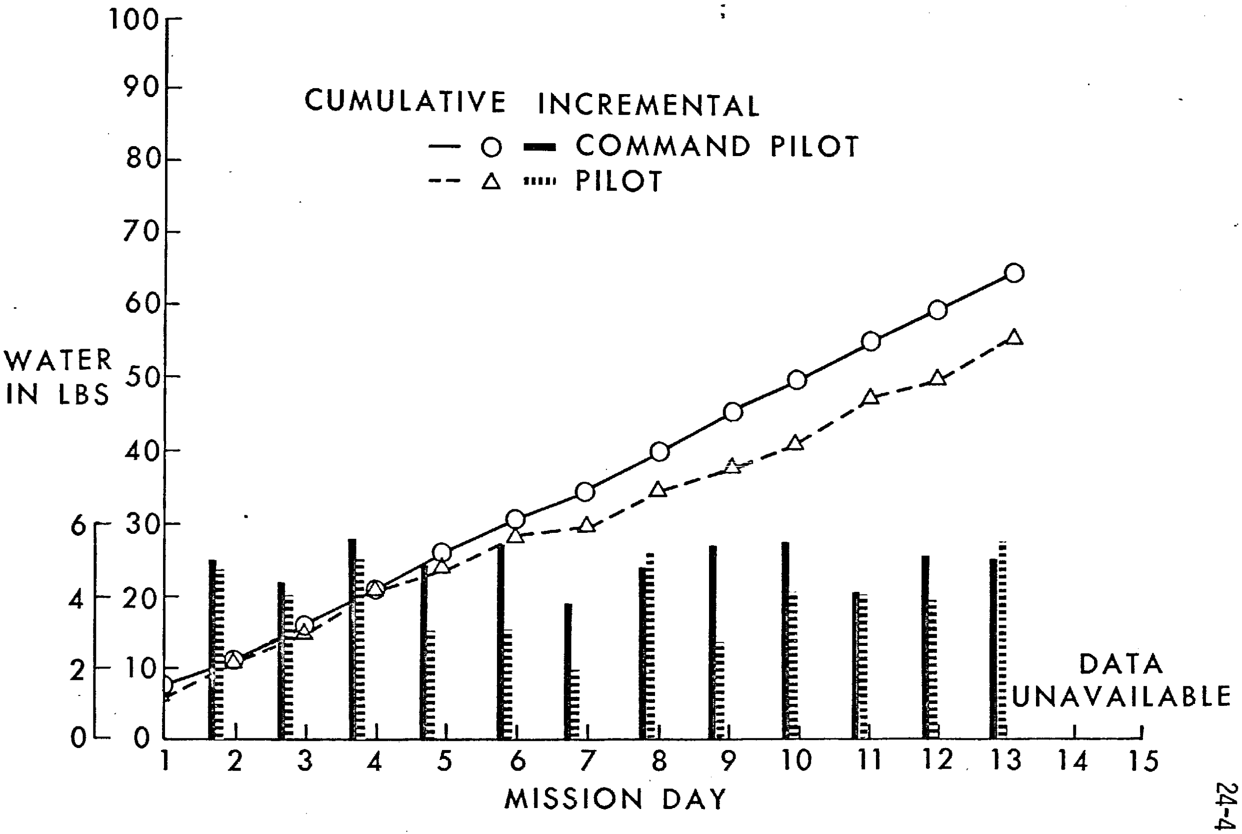
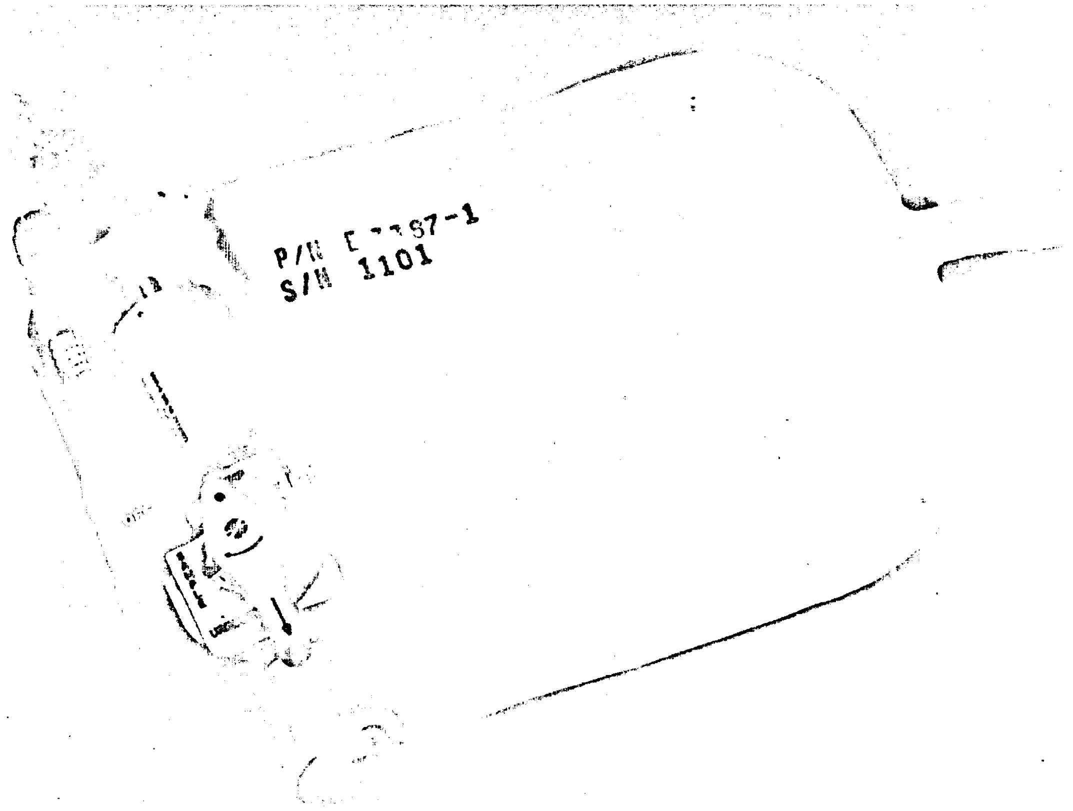


FIGURE 24-8

NASA S-66-1759 FEB18

URINE COLLECTION DEVICE



NASA-S 66 1758 FEB 18

FIGURE 24-9

FECAL BAG

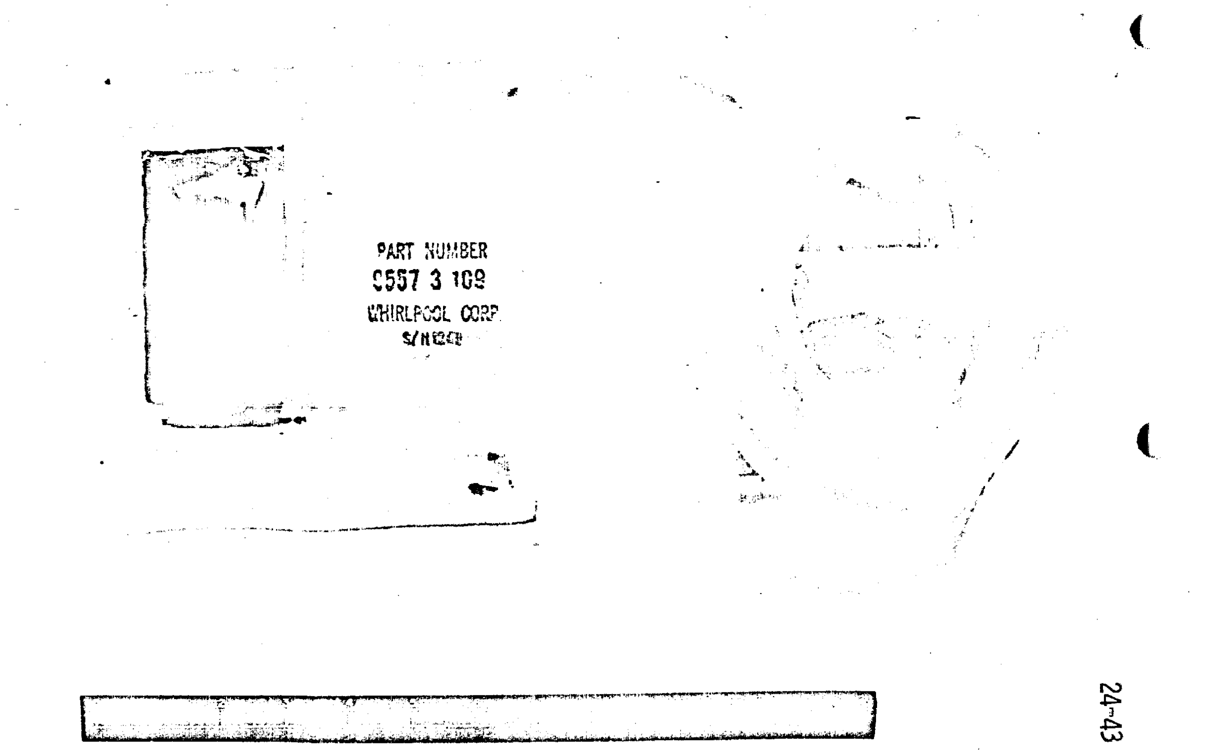


FIGURE 24-10

NASA-S-66-1707 FEB 17

GEMINI IN-FLIGHT DEFECATION FREQUENCY

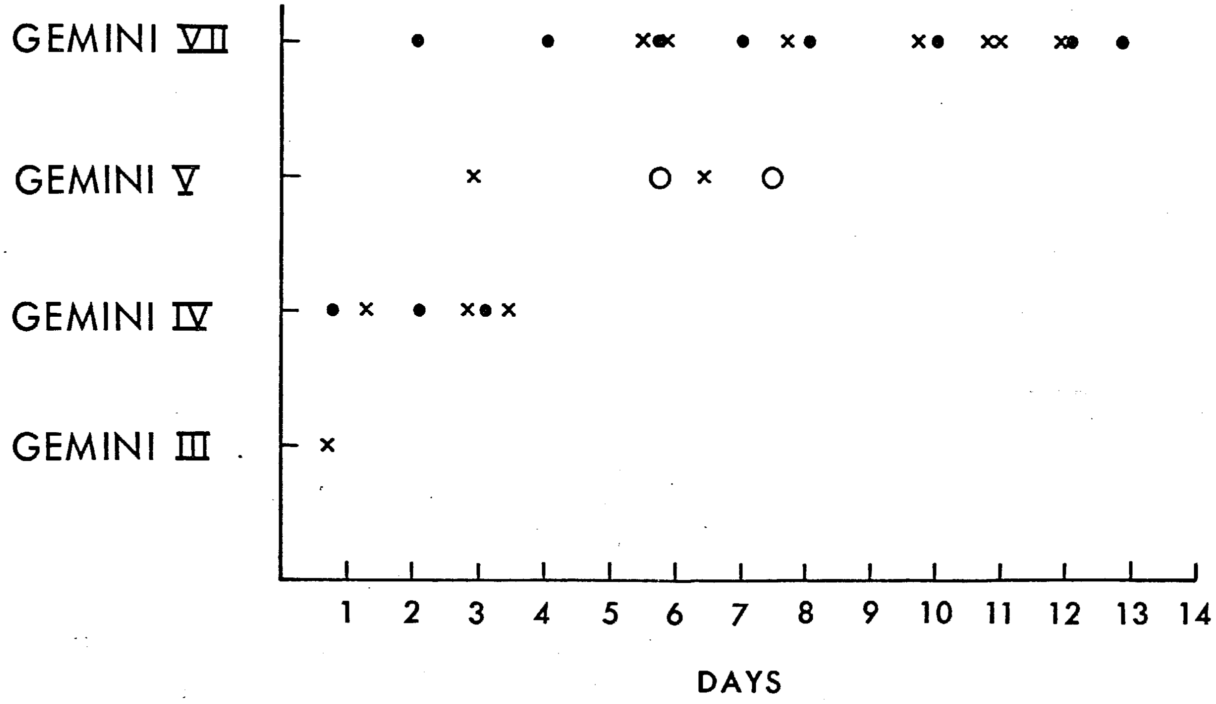
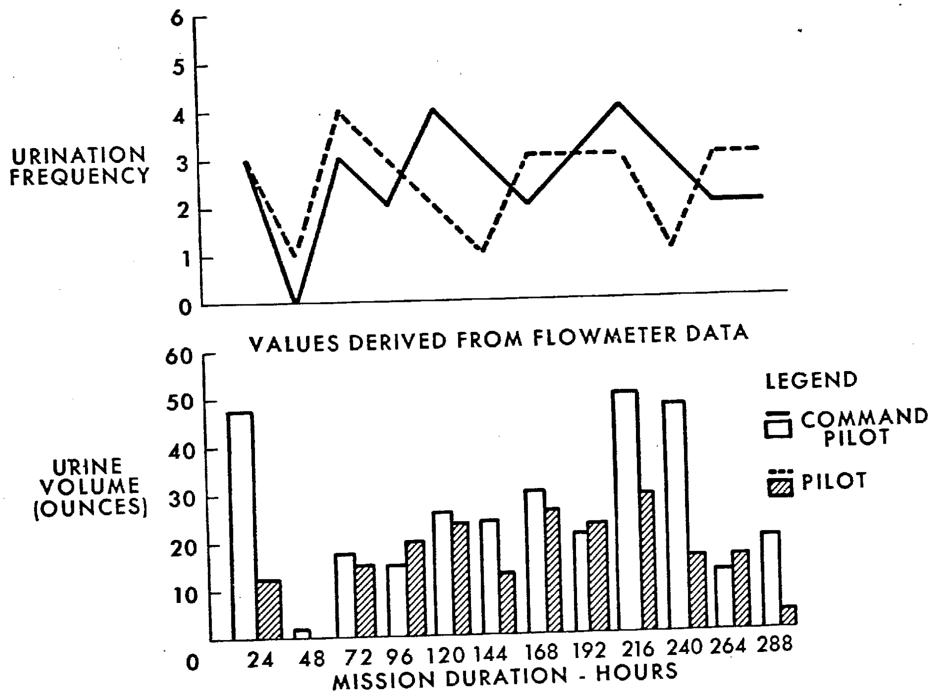


FIGURE 24-11

NASA-S-66-1713 FEB 17

GEMINI VII URINE VOLUME AND URINATION FREQUENCY



NASA-S-65-8900

FIGURE 24-12

GEMINI MEDICAL KIT

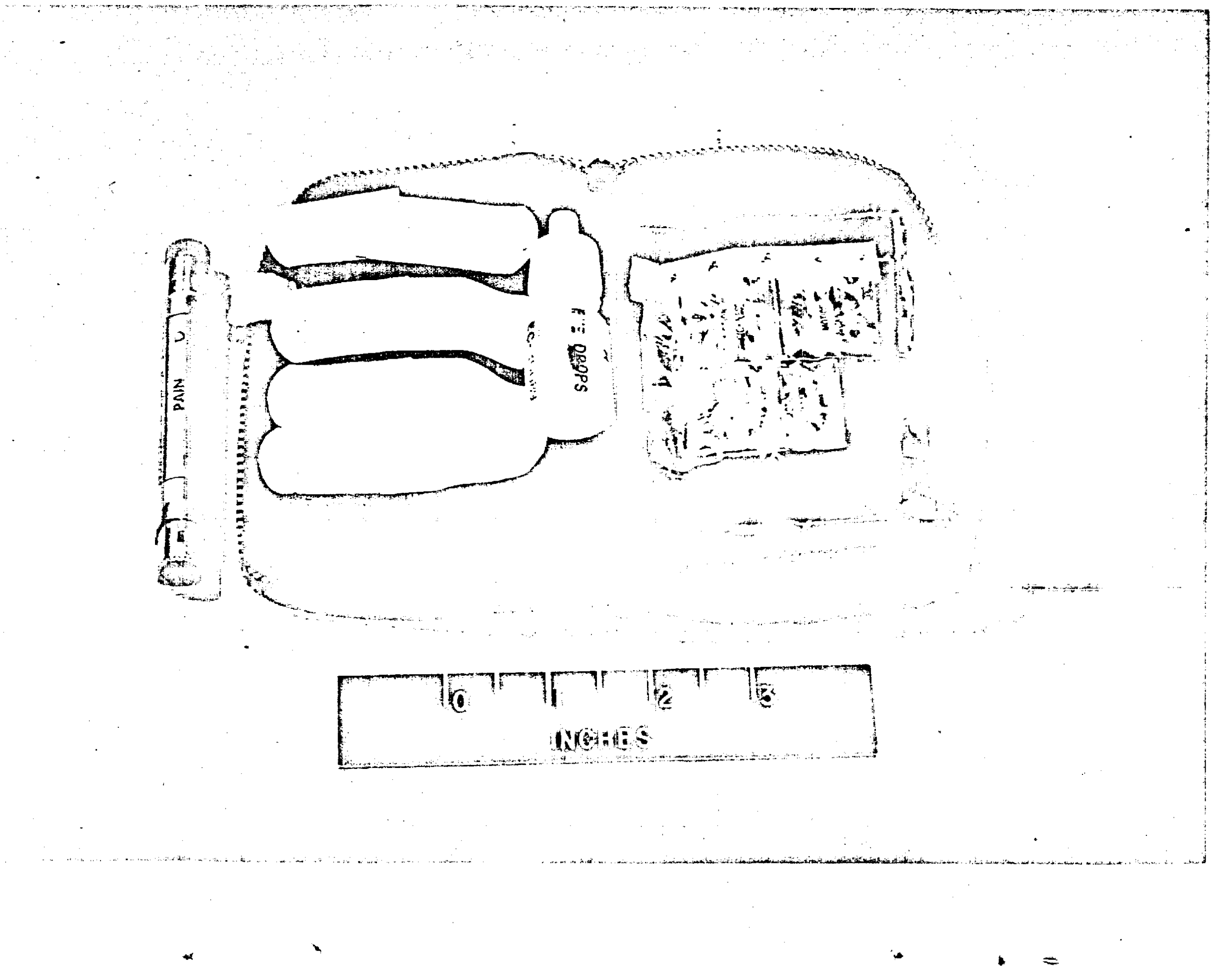


FIGURE 24-13

NASA-S-66-1760 FEB 18

GEMINI MEDICAL ACCESSORY KIT

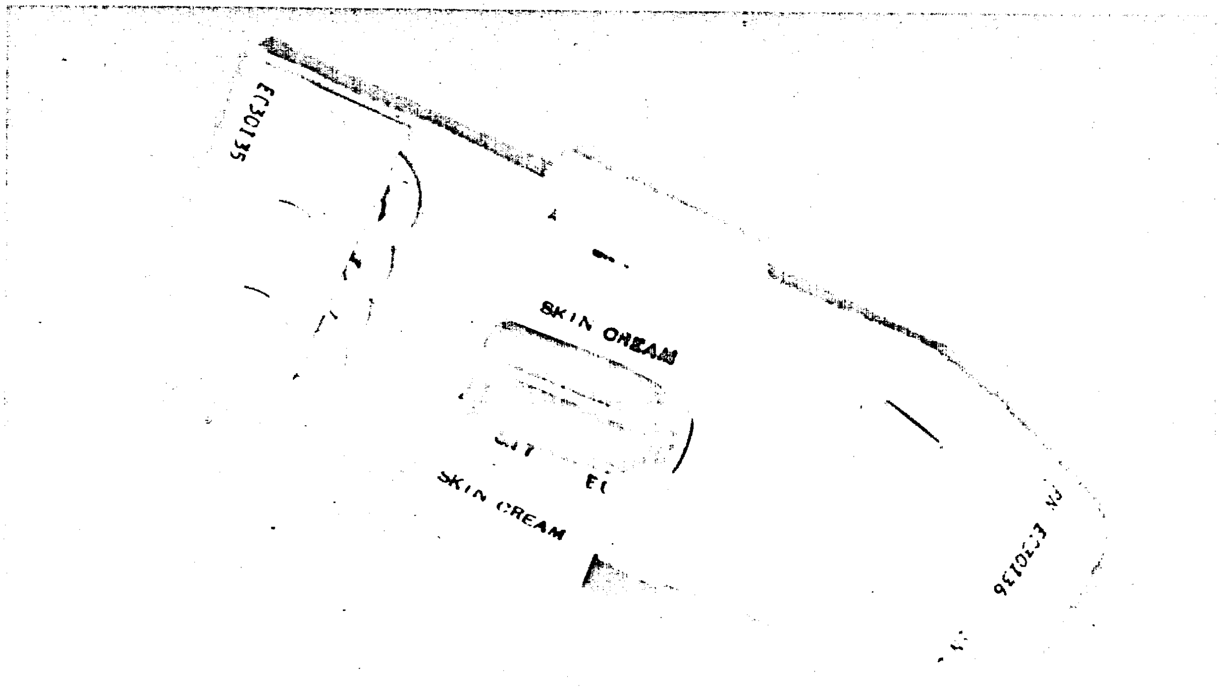


FIGURE 24-14

NASA-S-66-1719 FEB 17

GEMINI ASTRONAUT LEUCOCYTIC RESPONSE

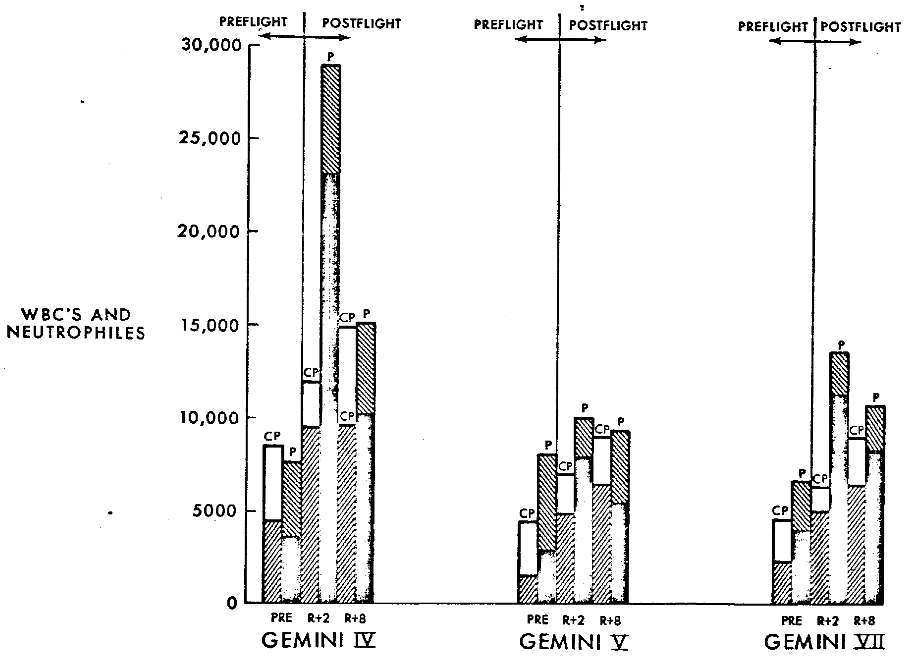
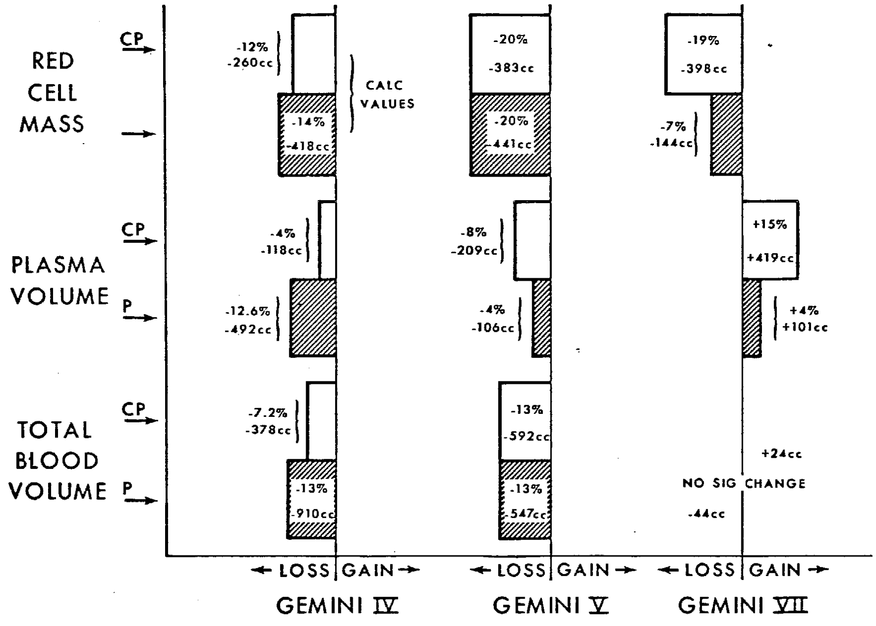


FIGURE 24-15

NASA-S-66-1715 FEB 17

GEMINI BLOOD VOLUME STUDIES



NASA-S-66 1761 FEB 18

FIGURE 24-16

TILT TABLE

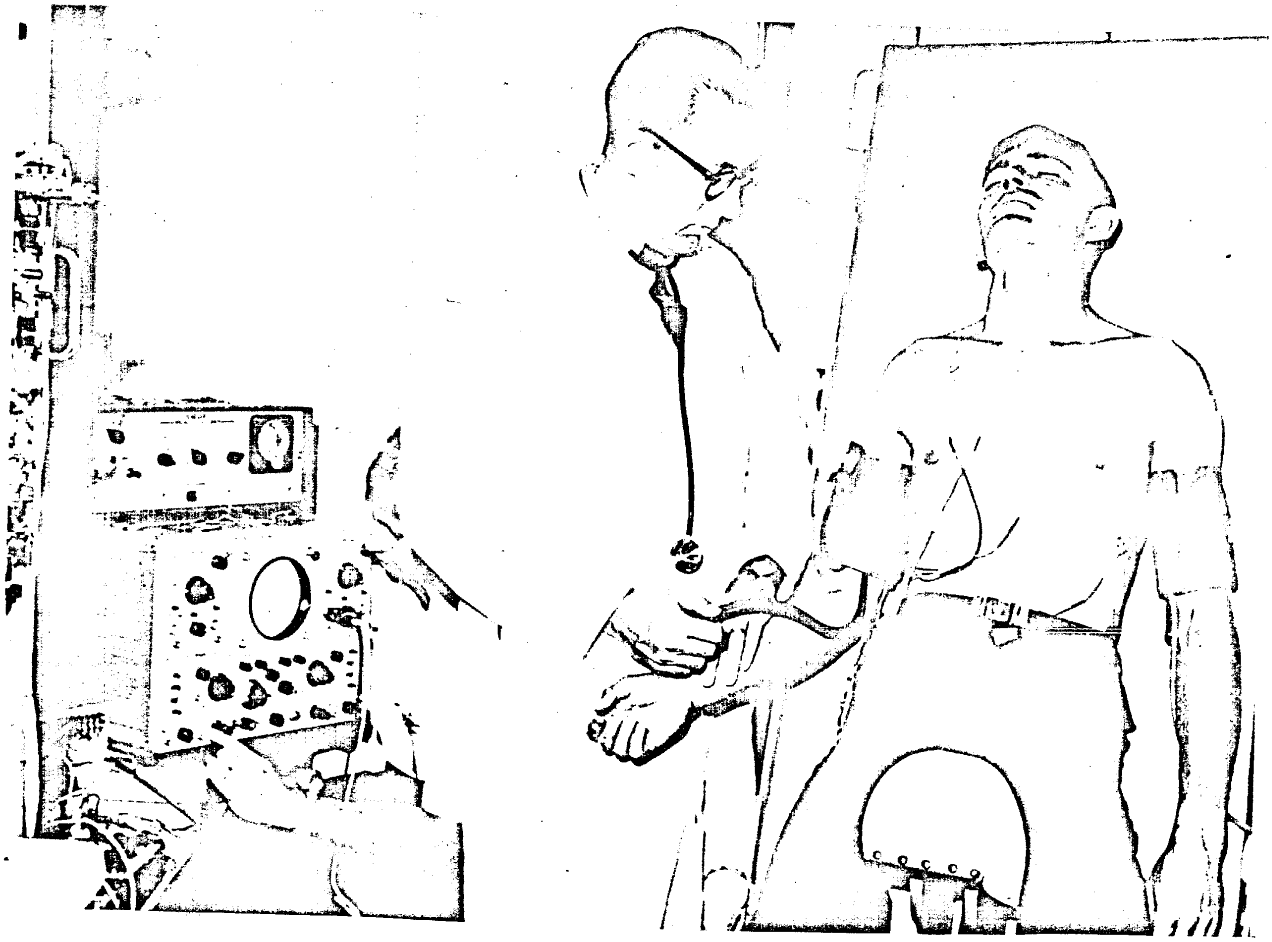


FIGURE 24-17 (a)

NASA-S-66-1768 FEB 18

GEMINI IV
TILT TABLE STUDIES
COMMAND PILOT

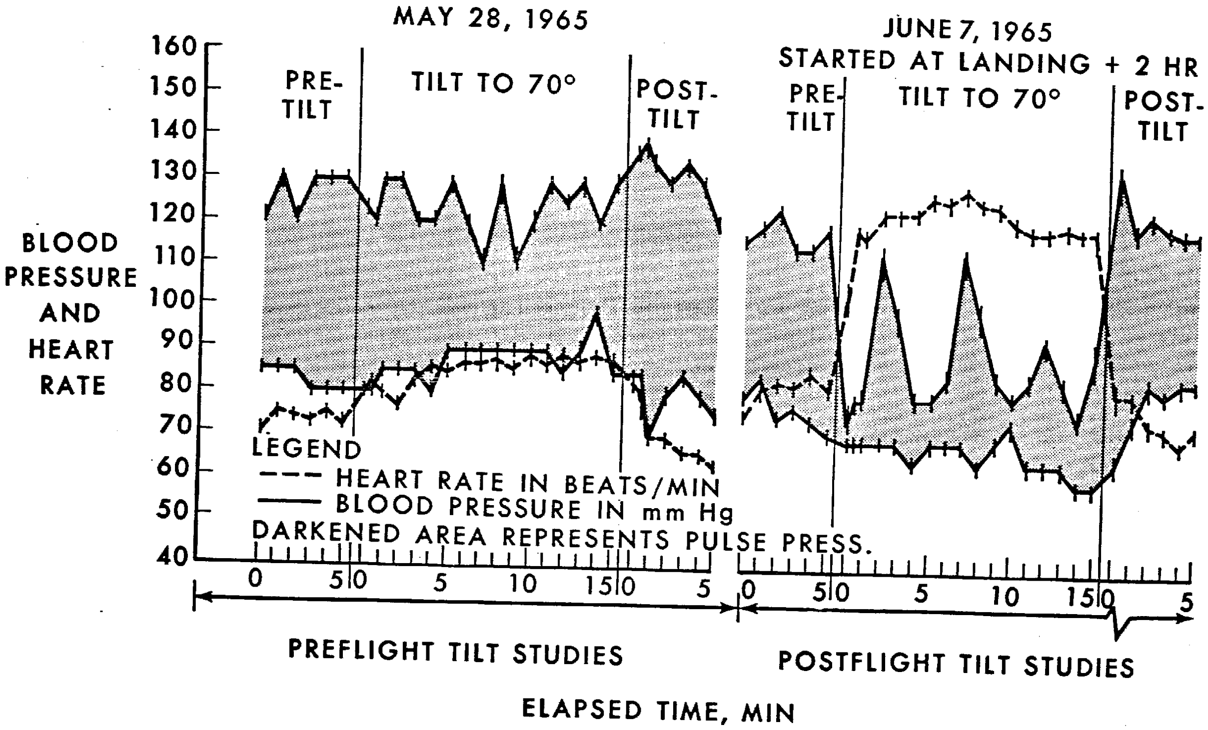


FIGURE 24-17 (b)

GEMINI IV

NASA-S-66-1766 FEB 18

TILT TABLE STUDIES CONCLUDED

COMMAND PILOT

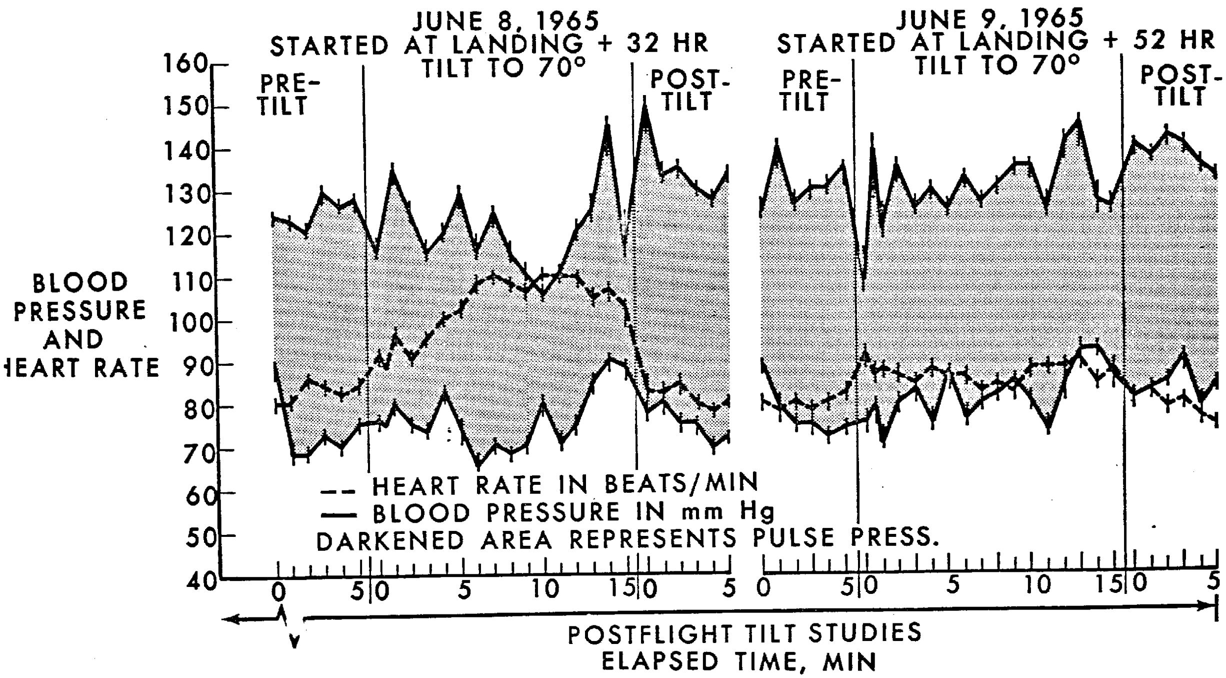


FIGURE 24-18 (a)

NASA-S-66-1771 FEB 18

GEMINI IV
TILT TABLE STUDIES
PILOT

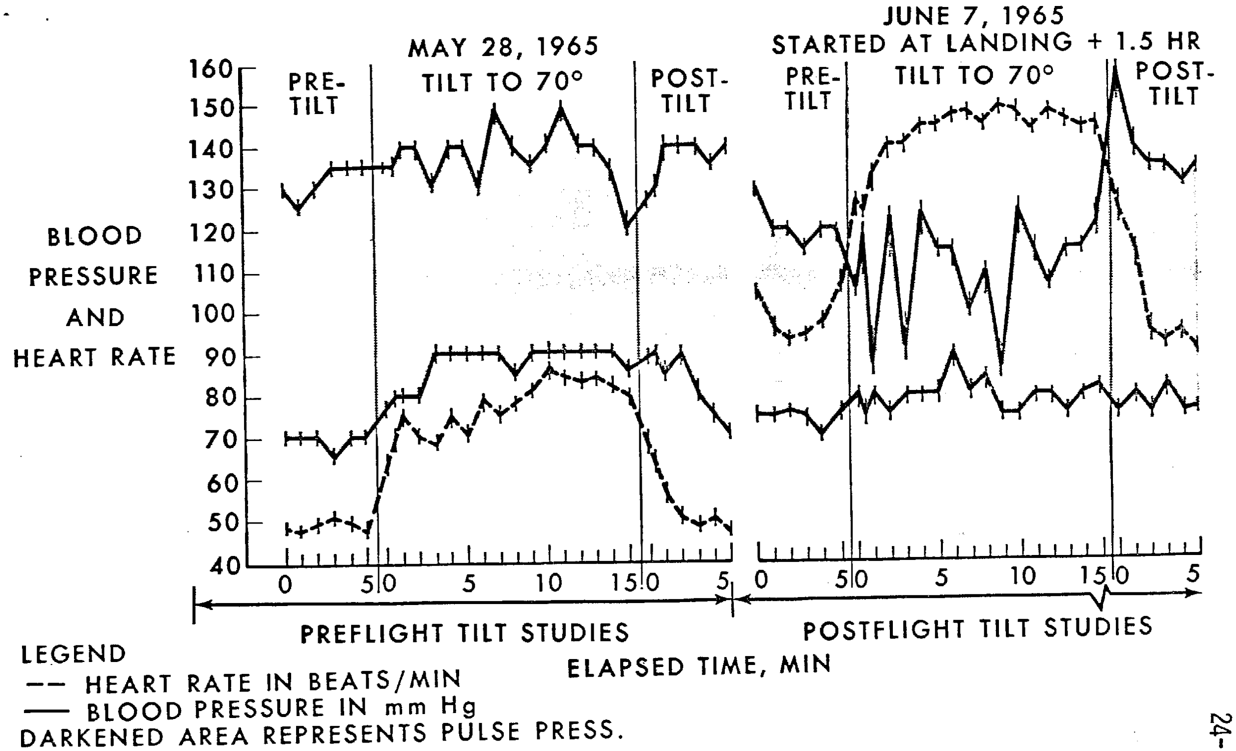


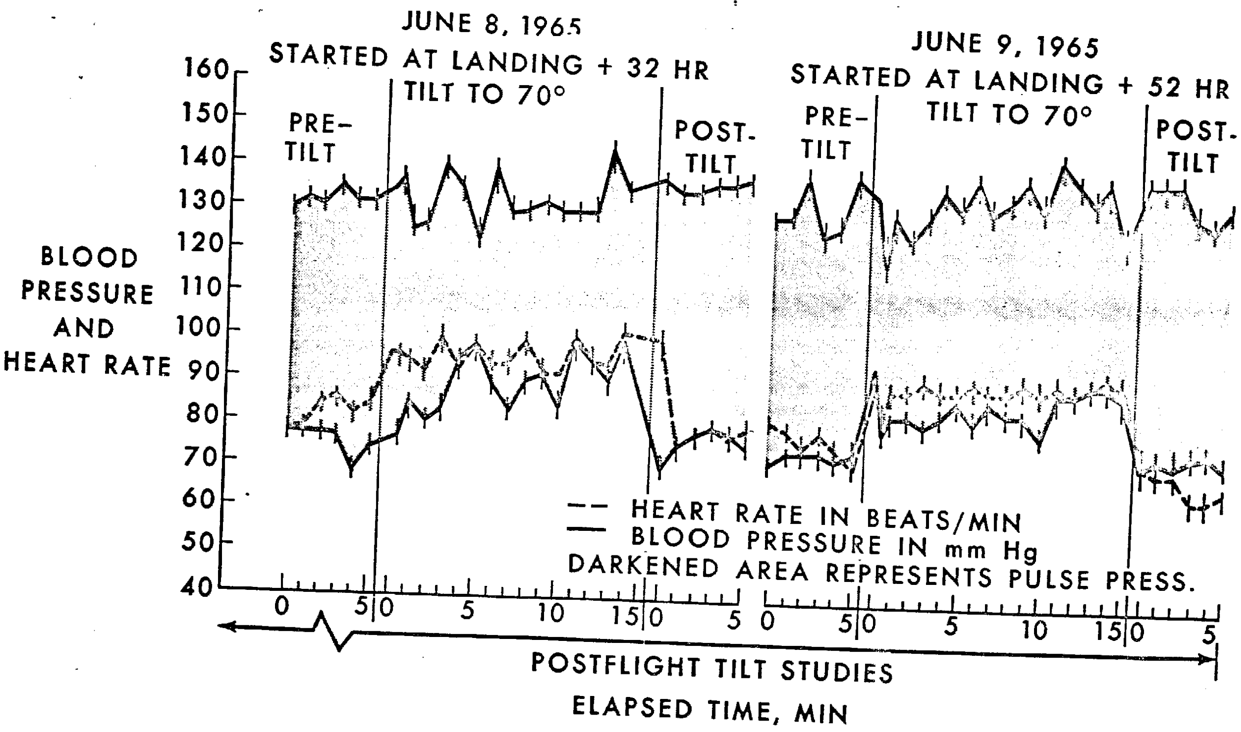
FIGURE 24-18 (b)

NASA-S-66-1767 FEB 18

GEMINI IV

TILT TABLE STUDIES CONCLUDED

PILOT



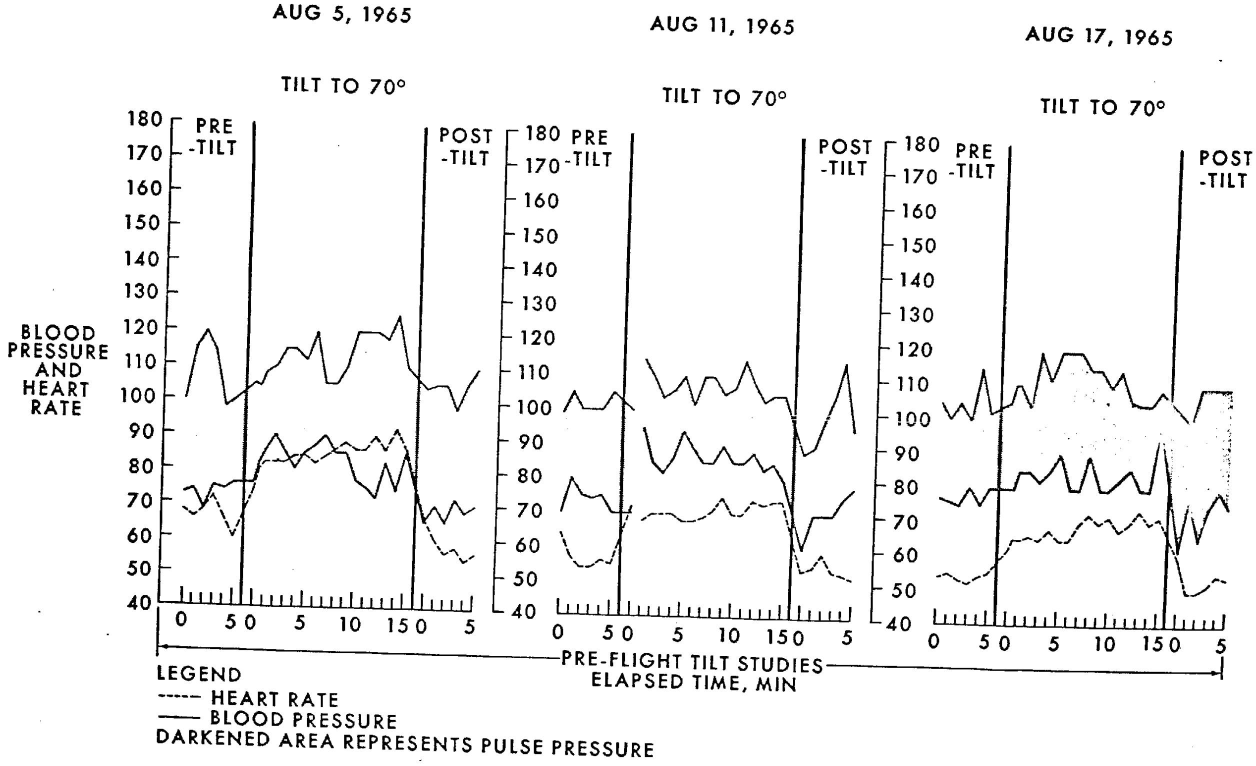
NASA-S-66-1774 FEB 18

FIGURE 24-19 (a)

GEMINI V

TILT TABLES STUDIES

COMMAND PILOT COOPER



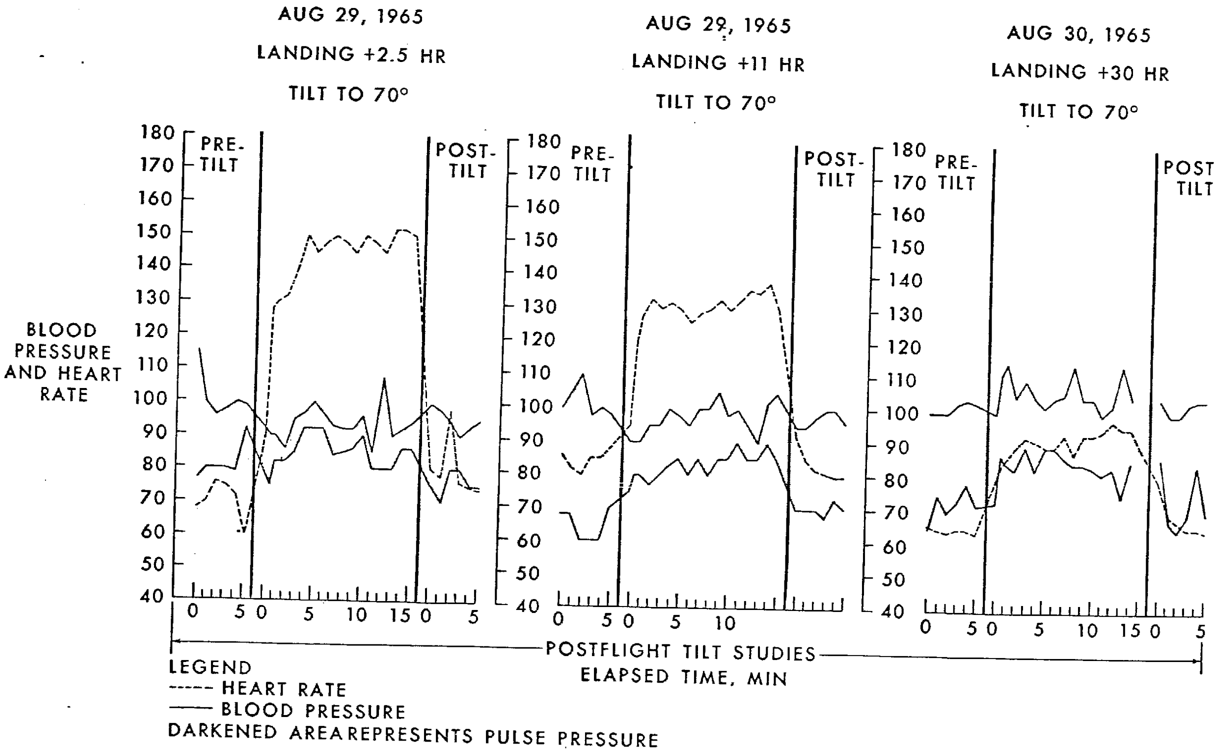
NASA-S-66-1782 FEB 18

FIGURE 24-19 (b)

GEMINI V

TILT TABLE STUDIES

COMMAND PILOT COOPER



AUG 29, 1965
LANDING +2.5 HR
TILT TO 70°

AUG 29, 1965
LANDING +11 HR
TILT TO 70°

AUG 30, 1965
LANDING +30 HR
TILT TO 70°

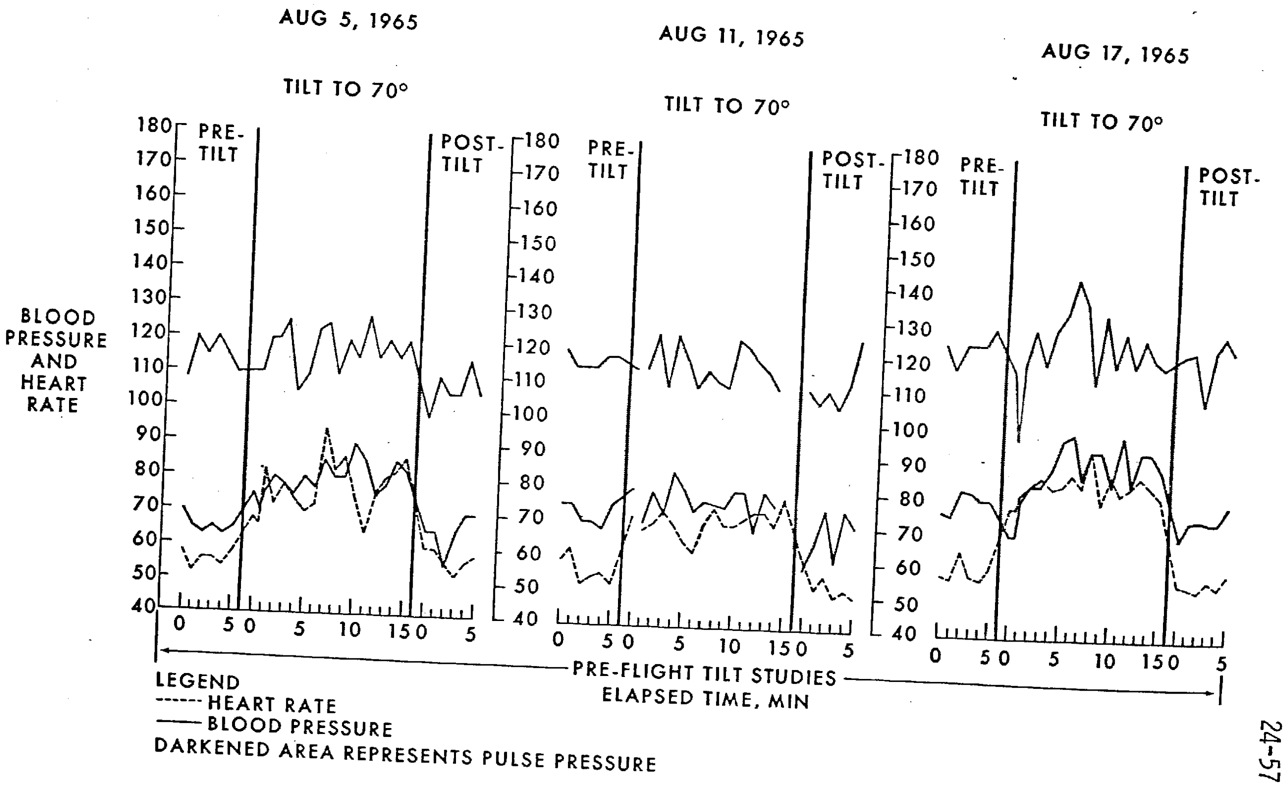
FIGURE 24-20 (a)

NASA-S-66-1783 FEB 18

GEMINI V

TILT TABLE STUDIES

PILOT CONRAD



AUG 5, 1965

TILT TO 70°

AUG 11, 1965

TILT TO 70°

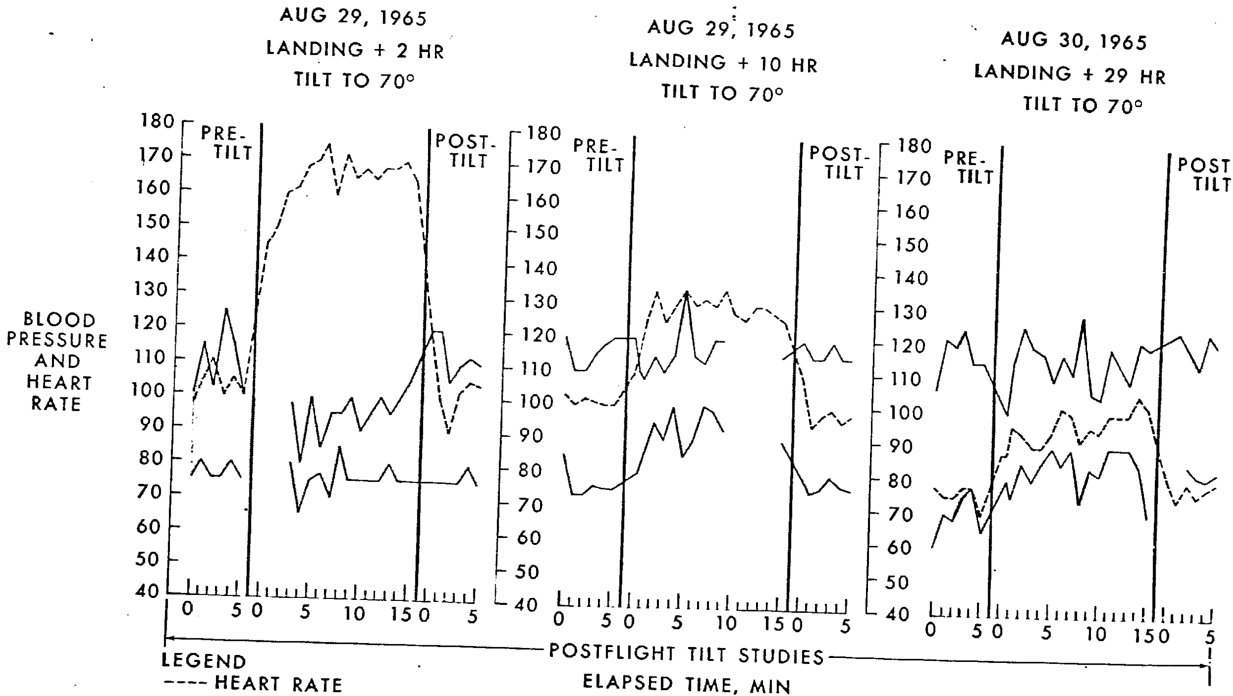
AUG 17, 1965

TILT TO 70°

FIGURE 24-20 (b)

NASA-S-66-1779 FEB 18

GEMINI V
TILT TABLE STUDIES
PILOT CONRAD



LEGEND
---- HEART RATE
—— BLOOD PRESSURE
DARKENED AREA REPRESENTS PULSE PRESSURE

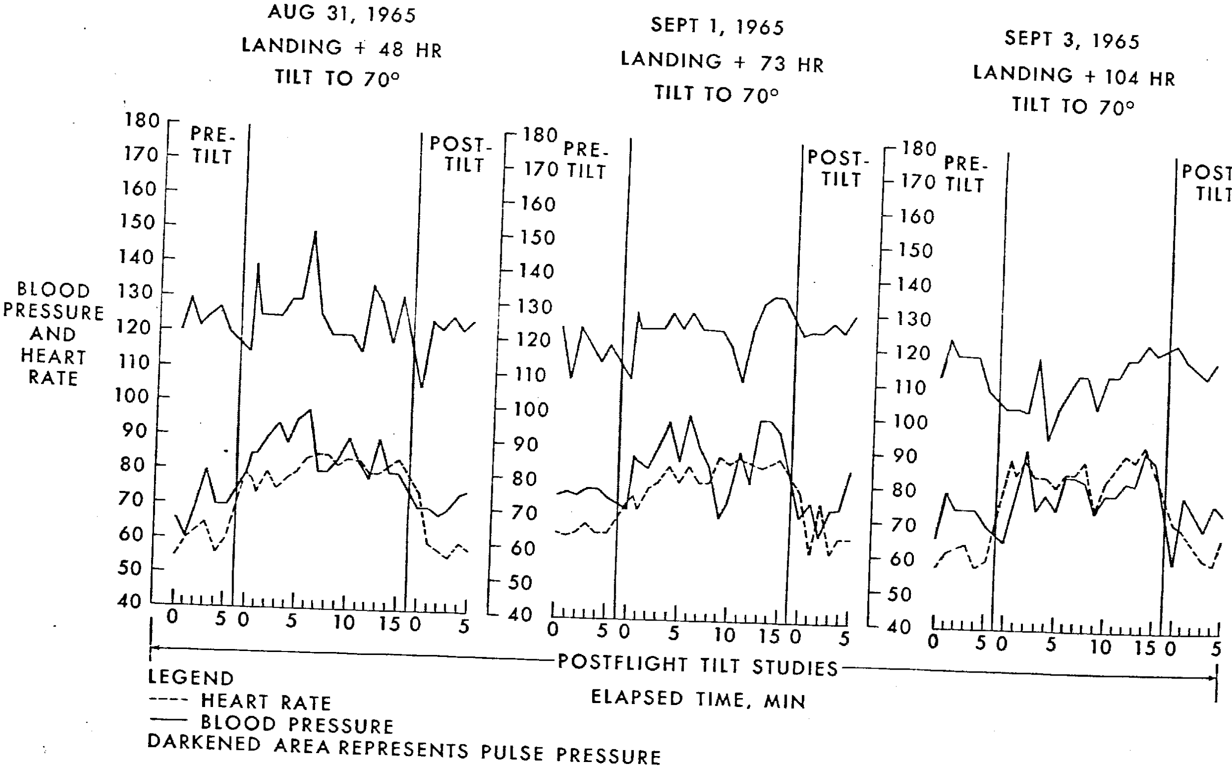
NASA-S-66-1775 FEB 18

FIGURE 24-20 (c)

GEMINI V

TILT TABLE STUDIES

PILOT CONRAD



NASA-S-65-12597A

FIGURE 24-21

GEMINI TILT RESPONSE VS MISSION DURATION

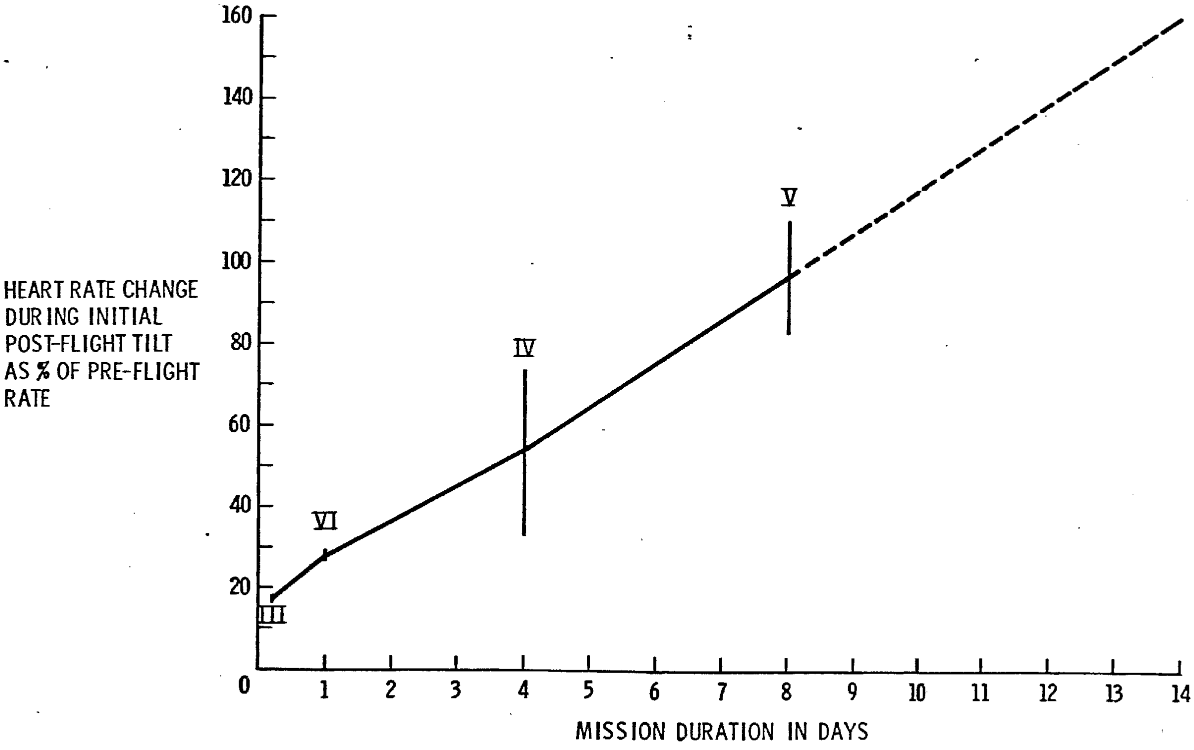
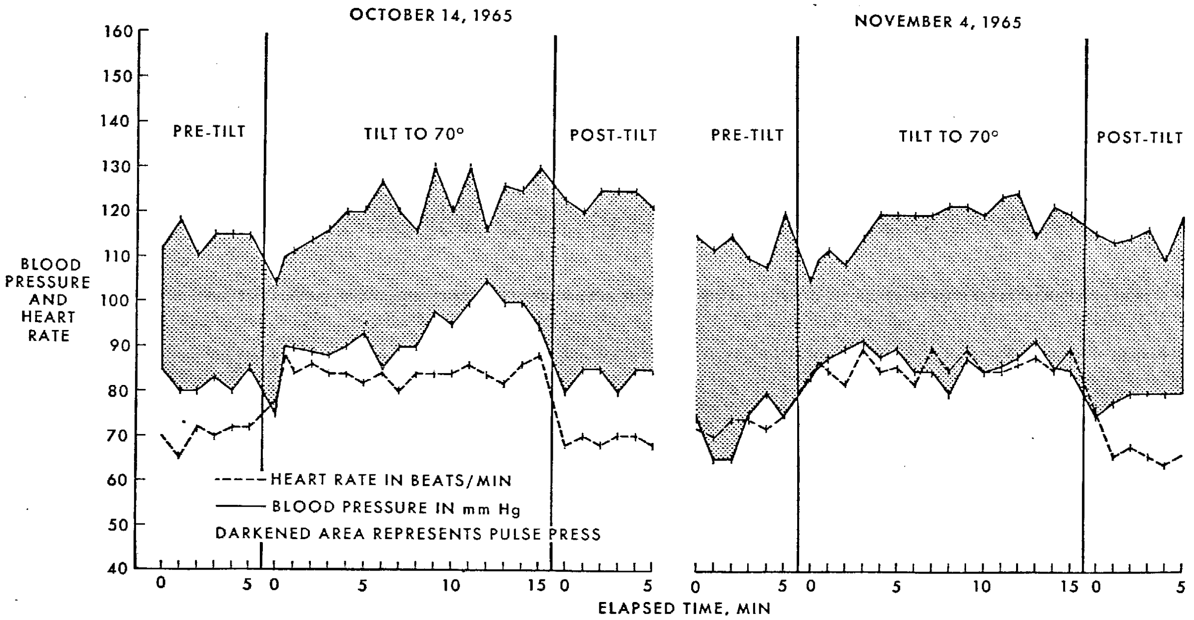


FIGURE 24-22 (a)

NASA-S-66-1776 FEB 18

GEMINI VII
TILT TABLE STUDIES
COMMAND PILOT



PREFLIGHT TILT STUDIES

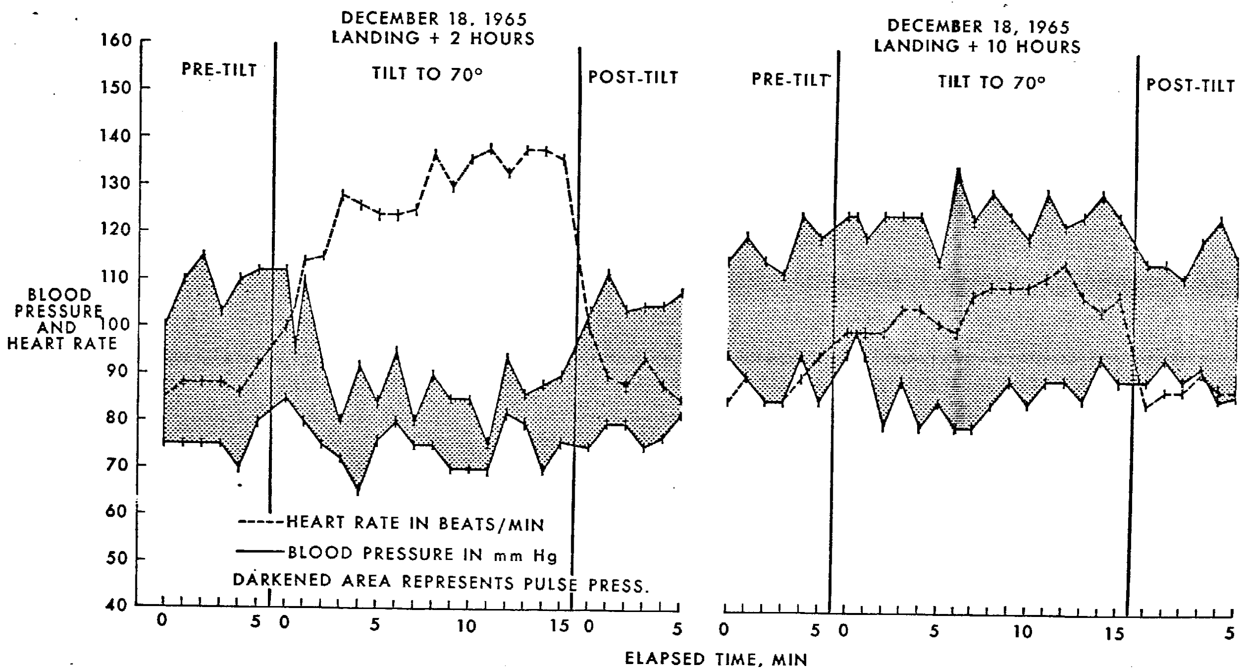
FIGURE 24-22 (b)

NASA-S-66-1784 FEB 18

GEMINI VII

TILT TABLE STUDIES

COMMAND PILOT



POST FLIGHT TILT STUDIES

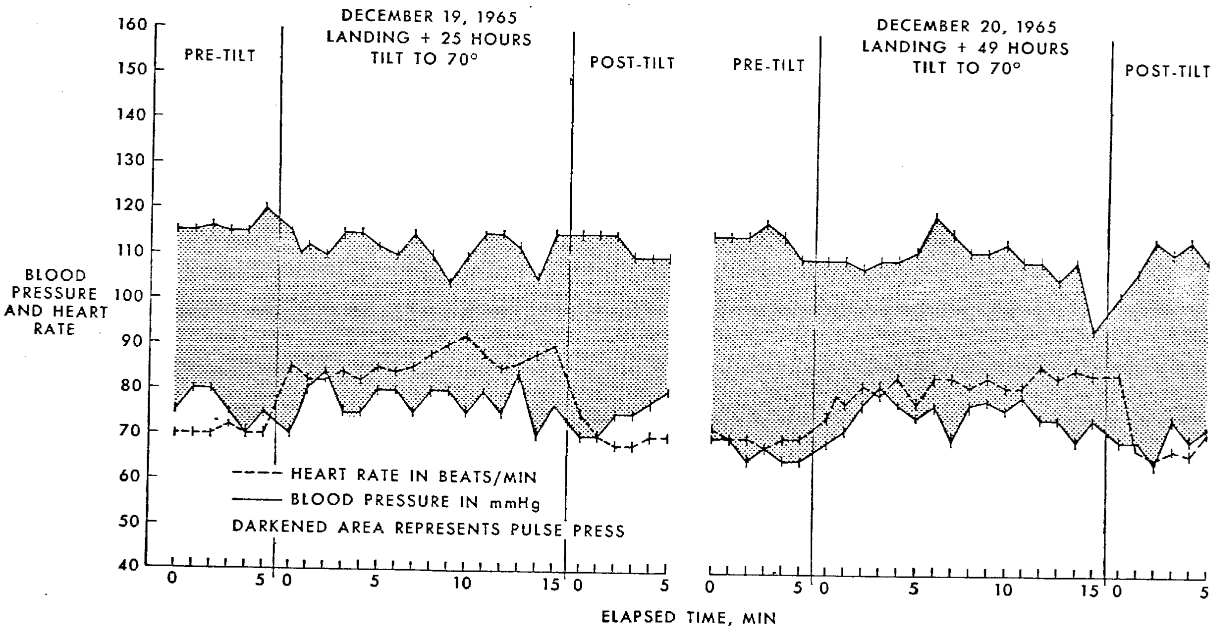
NASA-S-66-1777 FEB 18

FIGURE 24-22 (c)

GEMINI VII

TILT TABLE STUDIES

COMMAND PILOT



POSTFLIGHT TILT STUDIES

NASA-S-66-1778 FEB 18

FIGURE 24-23 (a)

GEMINI VII

TILT TABLE STUDIES

PILOT

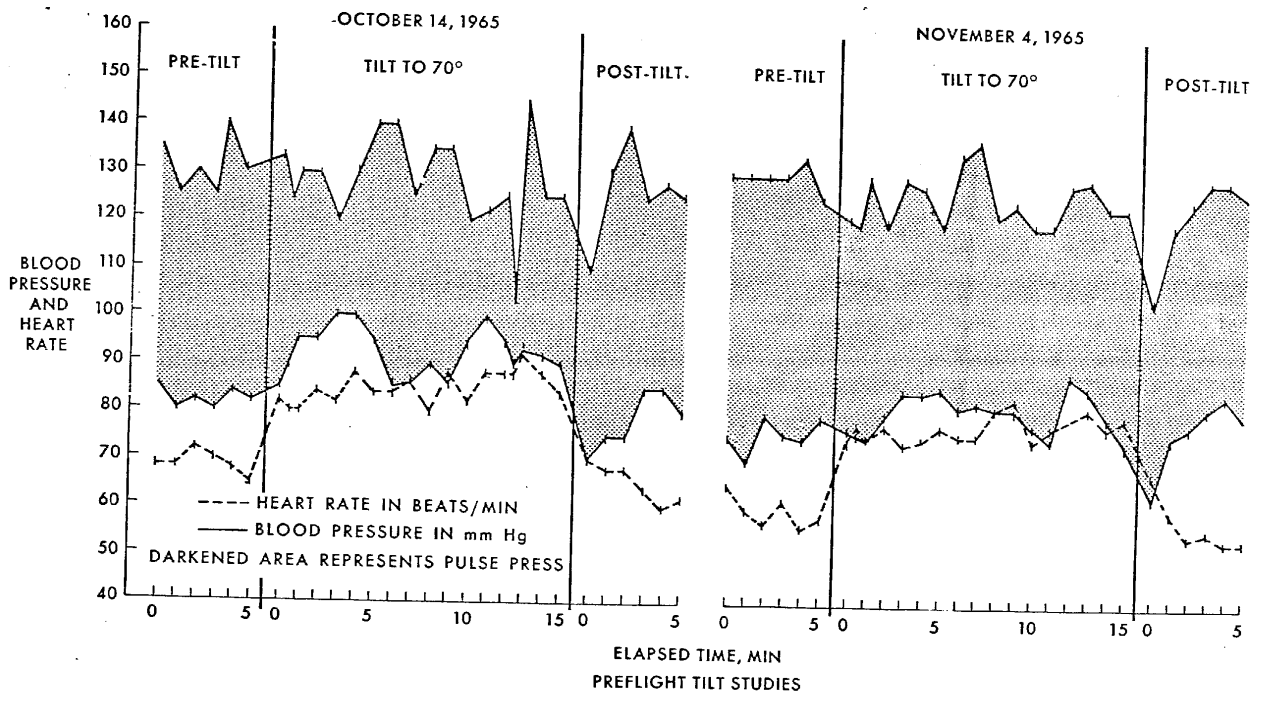


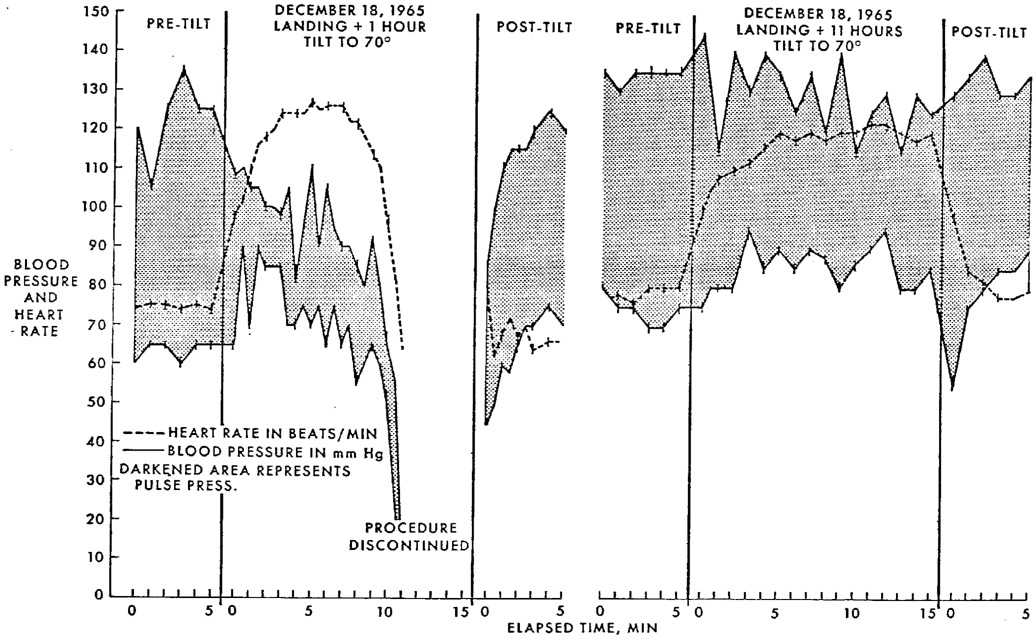
FIGURE 24-23 (b)

NASA-S-66-1781 FEB 18

GEMINI VII

TILT TABLE STUDIES

PILOT

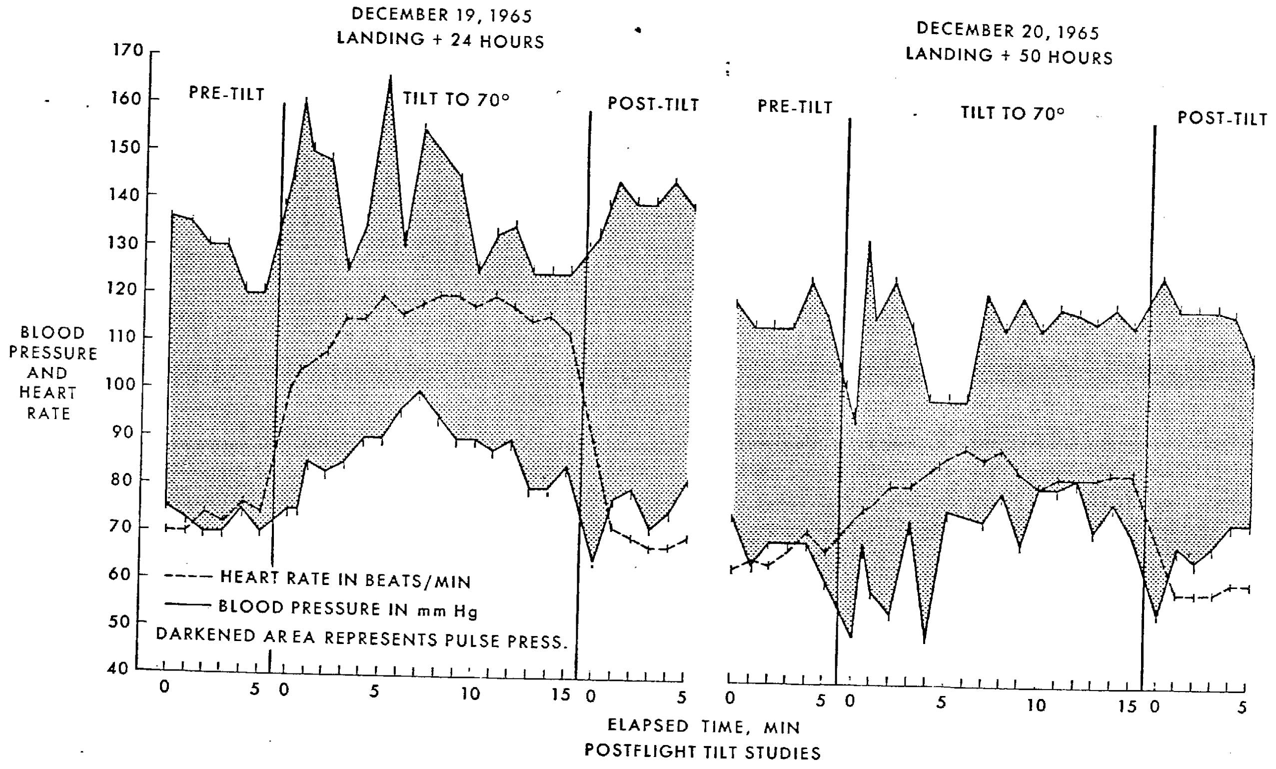


POSTFLIGHT TILT STUDIES

NASA-S-66-1786 FEB 18

FIGURE 24-23 (c)

GEMINI VII
TILT TABLE STUDIES
PILOT



NASA-S-66-1785 FEB 18

FIGURE 24-23 (d)

GEMINI VII

TILT TABLE STUDIES

PILOT

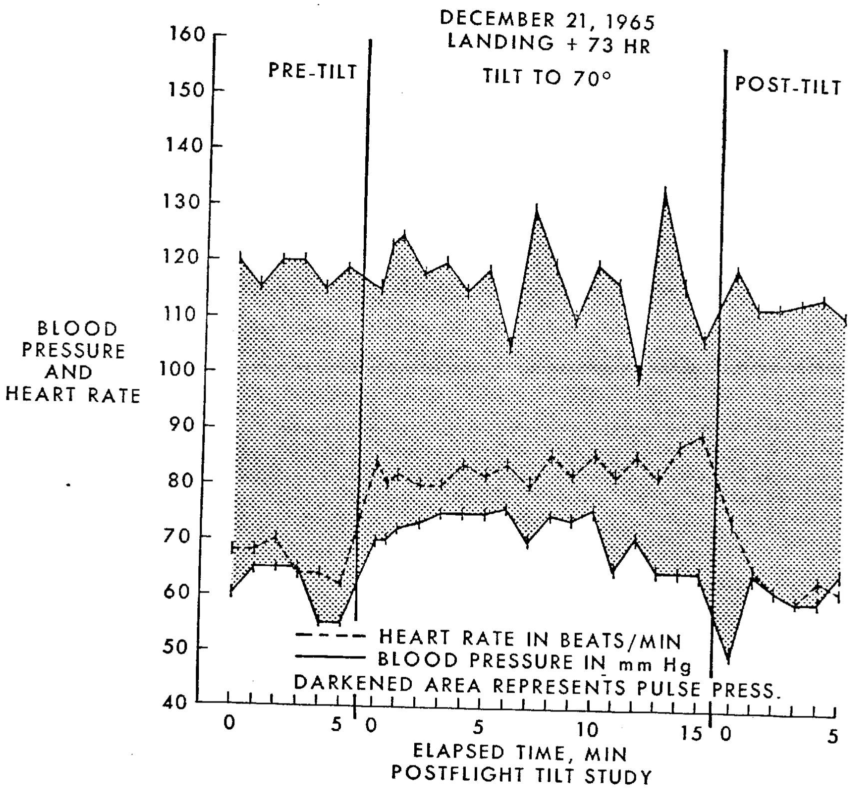
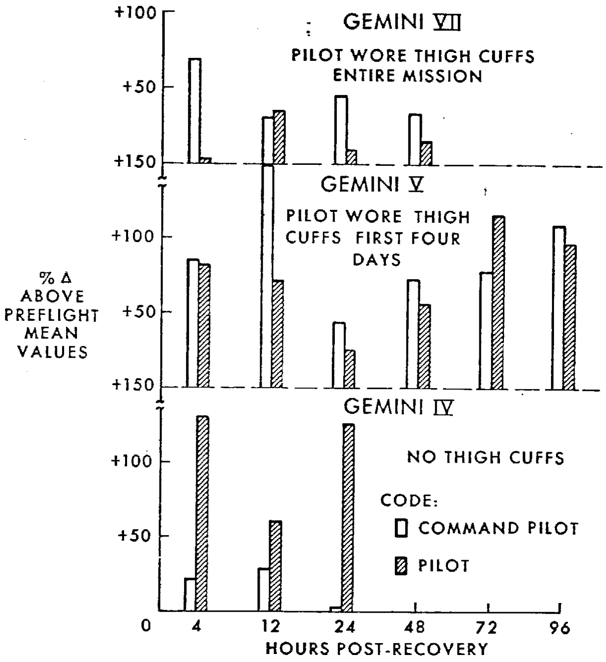


FIGURE 24-24

NASA-S-66-1714 FEB 17

LEG VOLUME CHANGES

DURING POSTFLIGHT TILT TABLE STUDIES



26. ASTRONAUTS REACTIONS TO FLIGHT

By Lt. Col. Virgil I. Grissom, Astronaut
Command Pilot, Gemini III
Astronaut Office
Manned Spacecraft Center

Lt. Col. James A. McDivitt, Astronaut
Command Pilot, Gemini IV
Astronaut Office
Manned Spacecraft Center

Col. L. Gordon Cooper, Jr., Astronaut
Command Pilot, Gemini V
Astronaut Office
Manned Spacecraft Center

Capt. Walter M. Schirra, Astronaut
Command Pilot, Gemini VI-A
Astronaut Office
Manned Spacecraft Center

Col. Frank Borman, Astronaut
Command Pilot, Gemini VII
Astronaut Office
Manned Spacecraft Center

SUMMARY

The Gemini spacecraft was designed to make use of man's ability to function in the space environment. The extravehicular activity carried out during the Gemini IV flight demonstrated that an astronaut could maneuver and work outside his spacecraft. Man's capabilities in space were further demonstrated with the successful rendezvous between Gemini VI-A and VII.

Very few anomalies occurred during the five manned Gemini flights, and most of the planned experiments were performed successfully. The flight crews have been well pleased with the Gemini spacecraft. Even though the cabin is small, the crews have been able to operate effectively and efficiently.

INTRODUCTION

The pilot's role in manned space flight has changed somewhat from the days of Project Mercury. Initially, man's reactions and his capabilities in a space environment were two of the big unknowns, but Project Mercury proved man to be both adaptable and capable. Therefore, the Gemini spacecraft was designed to use the pilot as the key system in its operation.

PREFLIGHT AND LAUNCH

When chosen for a specific mission, a flight crew is immediately faced with two tasks: training for the flight, and checkout of the spacecraft. The emphasis in these areas has changed from concentrating the major effort on spacecraft testing and checkout for the Gemini III mission to concentrating on training for the Gemini VI-A and VII missions. This was a natural evolution in that Gemini III was the first mission to use the new spacecraft for a manned flight, and the flight plan was designed to check out the spacecraft systems. The crews of the Gemini VI-A and VII spacecraft had high confidence in their vehicles through their association with previous missions, but they had difficult flights to accomplish since the emphasis was on operational mission requirements.

The schedule on launch day has greatly improved since the Mercury flights. For the Mercury flight, MR-4, the pilot was awakened at 1:10 a.m. and manned the spacecraft at 3:58 a.m. The Gemini launch is usually between the rather gentlemanly hours of 9 a.m. and 11 a.m. Also, the interval between crew awakening and insertion into the spacecraft has been shortened. However, it has not yet been possible to shorten the time between crew insertion and lift-off; although, it is recognized that efficiency is increased by shortening the interval between the time that the crew awakes refreshed from a good night's sleep and the time of lift-off. This increased efficiency is especially helpful during the early, critical phase of the flight when the crew members are becoming adjusted to their new environment. After long periods in the spacecraft (90 minutes or more) the pilots begin to become more uncomfortable from lying on their backs in the Gemini ejection seat. The back, neck, and leg muscles tend to become cramped and fatigued.

The pilots concentrate during the last few days prior to a flight on the details of the flight plan, the status of the spacecraft, and both normal and emergency operational procedures. During this period, the backup crew and the flight crew director endeavor to keep the crew from being disturbed by anything not connected with the operation of the mission.

Some experiments do place heavy burdens on the crew at this time, and an attempt should be made to avoid adding to the crew's workload during this period. A typical example of one of the heavy prelaunch activities was the preparation for the medical experiment M-7 by the Gemini VII flight crew. The preparation involved a rigid diet, complete collection of all body wastes, and two controlled distilled-water baths each day. The diet went well, the food was well prepared and tasty; however, the collection of body wastes was difficult to integrate with other activities, because the waste could only be collected at the places most frequented by the flight crew, such as the launch complex, the simulator, and the crew quarters. Fortunately, the fine cooperation of the M-7 experimenters resulted in a minimum number of problems.

Even though some of the flight crews, especially the Gemini V crew, had a comparatively limited time to prepare for their missions, they were well trained in all phases and were ready to fly on launch day.

During the prelaunch period, the backup crew is used extensively in the checkout of the spacecraft and, at the same time, this crew must prepare to fly the mission. But their prime responsibility, by far, is spacecraft testing and monitoring.

POWERED FLIGHT

All flight crews have reported lift-off as being very smooth. The Gemini VI-A crew indicated that they could tell the exact moment of lift-off by the change in engine noise and vibration, and all crews agree that vertical motion is readily apparent within seconds of lift-off. Even without clouds as a reference, it is easy to determine when the launch-vehicle roll program starts and ends.

The noise level is quite low at lift-off, increasing intensively until sonic speed is reached. At that time, it becomes very quiet and remains quiet throughout the remainder of powered flight.

With one exception, the launch has been free from any objectionable vibration. On the Gemini V flight, longitudinal oscillations, or POGO, were encountered. The crew indicated that the vibration level was severe enough to interfere with their ability to read the instrument panel. However, POGO lasted only a few seconds and occurred at a noncritical time.

The second stage of the launch vehicle ignites prior to separation from the first stage. This causes the flame pattern to be deflected and apparently to engulf the second stage and spacecraft. The crew of Gemini VI-A indicated that the flame left a residue on the exterior of the window, and every crew has reported a thin film on the outside of the window. The pilot of Gemini VI-A noted that a string of cumulus clouds was very white and clear prior to staging and that the clouds were less white and clear afterward, indicating that the port window obscuration could have occurred during staging.

The horizon is in full view during second-stage flight while the radio guidance system is guiding the launch vehicle. Each correction that the guidance system initiates can be readily observed by the crew. It would appear that, given proper displays and an automatic velocity cutoff, the crew could control the launch vehicle into a satisfactory orbit.

Second stage engine cutoff (SECO) is a crisp event! The g-level suddenly drops from approximately 7 to zero, and in no case has any tail off been felt by the crews.

The powered-flight phase has been closely duplicated on the dynamic crew procedures simulator (DCPS) trainer at the Manned Spacecraft Center. After the first flight, the vibration level and the sounds were changed to correspond with what the pilots actually heard during launch. The simulation has such fidelity that there should be no surprises for the crew during any portion of powered flight.

ORBIT INSERTION

The insertion into orbit has been nominal for every flight. The separation and turn-around of the spacecraft and the operation of the onboard computer have been as planned.

At spacecraft separation and during turn-around, there is quite a bit of debris floating all around the spacecraft. Some of these small pieces stay in the vicinity for several minutes.

During insertion, the aft-firing thrusters cannot be heard, but the acceleration can be felt. The firing of the attitude and translation thrusters can be heard, and the movement of the spacecraft is readily apparent.

SYSTEM OPERATION

Inflight Maneuvering

The flight crews have found the pulse-control mode to be excellent for fine tracking, and the fuel consumption to be negligible. The direct mode was needed and was most effective when large, rapid attitude changes were required. However, the use of the direct, and also the rate-command, mode is avoided whenever possible because of the high rate of fuel consumption. Rate command is a very strong mode, and it is relatively easy to command at any desired rate up to full authority. It is the recommended mode for the critical tasks, such as retrofire and translation burns, that are beyond the capability of the platform mode.

The platform mode is a tight attitude-hold control mode. It has the capability of holding only two indicated attitudes on the ball display, zero-degrees yaw and roll, and zero or 180 degrees in pitch. But the platform mode can be caged and the spacecraft pointed in any devised direction and then the platform released. This gives an infinite number of attitudes. It is the recommended mode for platform alignment and for retrograde or posigrade translation burns. The horizon-scan mode is a pilot-relief mode and is used when a specific control or tracking task is not required. It is better than drifting flight, because it controls the spacecraft through a wide dead band in pitch and roll, but has no control of yaw. Drifting flight is perfectly acceptable for long periods of time, as long as the tumbling rates do not become excessive (5°/sec or more). Spacecraft control with the reentry control system is very similar to that of the orbital attitude and maneuver system. Slightly more authority is available with the orbital attitude and maneuver system than with both rings of the reentry control system. This results in some tendency to overcontrol and, waste fuel. Actually the one-ring reentry control system operation is satisfactory for most tasks. All pilots used both rings for retrofire, but some used only one ring for reentry. The reentry rate-command mode has not been used by any crew, except, Gemini IV. The automatic reentry mode also has not been employed.

Two orbital maneuvers during the flight of Gemini VII were accomplished in a spacecraft powered-down configuration. This means they were without the platform, the computer, and the rate needles. The yaw attitude was established by using a star reference obtained from ground updates and the celestial chart. Roll and pitch attitudes were maintained with respect to the horizon, which was visible to the night-adjusted eye. The pilot made the burns, maintaining attitude on the star with attitude control and rate command, while the command pilot timed the burn. No unusual difficulty was encountered when performing the no-platform maneuvers, and the crew considered this procedure acceptable.

During the long duration flight, it was found desirable to adhere to the same work-rest cycle that the crew was used to on the ground. To support this schedule, both crew members slept simultaneously, except during the first night. The ground was instructed not to communicate except for an emergency.

The Gemini IV mission was a good test of the life-support systems for extravehicular activity. Preparations for extravehicular activity started during the first revolution and continued into the second. Extravehicular activity demonstrated that man can work in a pressurized suit outside the spacecraft and can use a maneuvering unit to move from one point to another. The maneuvering unit used short bursts of pulse mode. During extravehicular activity, the pilot used the spacecraft as a visual, three-dimension orientation reference. At no time did the pilot experience disorientation. The pilot made general observations and investigated tether-dynamics. Control with the tether was marginal, but it was easy to return to the hatch area using the tether. When the pilot pushed away, the spacecraft pitched down at rates of 2°/sec from the resultant force, and the pilot moved perpendicular to the surface of the spacecraft. It was difficult to push away from the surface of the spacecraft at an angle. After the pilot had reentered the spacecraft, the hatch was to be closed, but the latch handle malfunctioned. However, the pilot had been trained thoroughly in both the normal and failure modes of the hatch and was able to successfully close it.

Life-Support Systems

The bite-size foods for the crews were not as appetizing as had been expected. The rehydratable foods were good and were preferred to the bite-size foods. Preparing and consuming the meal takes time and must be done with care. The food is vacuum packed to eliminate any waste volume, but this capability does not exist when the crew is trying to restow the empty food bags. Thus, they have a restowage problem. Most of the food is in a semiliquid form and any that remains in the food bags is a potential source of free moisture in the cabin. The water has been good and cold. Even so, there seems to be a tendency to forget to drink regularly and in sufficient quantities.

On the first long-duration mission, the crewmen had a difficult time sleeping when scheduled. The spacecraft is so quiet that any activity disturbed the sleeping crewman. For the later missions, the crew members slept simultaneously, when it was possible.

Defecation is performed carefully and slowly; the whole procedure is difficult and time consuming, but possible. A major problem for long-duration flights was the storage of waste material. It was normally stowed in the aluminum container which held the food. It was necessary that a thorough housekeeping and stowage job be done every day. Otherwise, the spacecraft would have become so cluttered that it would be difficult for the crewmen to find anything.

The Gemini VII crewmen wore the G5C space suit, which is 8 to 10 pounds lighter than the normal suit. This suit contains no bumper material and has only two layers of nylon and rubber. The G5C space suit includes a zipper-type hood, which is designed to be worn over an ordinary pilot helmet.

For the Gemini VII mission, fully suited operations were conducted during launch, rendezvous, and reentry. When the hoods were on, there was considerable noise in the intercom system because of the airflow in the hood. Visibility while wearing the hood was acceptable during orbital flight, but during reentry, vision was somewhat obscured and the command pilot removed his hood. When fully suited, the crew found it difficult to see the night horizon and to observe and operate switches in the overhead and water-management panels. In the partially-suited configuration, which was maintained for approximately 2 days, there was a loss in suit cooling efficiency, and some body areas did not receive sufficient cooling. Intercommunication was improved with the hoods off, but mobility was restricted because of the hood being on the back of the head. On the second day, the pilot removed his suit, and his comfort was definitely improved. Ventilation was adequate, and the skin was kept dry. In the suit-off configuration, there was increased mobility. It was easier to exercise, unstow equipment, and perform other operations. It took approximately 20 minutes to remove the suit, including the time required to place the plugs in the suit openings in case emergency donning was required. During the sixth day of the mission, both pilots had their suits off. One apparent improvement was that all crews on the long-duration flight felt a need to exercise. Even though exercise periods were scheduled regularly, most crews requested more frequent and longer periods of exercise.

System Management

One of the crew's prime functions is to monitor and control the spacecraft's various systems. This requires a thorough knowledge of the details of each system as well as how to operate the system in any failure modes. It is true that the ground complex has much more information concerning the operation of systems than the crew does, and they have a staff of experts for each system. But, unfortunately, the crew is in contact with ground stations only for a small percentage of the flight. The crew must be prepared to rapidly analyze problems and make correct decisions in order to safely complete the mission. Every flight has had an example of this. Gemini III had the DC-DC converter failure and suspected fuel leak; Gemini IV experienced a computer memory alternator and Gemini V experienced fuel cell oxygen supply degradation while performing the rendezvous evaluation pod experiment. Gemini VI-A probably had the most difficult problem of all. The shutdown on the pad occurred in a manner that we had not considered in our training. Gemini VII had flight control and fuel-cell problems. These are the times that it pays to have a well-trained crew onboard.

VISUAL SIGHTINGS

The Gemini III crew were surprised at the flame that appeared around the spacecraft during staging. During the remainder of the flight, the Gemini III crew observed thruster firings, northern and southern hemisphere constellations, and the town of Mexicali, Mexico.

The Gemini IV crew were impressed at the clarity with which objects could be seen from directly overhead. Roads, canals, oil tanks, boat wakes, and airfields could be seen. The moon was a bright light; however, the stars close to it as well as the stars of the seventh magnitude could be seen. When the spacecraft passed from darkness to light, the airglow was clearly observed and the planets seemed to increase in brightness. Meteors could be seen as they burned in the earth's atmosphere below the orbital flight path.

The Gemini VI-A crew made some very accurate visual sightings which have been reported in the presentation of rendezvous.

The Gemini VII crew tracked their launch vehicle during the station-keeping exercise by using the acquisition lights on the launch vehicle, but they could not estimate the range. The spacecraft docking lights were turned on, but they did not illuminate the launch vehicle. As the time approached for rendezvous, spacecraft 6, at a range of approximately 2 to 3 miles, appeared to the Gemini VII flight crew like a point of reflected light against the dark earth background just before sunset. At approximately 0.5-mile range, thruster firings could be seen as thin streams of light shooting out from the spacecraft.

All crews reported that accurately tracking an object on the ground is an easy task. The difficult part is identifying and acquiring the target initially. It requires that the ground transmit accurate acquisition times and pointing angles. Also, a careful preflight study of maps and aerial photographs aids in early identification.

EXPERIMENTS

Experiments and their results are covered in other papers. But, the point should be made here, that for the crew to successfully complete any experiment, they must have a thorough understanding of what the experimenter is attempting to do. And, even more important, they must have equipment available at an early date to use in their training. One of the biggest problems is getting the actual flight equipment to work well in its environment. A ground rule has been established that all flight gear, experimental and operational, must be available and in the spacecraft for the altitude chamber test.

RETROFIRE AND REENTRY

During the Gemini III mission, a reentry control system plume-observation test was conducted. Because the reentry control system yaw thrusters obstruct the view of the horizon at night, a nightside retrofire would be impossible when using the horizon or stars as a reference. When the retroadapter was jettisoned, there was an audible noise. Jettisoning could be felt, and there was debris around the spacecraft. During reentry the spacecraft was stable, and there were no difficulties in damping out the oscillations.

During the Gemini IV reentry, the rate-command system provided excellent control, and the attitudes were held within plus or minus 1 degree. The reentry rate command with the roll gyro turned off was used so that the hand controller did not have to be held deflected in roll for the entire reentry. The spacecraft rolled about its longitudinal axis at the beginning of reentry, and, after aerodynamics started to take effect, the spacecraft rolled about its trim axis and reentered in a wide spiral.

The Gemini V crew performed retrofire during the middle of the night, using the attitude ball as a reference. At retrofire, the outside appeared to be a fireball. The command pilot reported that it felt as though the spacecraft was going back west, and the pilot reported that he felt that he was going into an inside loop.

The Gemini VI-A crew also performed their retrofire at night and did not see the horizon until just before the 400 000-foot-altitude point because of losing their night-visual adaption.

The Gemini VII crew had communications problems during retrofire, since the vented air noise in the helmets hindered good communications. During reentry, the command pilot had to remove his hood because it interfered with his vision of the horizon.

LANDING AND REENTRY

The drogue parachute is normally deployed at 50 000 feet to stabilize the spacecraft prior to main parachute deployment. After deployment, the spacecraft appears to oscillate about 20 to 30 degrees on each side. The onboard recordings indicated that these oscillations have never exceeded ±10°.

Main-parachute deployments take place in full view of the crew and it is quite a beautiful and reassuring sight. Up to this point, all events have been quite smooth with all loads being cushioned through line stretching and reefing. But, changing from the single-point attitude to the landing attitude causes quite a whip to the crew. After the Gemini III flight, all crews have been prepared, and there have been no problems.

The impact of landing has varied from a very soft to a heavy shock. The amount of spacecraft swing, and at what point during the swing the landing occurs, change the landing loads. The amount of wind drift, the size of the waves, and which part of the wave is contacted, also vary the load. Even the hardest of the landings has not affected crew performance.

CONCLUDING REMARKS

In conclusion, the flight crews have been well pleased with the Gemini spacecraft. Even though the cabin volume is very limited, they have been able to operate effectively and efficiently.