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# ZERO GRAVITY INDOCTRINATION FOR THE GEMINI/APOLLO ASTRONAUTS

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## FOREWORD

This brochure was prepared by the Crew Stations Branch, Human Engineering Division, Behavioral Sciences Laboratory, 6570th Aerospace Medical Research Laboratories, under Project No. 7184, "Human Performance in Advanced Systems," Task No. 718405, "Design Criteria for Crew Stations in Advanced Systems," for the purpose of familiarizing special groups with the effects of weightlessness on human performance. The training program described in this brochure was designed specifically for the National Aeronautics and Space Administration's Gemini/Apollo astronauts, however, the same program with some modifications has been used to indoctrinate special groups from the United States Air Force School of Aerospace Medicine at Brooks AFB, Texas, the Air University at Maxwell AFB, Alabama, and the Aerospace Research Pilot School at Edwards AFB, California.

Grateful acknowledgment is made to T/Sgt Harold Espensen, Crew Stations Branch, who prepared the photographs and charts, and to the many ASD research personnel whose ideas are reflected in this document.

## ZERO GRAVITY INDOCTRINATION FOR THE GEMINI/APOLLO ASTRONAUTS

### INTRODUCTION

This brochure describes the activities to be performed during weightless flight aboard the ASD zero-G aircraft for indoctrinating and training the Gemini/Apollo astronauts. The activities were chosen because they illustrate motions or behavior patterns that are significantly different during weightlessness from those under normal gravity conditions. The particular significance of each activity as it pertains to orbital flight is discussed. The number preceding the title of each activity refers to the corresponding activity on the schedule sheet included as the last page of this brochure. The schedule sheet is used to indicate the activity to be performed by each trainee on each weightless parabola.

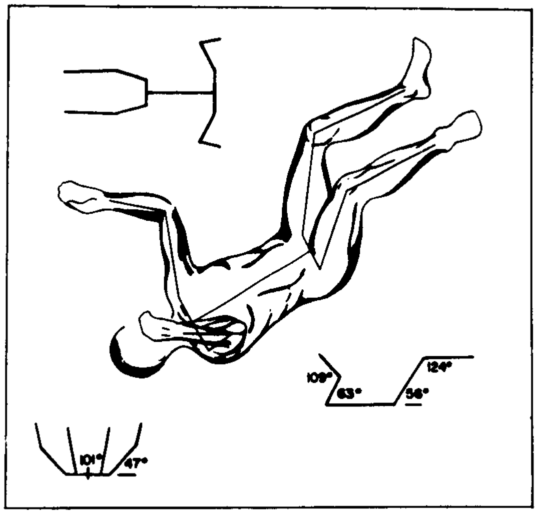
The period of weightlessness that can be produced aboard the KC-135 is approximately 30 seconds. Even in this relatively short period of time a considerable amount of data and experience concerning human performance can be obtained. On the other hand, the time period is too short to obtain reliable information about physiological functions of the body during weightlessness. Furthermore, the physiological data obtained during zero-G flights is suspect because of the high accelerations preceding and following each parabola.

The 2 1/2 G entry and recovery from each parabola constitute a potential injury hazard to inexperienced subjects. Most of the activities described in this brochure can be completed safely within the 30 seconds allowed. Some of the activities, however, will require that the subject be recovered by experienced monitors. Personnel from the Crew Stations Branch will be available for this purpose.

## DESCRIPTION AND SIGNIFICANCE OF ACTIVITIES

1. Strapped in seat - Astronauts will remain in seats with seat belts fastened.

An astronaut's first experience with weightlessness will be at burn-out of the booster stage rocket. At this time and for most of a typical Gemini or Apollo mission the astronaut will be strapped in his couch. The things to be noted during this demonstration are the tendency of the legs to rise off the floor and the arms to lift off the armrests. The reason for this phenomenon is that the muscles of the arms and legs are accustomed to supporting some of the weight of the limbs under 1-G even when relaxed. Under zero-G the absence of weight causes the limbs to assume a new relaxed posture. In the weightless posture the angle between the back and the upper leg is 56 degrees. This tendency to straighten out will cause pressure against the seat belt and may give the impression of negative G forces. For more information on the weightless posture see Ref 7, p B4 and Ref 8, p3.




2. Torque board - Two astronauts at a time will man the torque board - a small plywood panel with handles on both sides. One astronaut will attempt to hold the board while the other tries to turn it as both free-float.

Objects free-floating in the airplane are weightless and tractionless as well. Hence, Newton's third law (action and reaction) may be strikingly demonstrated. The astronauts working with the torque board will note the effect of body position as it affects their moment of inertia and their resistance to applied torques.

3. Soaring and tumbling - Astronauts will push off the cabin walls on bulkheads and attempt to soar across the free-float area.

Soaring represents the easiest and most efficient means of traversing short distances inside an orbiting vehicle or space station. Astronauts should note the difficulty of translating without rotating since this requires that the thrust imparted by the legs pass directly through the mass center of the body. The maximum velocity which a man can attain by propelling himself with his legs while weightless is approximately 15 feet per second. The astronauts, after impacting the padded walls of the cabin, should appreciate the fact that even though they are weightless they are not massless and must absorb the same amount of kinetic energy on impact while floating as if they had run into a wall under 1-G. For additional information on soaring see Ref 7, pp C12-12a; and Ref 8, pp 4-5.

4. Self-rotation - The astronaut will attempt to reorient his body to a new attitude by moving his limbs while free-floating.

Although it is not possible to move the center of mass of a body without external force, it is possible to change the attitude of the human body without external torques. If a man is not rotating he has zero net angular momentum which will be conserved in the absence of external torques. If he rotates his arms in one direction, the rest of his body must rotate in the opposite direction for the net angular momentum to remain zero. By this means it is possible for a man to rotate to any desired attitude without external propulsion. Similarly, an astronaut strapped to his couch can distrub the attitude of his vehicle by moving his arms to actuate switches, etc. Theoretically, an astronaut could change the attitude of his vehicle during drifting flight by appropriate limb motions. For more on self-rotation see Ref 8, p 10.

5. Psychomotor response - The astronauts will be asked to perform a simple positioning task with their eyes closed by drawing a series of x's in a straight line from the upper left hand corner to the lower right hand corner of a piece of paper during a complete parabola (including the 2 1/2 G entry and recovery).

The changes in muscle tension required to position the arm under varying g loads account for positioning errors particularly when there is no visual feed-back. Even with the eyes open there is a tendency to overshoot a switch or other object being reached for under zero-G. Subjects quickly learn to compensate for this tendency. For more information on psychomotor performance see Ref 3, pp 53-54; Ref 4, pp 13-18, and Ref 7, pp C9-9a.

6. Free-float sensations (blindfolded) - Astronauts will free-float while blindfolded noting their own peculiar sensations of weightlessness.

Subjects free-floating in the airplane have reported sensations ranging from a sense of exhilaration to nausea and motion sickness. The feelings varying greatly among individuals. By having the astronauts attempt to point toward the floor of the cabin while blindfolded and floating it will be possible to observe illusory sensations of rotation being experienced by the astronauts. For more information on free-float sensations see Ref 3, pp 27, 47-48, Ref 4, pp 6-13, and Ref 7, pp B8, C1, C12.

7, 8, 9, 10. Eating and Drinking - The astronauts will evaluate the ease with which drink and food can be handled, chewed and swallowed.

Weightlessness makes the conventional handling of drink and food somewhat difficult and awkward. Drinking from a cup or eating from a plate with a knife, fork, and spoon will not be possible. Instead, it is necessary to confine semi solid foods and liquids in "squeeze" containers. Food in these flexible packages can then be forced through the container into the mouth. Solids in bite-size form can be removed by hand from a closed box and placed directly into the mouth. Solids of a crumbly nature will need to be encapsulated to prevent particles of food from breaking off and floating in the cabin.

The available literature indicates a variety of experiences with respect to eating, digestion, and absorption during short periods of sub gravity. Nausea and vomiting are experienced by some people. Generally speaking, however, chewing and swallowing food present no difficulty nor is the absorption of metabolites a problem, as all of these functions appear to be independent of the force of gravity. See Ref 2.

11. Cockpit observations - Astronauts will observe the zero-G parabola from the cockpit where they may monitor the actions of the pilot and co-pilot during the maneuver.

During a zero-G parabola, the pilot must fly the airplane so as to maintain exactly zero lift at the same time the co-pilot manipulates the throttles to keep thrust precisely equal to drag. If this is done the only net force acting on the airplane is that of gravity and the airplane follows a true sub orbital trajectory whose duration depends only on entry airspeed and altitude. For more information on flying technique see Ref 3, pp 5-13.

12. Hand tool maintenance (untethered) - Astronauts will attempt to use conventional wrenches to tighten a bolt where no handhold or tethering device is provided.

Any attempt to apply forces or torques while tractionless results in motion of both the work and the worker. Astronauts should note the effect of different body positions, and hence, moments of inertia, on body accelerations. For more on use of hand tools see Ref 3, pp 49-50, and Ref 7, p C5.

13. Hand tool maintenance (tethered) - Astronauts will use conventional wrenches to tighten a bolt while tethered to the work site.

Three solutions to space maintenance problems arising from tractionless conditions have been proposed: design of fasteners that require no torque, design of torque cancelling tools, and provision for tethering the worker to his work site. The latter appears promising and can be demonstrated easily in the airplane.

14. Pendulum behavior - Astronauts will hold a swinging pendulum and observe its motion throughout the 2 1/2 G entry, zero-G, and 2 1/2 G recovery portions of the maneuver.

The effect of gravity on the oscillations of a pendulum may be strikingly demonstrated in the airplane. The astronauts should note the increased frequency and decreased amplitude of the motion during excessive G portions of the maneuver and the opposite effects during the reduced gravity portions. Changes to be expected in gravity induced oscillations on the lunar surface may be inferred from this demonstration.

15. Single-impulse mass ejection - Astronauts will attempt to throw a 10 pound medicine ball to each other while free-floating to observe the consequences of a single-impulse mass ejection on their own motion.

Newton's third law involving action and reaction can easily be demonstrated by propelling a massive object away from the body while free-floating. Unless the line of force used to propel the mass passes through the astronaut's center of mass, tumbling will accompany the resulting translational motion. Even slight force misalignments are effective in producing rotation. The astronauts should appreciate the difficulties of using a single-nozzle handheld propulsion system after this demonstration, as the same principles and problems of thrust misalignment apply.

16. Tumble and spin recovery - Astronauts will be spun while free-floating and the effectiveness of extending the limbs in reducing spin velocity will be demonstrated.

In the same manner than an ice skater can increase or decrease his spin velocity by changing the moment of inertia of his body around the spin axis, an astronaut can change his tumble velocity by extending or retracting his arms and legs. Obviously, no permanent change in angular momentum can be expected and astronauts will note that their spin velocity increases again when the limbs are returned to their original positions.

17. Self maneuvering unit demonstration - Astronauts will observe a demonstration flight of the prototype self maneuvering unit (SMU) developed for the Air Force by Vought Astronautics.

The SMU has ten fixed nozzles arranged on a back pack and uses high-pressure cold nitrogen gas as a propellant. The one-hand controller mounted on the stomach operates the nozzles through a stabilization system incorporating three rate gyros similar to the fly-by-wire scheme used on Mercury.

18. Self maneuvering unit flight - Astronauts will be given the opportunity of flying the self maneuvering unit described under item Nr. 17.

19. Fluid dynamics demonstration - The astronauts will hold plastic test models of different type tanks with and without screens and baffles and observe fluid configurations during zero-G. Some tanks will have wetting and some nonwetting fluids at different fill levels.

One of the major problems for the spacecraft system designer is adapting the propellant feed and tankage systems for operation in a weightless or low G environment. The problem includes venting of the tanks without loss of liquid propellant, expelling single phase fluids from the tanks, and the effect of heat transfer on tank and feed system design. The astronauts will note the effects of surface tension and capillary forces in determining fluid configurations. For a review of the principles determining fluid behavior under zero-G see Ref 1.

20. Coriolis effect demonstration - Astronauts will observe a demonstration of the Coriolis effect in the zero-G airplane.

Nearly everyone is familiar with Newton's second law of motion which states that force equals mass times acceleration. A fact which is not so universally appreciated, however, is that this law is not valid in a rotating coordinate frame. It is still possible to use Newton's second law in a rotating frame of reference, however, provided only that we introduce a "Coriolis force" which acts at right angles to the direction of motion of the mass.

The interior of the zero-G research aircraft fuselage provides the background against which the motion of a free-floating object is seen. Because the aircraft is pitching nose downward throughout the zero-G portion of the maneuver, this motion is observed relative to a rotating frame of reference and we should expect Coriolis forces to be present.

Similar effects will be observed by astronauts during drifting orbital flight when their vehicle is rotating slowly. Coriolis effects will also be apparent when retrieving an object on the end of a long tetherline in space. For more information on tetherline behavior see Ref 6 and for a description of the Coriolis demonstration apparatus see Ref 5.

21. Walking behavior under lunar gravity - The astronauts will attempt to walk during a 1/6 G airplane maneuver. Inflated pressure suits will be worn during this maneuver if available.

Until lunar roving vehicles are available the primary means of locomotion on the moon will be normal walking. Because the astronauts will leave their vehicle while on the lunar surface it is important that they practice walking (preferrably in a pressure suit) under the reduced gravity conditions which they will encounter.

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GEMINI/APOLLO ASTRONAUT INDOCTRINATION PLAN

A/C______ Flt No.______ Date__________

| | | PARABOLA NO. | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | ACTIVITY | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 1 | Strapped in seat | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | Torque board | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | Soaring & tumbling | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | Self-rotation | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | Psychomotor response | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | Free-float sensations (blindfolded) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | Drinking from open container | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | Drinking from tube | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | Eating from tube | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | Eating solid food | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | Cockpit observations | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | Hand tool maintenance (untethered) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | Hand tool maintenance (tethered) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | Pendulum behavior | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | Single-impulse mass ejection | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | Tumble & spin recovery | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | Self-maneuvering unit demonstration | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | Self-maneuvering unit flight | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | Fluid dynamics demonstration | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | Coriolis effect demonstration | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | Walking behavior under lunar gravity | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Astronauts: A______ B______ C______

Monitors: X______ Y______ Z______

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GENERAL PURPOSE DATA SHEET