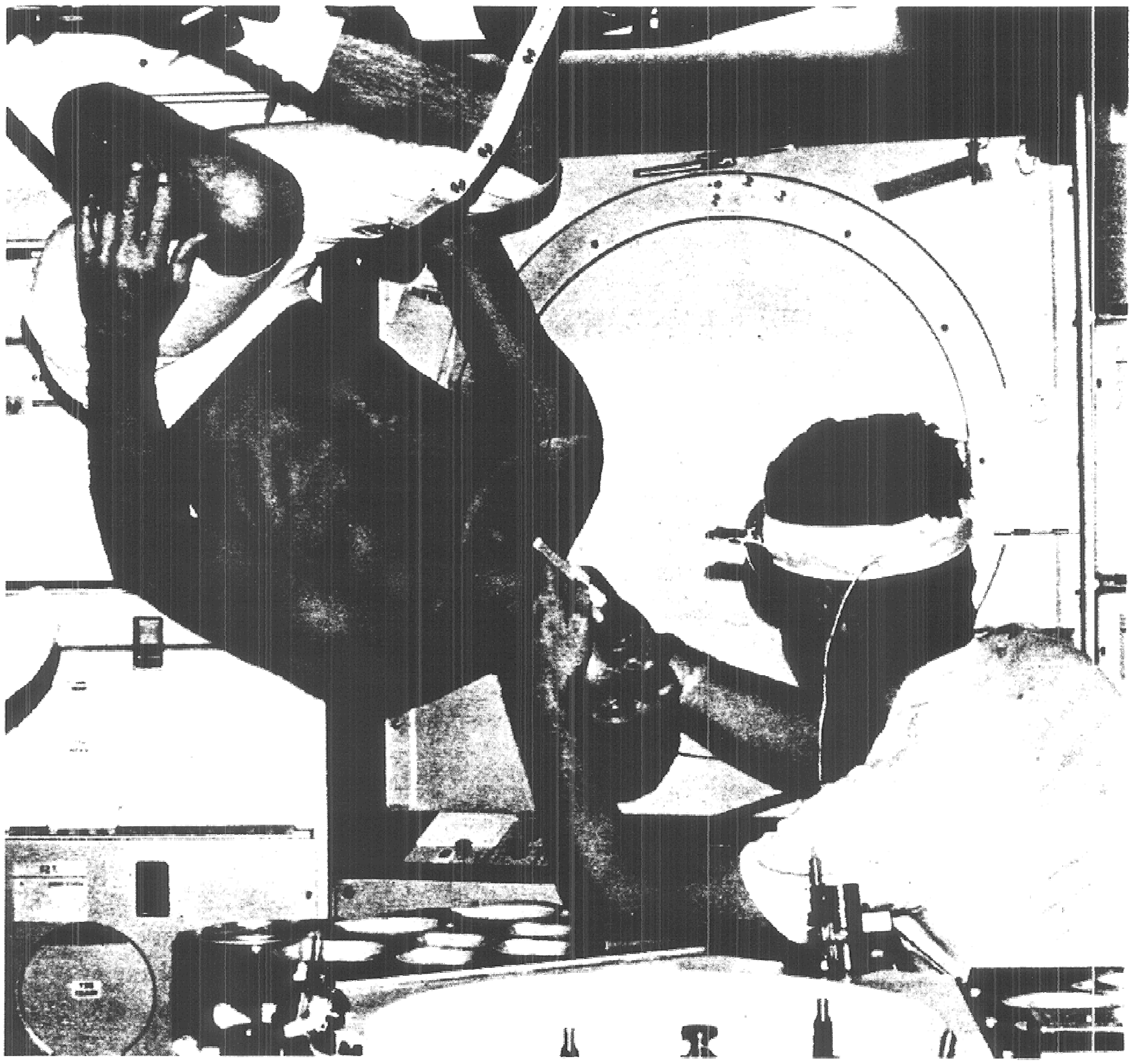
A Teachers Guide for the Videotape
Segment 2

Starts at 02:12:24
Run Time 01:57:14

REFERENCE FRAMES



National Aeronautics and Space Administration

FILM FOOTAGE FROM NASA SKYLAB MISSIONS

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I. Introduction

Skylab served as a facility to test the endurance and adaptability of man to the weightlessness of space. Skylab 4 with a crew of Pogue, Gibson, and Carr occupied the orbiting laboratory a total of 84 days, breaking all previous flight records. The Skylab equipment also represented the largest habitation volume ever assembled for spaceflight and provided the three crews freedom of movement never before experienced in spaceflight. (Basic Skylab dimensions and configurations are provided in a schematic sketch shown on page 5.)

During the first few days of their mission, most crew members experienced orientation difficulties which hampered their ability to work effectively. This phenomenon may have been brought about by the infinite number of equilibrium orientations, which is a unique characteristic of a weightless environment. On the earth's surface we orient ourselves to a relative upward direction using the vertical and horizontal lines which exist in our surroundings. In Skylab, the usual definition of down (the direction a plumb bob hangs) is of no value, and the Skylab crew members were required to assess their own orientation. Joe Kerwin, member of the first Skylab crew expressed his sense of orientation in the weightless environment this way:

> "You do have a sense of up and down and you can change it in two seconds, whenever it is convenient to you. If you go from one module into the other and you're upside down, you say to your brain, 'I want that way to be up,' and your brain says, 'OK, then that way is up.' It's strictly eyeballs and brain."

This film will provide the viewer with an inflight view of the Skylab quarters and illustrate many of the views provided the astronauts as they maneuvered themselves about. As you view the film attempt to release yourself from the single orientation concept and allow your view to be the at-rest orientation. This will put you "in the driver's seat" and for a few seconds you may get the psychological feel for being in a weightless environment.

II. Inertial and Non-Inertial Frames of Reference

Our description of the motion of an object, whether it be an automobile, an astronaut, or a satellite, depends on the reference frame (observation point) chosen for the description. In classical mechanics, the frame of reference is usually chosen for its simplicity of application and is called an Inertial Reference Frame. This frame is not accelerated and is either at rest or moving with a constant velocity relative to the fixed stars. This definition specifies an infinite set of equivalent reference frames, all of which yield an equivalent description of motion of a body.

A Non-Inertial reference frame is a frame which is accelerating (changing speed and/or direction) with respect to the fixed stars. Although not incorrect, the description of motion of a body with respect to a non-inertia frame will not be equivalent to the description as viewed from an inertial frame. The acceleration of the non-inertial frame produces inertial forces (fictitious or non-real forces) which enter our equations because of the motion of the reference frame. An example illustrating these inertial forces is provided below.

A. While at rest or while moving with a constant speed down a straight level road, you sit comfortably in the seat of an automobile. As the speed of the car is increased, you feel a force pushing you back against the seat. From your frame of reference (accelerated and non-inertial) there seems to be a force pushing against your body.

B. When the car is accelerated around an un-banked curve you feel a force pushing you toward the outer side of the curve. From your frame of reference (accelerated and non-inertial) you experience a sidewise force.

Note that in both cases described, the acceleration of the reference frame is responsible for the fictitious forces produced. If the frames were not accelerated, these forces would not exist.

This film will provide the viewer with scenes which alternate between fixed and moving camera positions. The fixed camera positions provide a view of motion from a frame of reference which is rigidly attached to the Skylab spacecraft. Is this frame of reference an inertial frame? From the discussion above you can easily answer that it is not, for Skylab is moving in a nearly circular orbit, constantly accelerating toward the center of the earth.

If the fixed camera position is actually a non-inertial reference frame, what about the usual inertial forces that result? In both examples given above for non-inertial reference frames, these type of forces entered. Will the resulting inertial effects be large enough to detect?* These questions will be treated in the Questions and Exercises section of these film notes.

*In some non-inertial reference frames the acceleration is small and thus produces only small inertial-force effects. The Earth's surface is such a reference frame, the acceleration of which produces an inertial effect called Coriolis Force (see reference C).

III. Film Synopsis

The scenes provided by this film alternate between fixed and moving camera positions relative to the Skylab spacecraft. These scenes provide the viewer a contrast between several relative reference frames available daily to members of the workshop crew.

A. Skylab's Long Axis

SCENE 1: Fixed Camera - Allen Bean twists freely through the forward dome hatch of the orbital workshop's forward compartment.

SCENE 2: Fixed Camera - Joe Kerwin floats effortlessly from the forward dome toward the camera located in the lower hatch of the forward compartment.

SCENE 3: Moving Camera - The camera is held by a moving astronaut who starts in the forward compartment and moves slowly through the forward hatch, into the airlock module (DARK), and into the multiple docking adapter.

B. Skylab's Forward Compartment

SCENE 1: Rest Camera - The astronaut moves himself through the forward compartment with an experimental unit called the Astronaut Maneuvering Unit (AMU).

SCENE 2: Moving Camera - The astronaut moves about the foward compartment and holds a camera fixed in his reference frame showing his feet near the bottom of the picture.

C. Skylab's Stowage Ring (25 stowage lockers arranged in a circular configuration).

SCENE 1: Rest Camera-Astronauts Weitz, Conrad, and Kerwin (left to right) gain the speed necessary to run around the inside of the locker arrangement.

SCENE 2: Moving Camera - The running astronaut carries the camera as he makes several revolutions around the foot locker arrangement.

SCENE 3: Moving Camera - The rotating camera tracks astronaut Kerwin as he moves around the foot lockers.

IV. Questions and Exercises

A. Run the film through from beginning to end noting the scenes which were taken with a camera moving with respect to Skylab (either translation and/or rotation). As the film continues for the second time, determine which of these moving camera scenes you can view as though they were photographed with a rest camera. It may be helpful to stop frame the film between rest and moving camera frames to allow your subconscience relaxation time before the next sequence is shown.

B. Identify each of the camera reference frames used in this film as either an inertial frame or a non-inertial frame. Make a list of all the scenes and write out a statement about each scene describing your reasoning (you may want to reread section II of these film notes).

C. In section II, the camera positions at rest with respect to Skylab were identified as non-inertial reference frames. Can you correctly identify the inertial forces which result in this non-inertial system due to the orbital motion of Skylab? (Hint: If Skylab were suddenly brought to rest in space and supported so that it would not fall toward the earth, any inertial forces which were present due to the motion would disappear.)

D. Allow the film to run through several times noting scene 1 of section C showing three astronauts running along the foot lockers as viewed from a rest camera. The beginning of the scene illustrates the difficulty the astronauts experience in gaining enough speed to make running possible.

What physical factors are important in determining how rapidly the astronaut can gain speed? What dynamical forces act on his body as he runs with constant speed around the lockers?

E. As the three crewmen run along the lockers (Scene 1, section C), time their period of revolution with a stopclock. The strap down the center of Skylab will provide a convenient point with which to start and stop the clock. (Be sure that you start and stop the clock on the same astronaut.) Calculate the average speed of the astronaut's center of mass. Do his feet and head have this same speed?

Locker Diameter = 16.3 feet
Astronaut Height = 5 feet 9 inches

F. As the astronauts were running on the circular lockers, the lockers provided an inward force restraining the body movement to a circular path. This force is called the centripetal force and it provided the astronaut some feeling of weight. From the calculation made in Part C, calculate the magnitude of the centripetal force exerted on the astronaut as he ran around the locker ring.

V. References

A. R. Feynman, R. Leighton, M. Sands, The Feynman Lectures on Physics, Addison-Wesley Publishing Company, New York, 1963. (Pseudo forces, page 12-11, and Coriolis Force, page 19-8.)

B. D. Halliday, R. Resnick, Physics, John Wiley & Sons, Inc., New York, 1960. (Forces and Pseudo forces, page 121-122).

C. H. White, Modern College Physics, D. Van Nostrand Co., Inc., Princeton. (Moving Frames of Reference, page 502-511).

SKYLAB SPECIFICATIONS

MDA <u>Multiple Docking Adapter</u>
Dia: 3 meters (10 feet)
Length: 5.2 meters (17.3 feet)
Mass: 6,260 kg.

AM <u>Airlock Module</u>
Dia: STS 3 meters (10 feet)
Dia: FAS 6.6 meters (21.7 feet)
Length: 5.3 meters
Mass: 22,226 kg.

IU <u>Instrument Unit</u>
Dia: 6.6 meters (21.7 feet)
Length: .9 meters (3 feet)
Mass: 2,064 kg.

OWS <u>Oribital Workshop</u>
Dia: 6.6 meters (21.7 feet)
Length: 14.6 meters (48.5 feet)
Mass: 35,380 kg.