

## UNIQUE LIFE SCIENCES RESEARCH FACILITIES AT NASA AMES RESEARCH CENTER

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### INTRODUCTION

The Life Science Division at NASA's Ames Research Center has a suite of specialized facilities that enable scientists to study the effects of gravity on living systems. This paper describes some of these facilities and their use in research. Seven centrifuges, each with its own unique abilities, allow testing of a variety of parameters on test subjects ranging from single cells through hardware to humans. The Vestibular Research Facility allows the study of both centrifugation and linear acceleration on animals and humans. The Biocomputation Center uses computers for 3D reconstruction of physiological systems, and interactive research tools for virtual reality modeling. Psychophysiological, cardiovascular, exercise physiology, and biomechanical studies are conducted in the 12 bed Human Research Facility and samples are analyzed in the certified Central Clinical Laboratory and other laboratories at Ames. Human bedrest, water immersion and lower body negative pressure equipment are also available to study physiological changes associated with weightlessness. These and other weightlessness models are used in specialized laboratories for the study of basic physiological mechanisms, metabolism and cell biology. Visual-motor performance, perception, and adaptation are studied using ground-based models as well as short term weightlessness experiments (parabolic flights). The unique combination of Life Science research facilities, laboratories, and equipment at Ames Research Center are described in detail in relation to their research contributions.

### BACKGROUND

Everything on Earth is exposed to gravity and living things are exposed to varying gravitational forces in their environment. Thus the mission of NASA's Ames Research Center

Life Science Division is to study the effects of gravity on living systems. When physiological changes in response to altered gravity are observed, scientists in the Ames Life Science Division are not just focused on how to develop countermeasures to these changes, but why the changes happen in the first place, i.e. the fundamental mechanisms of gravity on biological systems. From a better understanding of the fundamental physiology will come knowledge useful in both Earth research and space countermeasures. Therefore, a range of gravitational fields (hypergravity, normal gravity and microgravity) and its effects on living systems are studied. Hypergravity is studied using centrifuges and microgravity can be studied in space or through any of a number of microgravity-like models here on earth.

## **HYPERGRAVITY**

### **Centrifuges**

Several facilities are available at the NASA Ames Research Center to provide scientists with unique research opportunities at greater than Earth's gravity. In addition to their use for basic research, these facilities can also help to provide answers to many of the questions posed by proponents of rotating human space vehicles.

Extensive hypergravity studies can be performed on the seven centrifuges. A list of the centrifuges and their capabilities is provided in Table 1. Studies done at Ames investigate both behavioral and morphological changes and how they are associated with altered gravity. Using the 24 and 8 foot centrifuges, animals are exposed to hypergravity and their responses studied. Animals exposed to 2 weeks of 2 G will have altered behavior (i.e. unable to right, swimming abnormally, walking abnormally). These behavioral changes may find their cause in alterations in neural, vestibular or muscular systems.

These centrifuges are also used for muscle and bone studies. In microgravity, not only is muscle fiber size reduced in the antigravity muscles but some of the fibers change from the slow, postural type to a faster locomotion type. This could be of critical importance for humans when returning to a gravity environment. Bone is also not a static system but is constantly changing in size and dimension to fit the environment and is particularly sensitive to changes in load. Biomechanical forces, metabolic changes and hormonal changes can be studied using many of the Ames facilities. A better understanding of bone and mineral metabolism may lead to answers regarding diseases such as osteoporosis.

Adaptations of other species provide insight into how basic physiology functions. For example, one study using the 8 Foot Centrifuge (Figure 1) is comparing aquatic and arboreal

(tree climbing) snakes. The aquatic snakes have evolved in a weightless like environment whereas arboreal snakes climb trees head first and climb down head first. They therefore have different cardiovascular adaptations to prevent blood pooling and maintain proper circulation. A comparison of their responses to hypergravity is underway .

One of the more unique centrifuges that is still being developed is the Spaceflight Environmental Simulator. Using an existing 52-foot diameter cylindrical rotating platform design centrifuge, the revised facility design includes the provision of two human habitats (Figure 2) for long duration studies of the effects of chronic hypergravity on humans. Up to four humans per habitat will be able to live at up to 2 G for as long as one month without stopping the centrifuge. Each habitat, constructed of lightweight honeycomb sandwich panels, is nominally 9 ft high x 11 ft wide x 25 1/2 ft long. A habitat-positioning system provides for radial positioning of each habitat at a distance of 15 to 21 feet from the centrifuge's axis of rotation and adjusts floor angle so the resultant acceleration vector is perpendicular to the midpoint of the habitat's interior floor.

The Man Carrying Rotation Device (MCRD) is another unique hypergravity research tool. The MCRD has a 0-3 meter variable radius and one cab for human or animal research. The center of the cab can be positioned at variable distances from the center of rotation and provides variable gravity levels up to 4.5 G. Hydrostatic bearings allow for precise angular accelerations. Designed primarily for human research, the MCRD can also support research on rodents and primates. It can also be modified for specific needs. For example, it has been recently fitted with a swing platform incubator for hypergravity cell studies (Figure 3).

The human powered centrifuge was developed as a research tool to provide exercise and gravitational forces simultaneously using only human effort (Figure 4). Currently configured with a pedal mechanism, a variety of exercise methods (stair stepper, rowing, etc.) can be incorporated into the drive system to evaluate the benefits of different types of exercise and G levels.

Visual and vestibular systems give the body it's sense of position and direction. The inside of the inner ear is lined with hair cells. Small crystals, otoconia, sit on top of these hairs. As a person turns their head the crystals move due to gravity, stimulating other hair cells. The brain processes this information and that of vision and touch (proprioception) to give the body a sense of position. When entering an altered gravity environment the subject experiences perceptual illusions caused by miscues from the vestibular and visual-motor systems. Perceptual illusions can cause reduced performance which can be disruptive but can also be dangerous for pilots and crew. These miscues from the vestibular and visual-motor systems must be compensated for and adapted in order to function in an altered gravity

environment. The centrifuge suite also includes a 20G human-rated centrifuge often used for these studies (Figure 5).

### **Vestibular Research Facility**

Scientists also study the differences and similarities in how the brain processes and uses information from vertical and horizontal head movement and vestibular responses to linear acceleration, to better understand how linear acceleration and gravity receptor stimulations control eye movements. The VRF centrifuge and linear sleds enable the study of responses to smooth, linear motion or to combinations of linear and angular motion over the frequency range of natural head movement (Figure 6) . The facility permits the study of how complex linear and/or rotational accelerations are processed by the brain.

## **MICROGRAVITY MODELS**

### **Parabolic Flights**

Since actual flight opportunities are limited, much of the microgravity research is done using models that mimic the effects of microgravity. One of the methods used to test microgravity issues without going into space is parabolic flights. The Lear Jet & the larger KC-135 aircraft are used for these tests. A brief exposure to weightlessness is achieved by flying the plane up following a parabolic pattern at a 45° angle at over 400 mph and then down much the same way. The subjects and equipment in the plane are exposed to 30 seconds of zero gravity from the top to the bottom of each parabola. This allows scientists to conduct experiments as well as test spaceflight hardware prior to a Shuttle mission. The Lear Jet completes approximately 20 parabolas in one flight (40 parabolas for the KC 135).

### **Cell Culture Facility**

Scientists are looking at individual cells in response to microgravity and physical forces to determine how cellular communication changes under these conditions. The Cell Culture Facility is equipped with basic cell culture equipment as well as a cell spinner. The cell spinner continuously reorients the cells with respect to the direction of the gravity vector. This continuous rotation-reorientation has been shown to nullify the effect of gravity and allows studies in a microgravity-like environment.

## **Human Research Facility**

When a person lying down suddenly stands up, there is a multitude of force and pressure changes that the body quickly compensates for in order to insure that plenty of blood continues to the brain. When exposed to microgravity, body fluids do not have gravity pulling them down and are redistributed with much of the fluid pooling in the head and chest. The body interprets this as excess fluid, so these extra fluids are excreted. When an astronaut returns to 1 g, gravity forces the fluids forward reducing blood flow to the brain and can cause the person to pass out. This is referred to as orthostatic intolerance.

One of the facilities used to study the effects of fluid redistribution is NASA Ames Research Center's Human Research Facility (HRF). It is designed specifically for conducting ground-simulation studies of the physiological responses of humans to spaceflight. It provides a highly controlled environment with temperature, light intensity, and light cycle automatically controlled, and is suitable for research on both ambulatory and bed-rested subjects. Gurneys and beds are available either supine or 6° head down tilt. Up to 12 subjects can live comfortably in a non-hospital environment, on either an 8 hour or 24 hour basis, for weeks or months, with all their living requirements provided.

Lower body negative pressure (LBNP) is used to challenge the cardiovascular system. A person is placed in the chamber that seals at the waist and negative pressure is applied to the lower half of the body. Ground based studies using LBNP examine the cardiovascular system and in space, LBNP is used to produce cardiovascular and musculoskeletal loads similar to those normally received on earth. The LBNP devices and other test equipment available at ARC that can be used in conjunction with the HRF include the seven centrifuges, a water-immersion tank, a 30 foot linear sled (for conducting human perceptual studies) and the certified Central Clinical Laboratory.

## **SCIENCE APPLICATIONS**

### **Biocomputation Center**

The Biocomputation Center at Ames Research Center is dedicated to computer-based three-dimensional (3-D) visualization of cells, tissues and organs, mathematically based modeling, and 3-D simulations of the functioning of living systems from the subcellular and molecular to the organismal level. The emphasis is on teams of broadly based,

interdisciplinary investigators and on a union between computational, theoretical and experimental research.

Cells of the inner ear are gravity sensing receptors that are sensitive to both gravitational and linear acceleration. The Biocomputation Center is used to study the structures and function of these cells. Also examined is the cell circuitry (synapses). A significant increase occurs in the number of synapses in animals exposed to microgravity and a significant decrease after exposure to hypergravity.

## **SUMMARY**

Basic scientific questions can be investigated with the use of Ames Research Center's unique facilities. The individual facilities themselves offer great opportunities for study, and in combination provide truly unique capabilities for research in the fundamental mechanisms of gravity on living systems.

<b>Table 1</b>	<b>Centrifuge Facilities</b>
<b>Figure 1</b>	<b>8 Foot Diameter Animal Centrifuge.</b>
<b>Figure 2</b>	<b>Space Flight Environmental Simulator Human Habitat</b>
<b>Figure 3</b>	<b>Man Carrying Rotation Device With a Cell Incubator.</b>
<b>Figure 4</b>	<b>Human Powered Centrifuge</b>
<b>Figure 5</b>	<b>20G Human Rated Centrifuge</b>
<b>Figure 6</b>	<b>30 Foot Linear Sled</b>

TABLE 1 CENTRIFUGE FACILITIES

FACILITY	DIAMETER (M)	PAYLOAD (KG)	MAX G	MAX RPM (RAD/SEC)	ONSET RATE	TIME AT G	USE
20G CENTRIFUGE	17.7	544.3	20	5.2	1 G/Sec	MIN-HOURS	3 CABS-HUMANS, ANIMALS, EQUIP.
SPACE FLIGHT ENVIRON-SIMULATOR	15.9	2268	3	2.4	NOMINAL	WK-MONTHS	2 CABS-HUMANS, 4 CAGES
MAN CARRYING ROTATION DEVICE	VARIABLE 0-3.1	226.8	4.5	4.7	0.007-0.52 RAD/SEC SQ.	MIN-WEEKS	1 CAB-HUMANS, INCUBATOR
HUMAN POWERED CENTRIFUGE	3.8	226.8	5		NOMINAL	MIN-HOURS	HUMANS
24 FOOT CENTRIFUGE	7.3	20 LG CAGES	4	3.1	NOMINAL	DAYS-WEEKS	SMALL PRIMATES, RODENTS
8 FOOT CENTRIFUGE	2.4	20 SM CAGES	10	8.9	NOMINAL	DAYS-WEEKS	RODENTS, SNAKES
VRF-MULTI AXIS CENTRIFUGE	1.2	2 CANISTERS	1.75	4.2	8.7 RAD/SEC SQ.	MIN-HOURS	SMALL PRIMATES, RODENTS



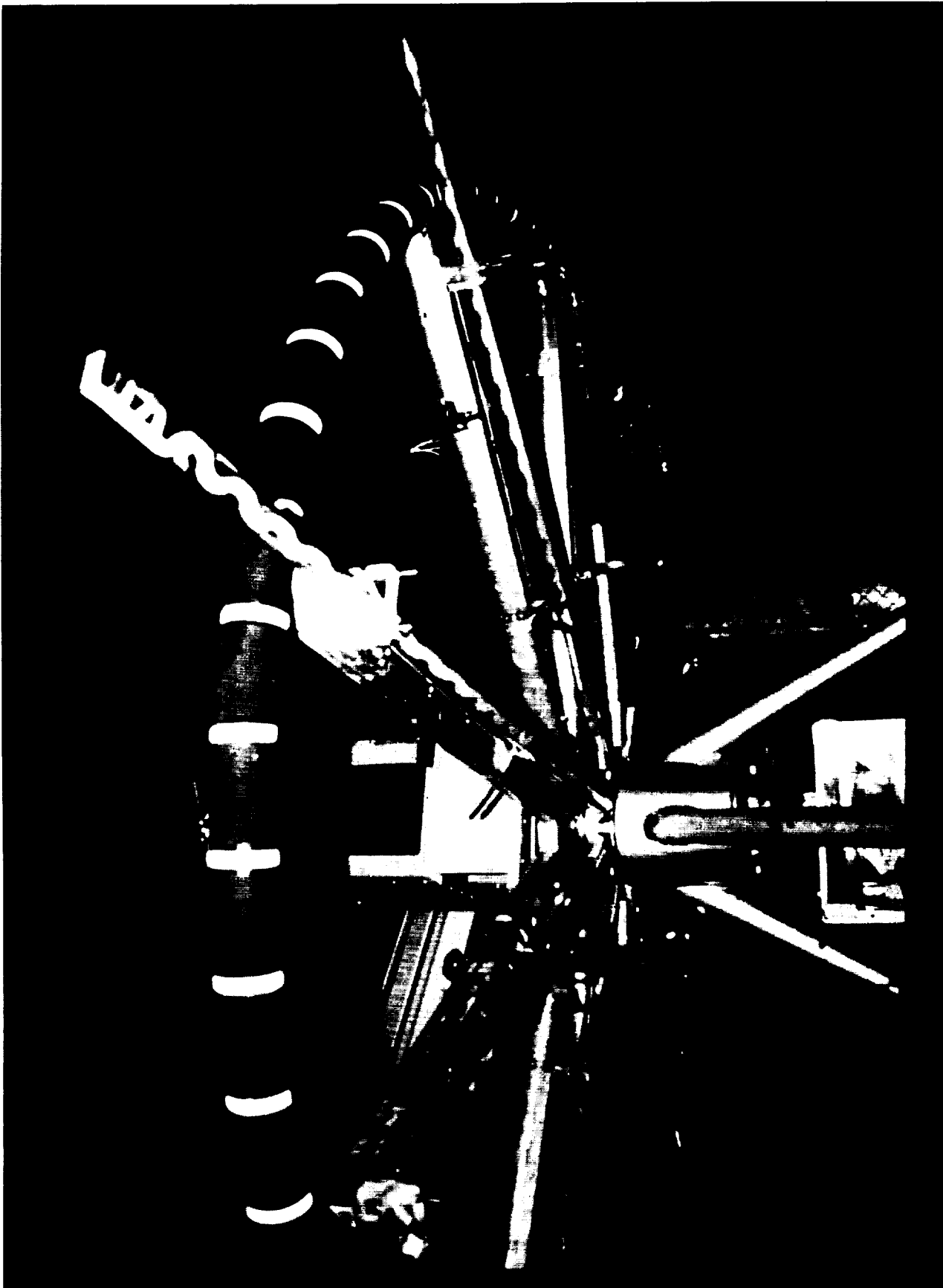
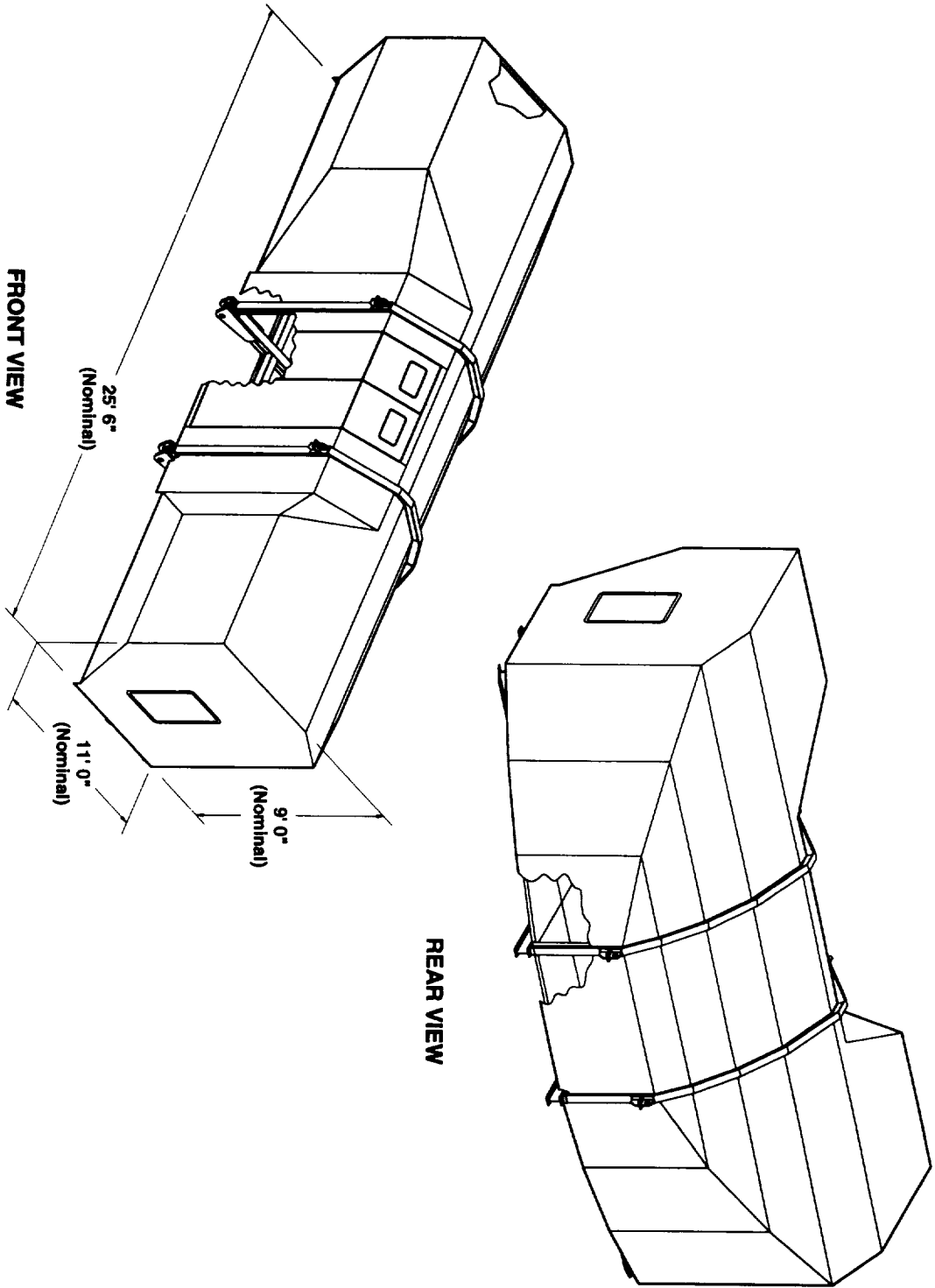


FIGURE 1 8-FOOT DIAMETER ANIMAL CENTRIFUGE

FIGURE 2 SPACE FLIGHT ENVIRONMENTAL SIMULATOR HUMAN HABITAT



**HUMAN HABITAT ASSEMBLY**

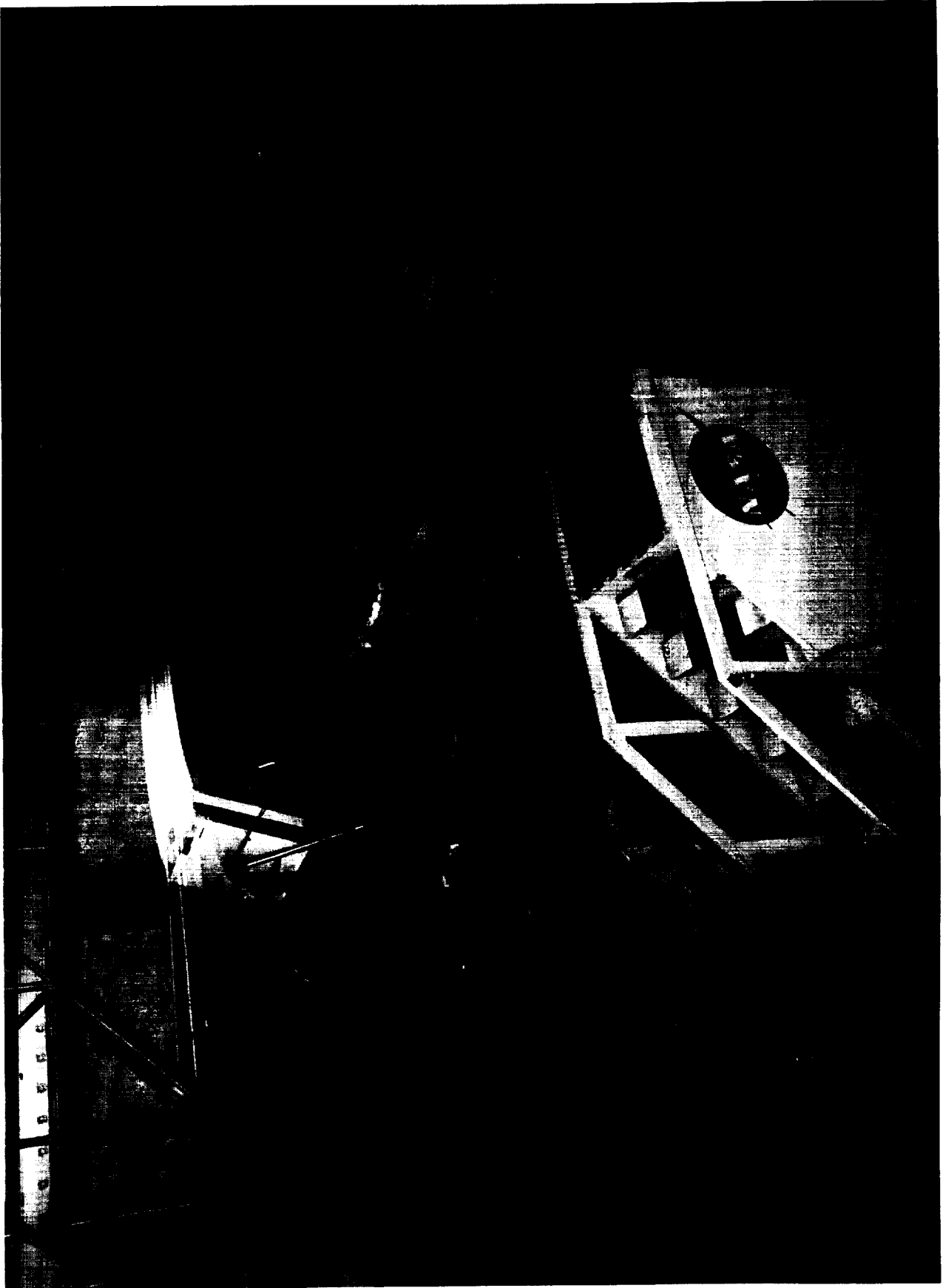


FIGURE 3 MAN-CARRYING ROTATION DEVICE WITH A CELL INCUBATOR

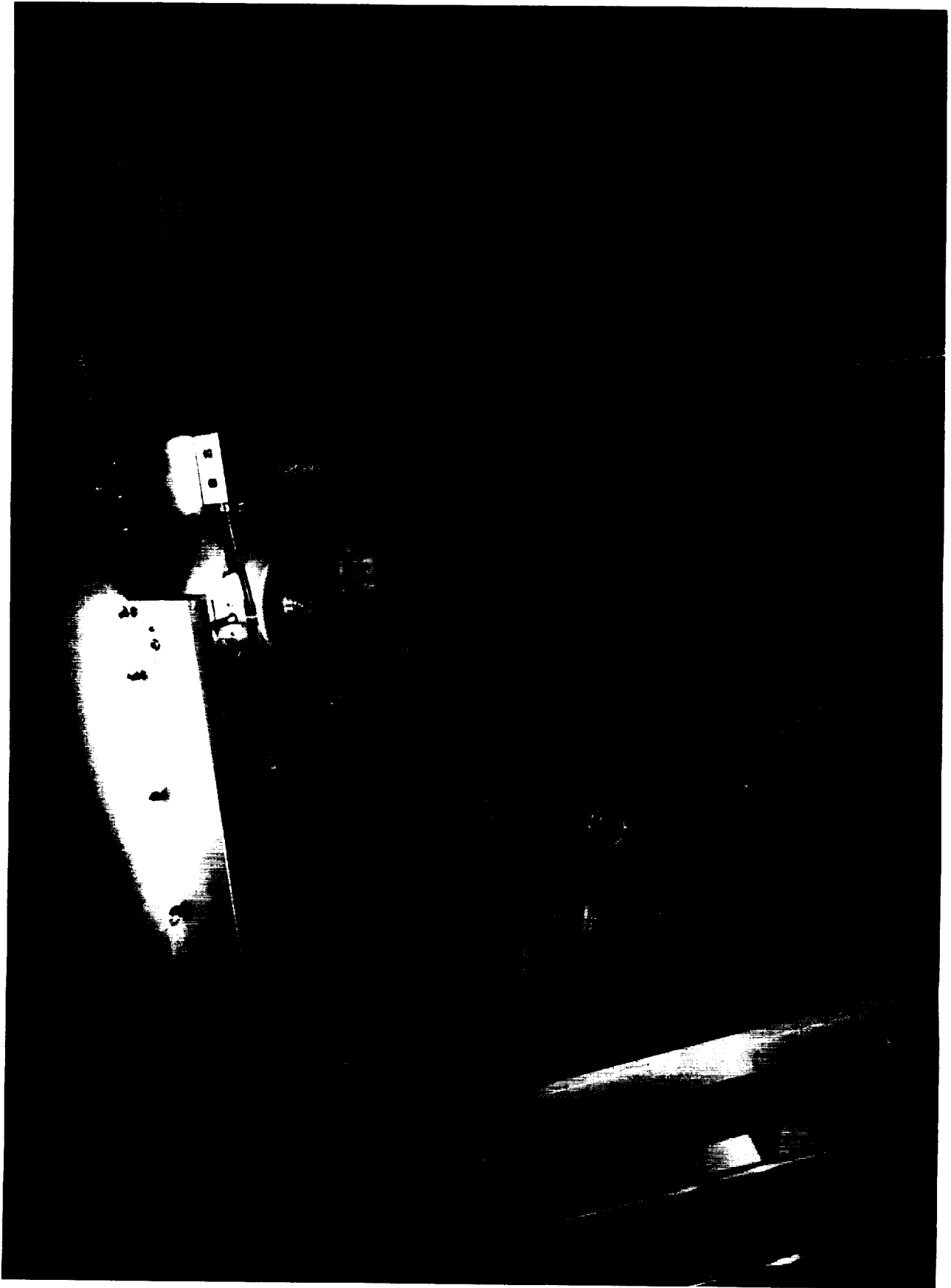


FIGURE 4 HUMAN-POWERED CENTRIFUGE

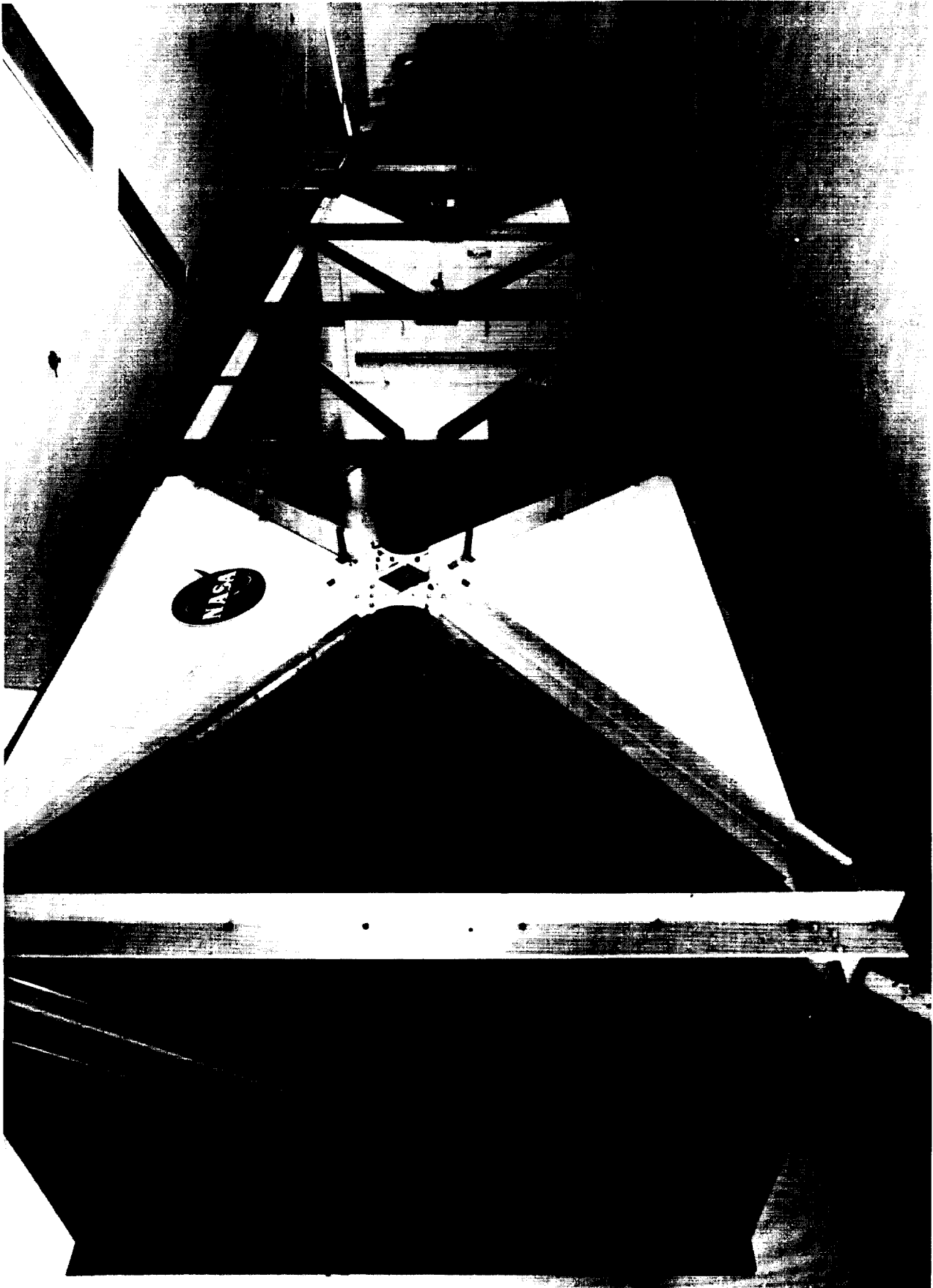


FIGURE 5 20G HUMAN-RATED CENTRIFUGE



FIGURE 6 30-FOOT LINEAR SLED