National Aeronautics and Space Administration

MSF

Microgravity Simulation Facility (MSF)

The Microgravity Simulator Facility (MSF) at Kennedy Space Center (KSC) was established to support visiting scientists for short duration studies utilizing a variety of microgravity simulator devices that negate the directional influence of the "g" vector (providing simulated conditions of micro or partial gravity). KSC gravity simulators can be accommodated within controlled environment chambers allowing investigators to customize and monitor environmental conditions such as temperature, humidity, CO_2, and light exposure.

Slow Rotating Clinostats

KSC engineers have designed a slow rotating clinostat that allows researchers to subject biological specimens contained within ISS stowage lockers (containing hardware used for spaceflight experiments), or other large containers, to simulated microgravity conditions (see Fig. 1A, B). The clinostat rotates in one dimension along the horizontal axis at 2-4 rpm. Power is provided for built-in computers, lamps, fans, and auxiliary equipment. Adapters can be developed to accept various hardware configurations. Other slow rotating clinostats are also available for 10 cm x 10 cm Petri plates and other containers specialized for particular life science model organisms.

Rotating Wall Vessel (RWV) Bioreactors

Rotating Wall Vessels (Fig. 1C, D; http://synthecon.com/pages/home.asp) or rotating bioreactors (initially developed by NASA) have been successfully used to investigate gravitational effects on biological specimens, cell cultures, aquatic organisms such as zebra fish eggs/embryos, tissue cultures, etc. Microgravity effects are simulated within liquid media by RWVs and are studied by aligning cultures on a rotating horizontal axis at a defined rotational speed that regulates the fall velocity, thereby allowing specimens to remain in constant free fall simulating near weightlessness conditions.

Some studies have shown that morphological and structural changes in cells cultured in rotating wall vessels resemble those observed *in vivo* after exposure to microgravity during spaceflight. RWVs can also produce a partial gravity simulation effect by either increasing or decreasing the rotation speed in combination with changing the density of the suspension fluid, and/or other means.

Random Positioning Machines (RPM)

3-D clinostats have two independently rotating frames that are mounted perpendicular to each other (Fig. 1E, F). The term "3-D clinostat" is used when both rotating axes of the device are running with constant speed and constant direction. However, both frames can also be operated with different speeds and different directions, in which case the term "random positioning machine" is often used. Randomness is achieved when the rotational angle differs between the two axes and changes over time.

An experimental apparatus containing research specimens is placed within the inner of two counter-rotating platforms. Modifications to the inner platform can allow use of various hardware configurations (up to 1.5 kg). Two RPM versions are currently available at KSC, the Airbus RPM 2.0 (Fig. 1E; www.airbusDS.nl) and the Space Bio-Laboratories, Inc. GRAVITE (Fig. 1F; http://www.spacebio-lab.com/ENG-index.html). Based upon operating configurations, treatments of simulated microgravity ($<10^{-3}$ *g*), partial gravity, or hypergravity (to 2-3 *g*) can be achieved.

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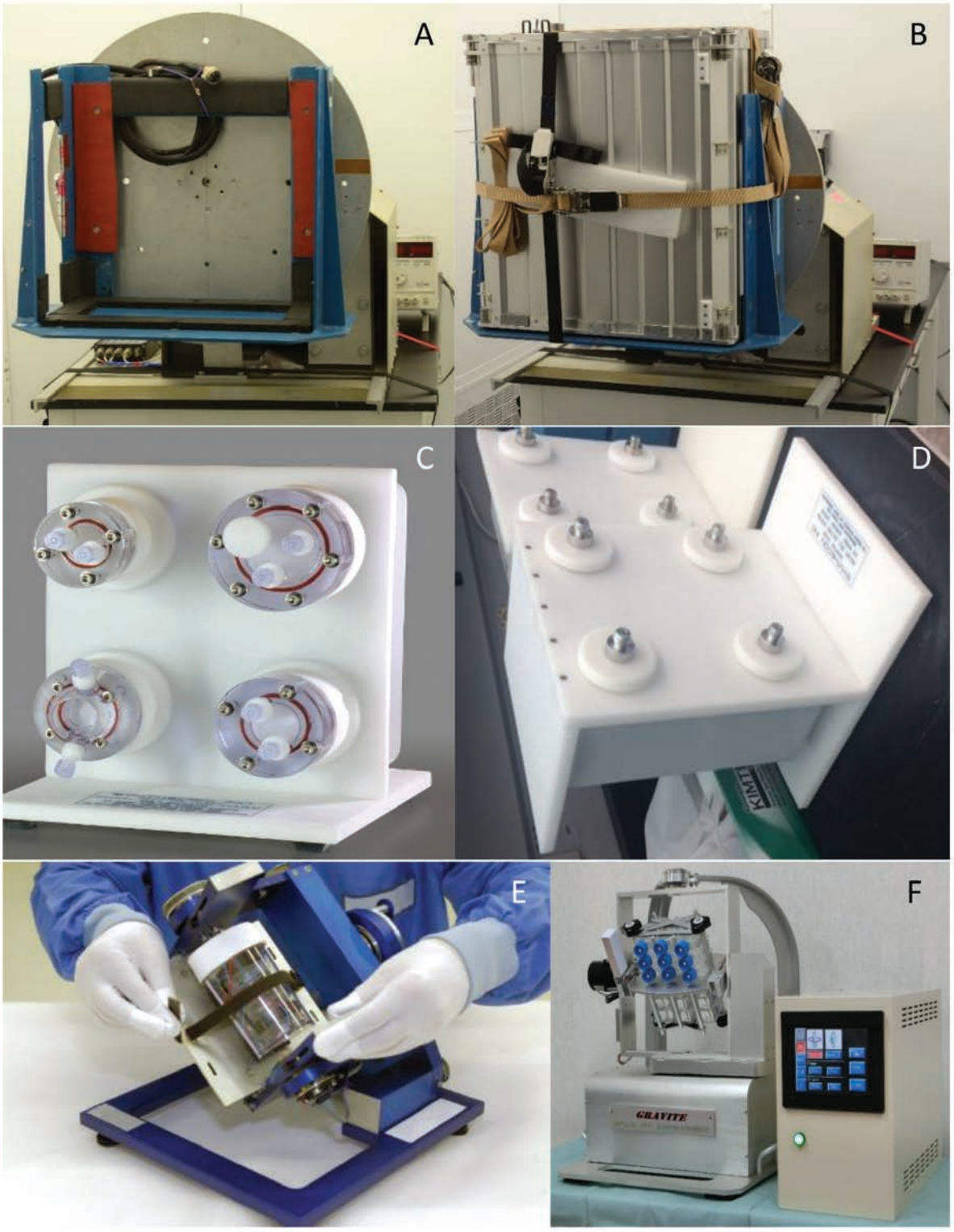

A. KSC Slow Rotating Clinostat. **B.** KSC Slow Rotating Clinostat in ISS stowage locker configuration. **C.** Rotating Wall Vessel (Microgravity configured with HARV's attached). **D.** Rotating Wall Vessel holder in 1 *g* "control" configuration. **E.** Airbus RPM 2.0 configured with experimental vessel. **F.** Space Bio-Laboratories, Inc. GRAVITE RPM.