Measuring Microgravity

Frequently, news commentators refer to zero-g, or zero gravity, when showing pictures of Space Shuttle crews working, tumbling, and floating in space. Indeed, as one watches floating drops of water or food as well as crewmembers working "upside down," it is easy to think that they have completely escaped from the force of gravity.

At the altitude the Shuttle orbits Earth, however, gravity is still almost as strong as it is on the ground. You would have to travel millions of miles away from our solar system to obtain zero gravity. If it were possible to drop a ball from the top of a tower the same height that the Shuttle circles Earth, the ball would fall toward the ground just as it would if it were dropped from a tall building. The apparent weightlessness of everything in the orbiter is the result of a condition known as "free-fall."

Any object that is dropped experiences free-fall. As the object falls toward Earth's surface, it and any objects in it are falling at the same rate, so they "float" in relation to each other as if there were no gravity. Even though gravity is still present, its effects are almost eliminated by free-fall. Thus, the conditions created by free-fall are referred to as a *microgravity environment*.

An experiment canister dropped down a tube from a tower experiences a very brief period of microgravity before it hits the ground. An airplane flying a special series of climbs and dives will experience microgravity for a slightly longer period of time than possible using a drop tower. The Shuttle, however, is falling around Earth in such a way that it never hits the ground, allowing its contents and passengers to experience microgravity for as long as it stays in orbit.

This continuous free-fall is possible because the orbiter is at the right height and speed to cause its "fall" to match the curvature of Earth's surface. An easy way to visualize this is to imagine shooting a cannon. The more powder you use, the farther the ball will go. If the cannon could be placed above the tops of the mountains and you could load enough powder, the cannon ball would fly all the way around the globe.

The Shuttle can be thought of as just such a projectile. It is launched in a path, known as a *trajectory*, and with enough power that it constantly falls around Earth. Because the Space Shuttle is in continuous free-fall and upper atmospheric friction is extremely low, a microgravity environment is obtained.

As the name states, however, microgravity is not the absence of gravity but a state where the effects of gravity have been reduced. In addition to the small amount of gravitational effects present, changes in motion and vibrations from routine operations can mimic the effects of gravity.

The motion of the Shuttle around Earth is not as stately and unchanging as it might appear to the casual viewer. As it orbits Earth, the Shuttle is in the extremely thin upper atmosphere and encounters atomic oxygen that provides resistance to its movement, slowing it down. Since the density of the atmosphere encountered by the Shuttle varies from night to day, the amount of deceleration also varies. Also, the Shuttle fires thrusters to maintain a particular position or to maneuver to a new

Each change in motion produces *accelerations* (rates of change in velocity) that can mimic gravity in much the same way that the sudden forward motion of an automobile can imitate gravity and push you back in your seat. Nor are changes in the motion of the Shuttle the only things to mimic gravity: vibrations within the orbiter also produce accelerations because vibrations are nothing more than an extremely fast series of back-and-forth movements. The reason the case holding a stereo speaker vibrates is because it is moving very rapidly in response to the sound coming from the speaker. Just as a balcony, stair, or elevator can move or vibrate in response to activity, the Shuttle vibrates in response to the activities taking place in it.

The microgravity environment created by an orbiting spacecraft allows people to float and events to occur as if there were no gravity present.

The crew creates movements in the Shuttle as they exercise, perform experiments, and tend to housekeeping duties. The KU band antenna, which transmits data and communications from the orbiter to the Tracking and Data Relay Satellite System, moves continually during the Shuttle mission, changing its alignment to maintain contact with the appropriate satellite. To prevent a condition called *stiction*, where mechanical components stick slightly and then release with a slight jerk, the antenna quivers at a frequency of 17- hertz, providing a noticeable vibration for certain science experiments. Other orbiter systems produce vibrations with the operation of Freon pumps, air fans, coolant loops, and the motion of cameras in the cargo bay.

In microgravity, even minute forces can affect experiments; therefore, investigators need to know the precise strength of gravitational influences and vibrations affecting their experiments to interpret results correctly and to develop an understanding of the effects caused by these forces. As a result, the Second United States Microgravity Laboratory payload will include the Space Acceleration Measurement System and the Three Dimensional Microgravity Accelerometer. Also, while not a part of the scientific payload, the Orbital Acceleration Research Experiment will fly as a part of the ongoing Orbiter Experiments Program, and its measurements will complement those of the other two accelerometers.

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Space Acceleration Measurement System (SAMS)

Project Manager: Ron Sicker, NASA Lewis Research Center

Purpose: To monitor and record onboard accelerations and vibrations experienced during the orbital flight of the Space Shuttle so researchers can use the data to assess the influence of Shuttle accelerations on their experiments

Method: Each Space Acceleration Measurement System sensor head has three triaxial accelerometers that are oriented at right angles to each other to detect accelerations in three dimensions. The sensors, located on the Surface Tension Driven Convection Experiment, the Crystal Growth Furnace, and the Glovebox, are connected by cables to a control and data storage unit located in the Spacelab center aisle between racks three and four.

Each accelerometer consists of a mass suspended by a quartz element, allowing movement along one axis only. A coil is attached to the mass, and the assembly is placed in a magnetic field. An applied acceleration moves the mass from its rest position, altering the magnetic field and causing current to flow in an electrical circuit. The current is proportional to the force of the acceleration. The instrument's electronics convert the current into voltage and then into digital data for processing by its computer.

Three Dimensional Microgravity Accelerometer (3DMA)

Principal Investigator: Jan Bijvoet, University of Alabama in Huntsville, Huntsville, Alabama

Purpose: To measure the absolute level of microgravity as well as the microvibrations in the Shuttle

Method: While the effects of gravity are almost eliminated by free-fall, they have not been completely eliminated. For scientists to interpret correctly the data and results from their experiments, it is critical that they know the exact strength of gravitational effects present at any time during their experiments. The absolute level of microgravity acceleration — the difference between zero gravitational effects and what is experienced on the mission — will be measured by the Three Dimensional Microgravity Accelerometer.

This instrument uses three special accelerometers, located in its central housing, to measure the level of absolute microgravity in three separate *axes*, or dimensions. The instruments are invertible accelerometers because they invert periodically to allow *bias* — or inaccuracies present in all accelerometer data — to be eliminated. This allows the absolute level of microgravity to be determined. In addition, three remote sensors record the different vibrations and accelerations caused by experiment and orbiter operations.

On board, the data will be recorded automatically on hard disc drives in the central unit for analysis after the mission. In addition, the data will be sent to the ground in real time. Principal Investigators can call up displays that show absolute gravity for each axis and microvibrations in each axis for the four locations. The absolute level of microgravity and data from the three remote sensors will be recorded on three different scales, allowing quantification of disturbances. All three scales will be displayed simultaneously in the data package.

At the start of the mission, the crew will turn the unit on and check to be sure it is operating properly. No further crew involvement will be necessary until the unit is shut down.

Orbital Acceleration Research Experiment (OARE)

Project Manager: Jose L. Christian, Jr., NASA Lewis Research Center

Purpose: To measure accurately low-level on-orbit accelerations and to detect perturbations from aboard the Shuttle

Method: As the Orbiter free-falls around Earth, it is subject to Earth's gravitational pull, which keeps it "tied" to the center of our planet. This force is called *centripetal force*, and while in orbit, the Shuttle experiences changes in its velocity because of this force and because of changes in the strength of Earth's gravity (*gravity gradients*). This experiment measures these perturbations as well as changes caused by atmospheric drag. The latter is extremely important as it could provide vital information to scientists about the density of the upper atmosphere from 120 to 180 kilometers and could help to validate Shuttle aerodynamic models.

The Orbital Acceleration Research Experiment has a cylindrical mass (*a proof mass*) suspended within an electrostatic field found in the accelerometer housing. The proof mass will be pulled in different directions by static electric fields generated by the electrodes within the housing. When the fields exert equal pulls in all directions on the proof mass, it floats between them. This is known as *electrostatic suspension*. An acceleration in any direction will cause the proof mass to move with respect to its enclosure, distorting the suspending electrostatic field. These field distortions are proportional to the applied acceleration and are measured and interpreted by the instrument's electronics. Computer software will condition the acceleration data by removing frequencies above 1 hertz and by downlinking part of the data to scientists monitoring the experiment from the ground. Highly filtered and full engineering data from the instrument will be stored in an internal electronic memory for postflight analysis. This experiment has flown four times and is part of the Microgravity Measurements and Analysis Project.