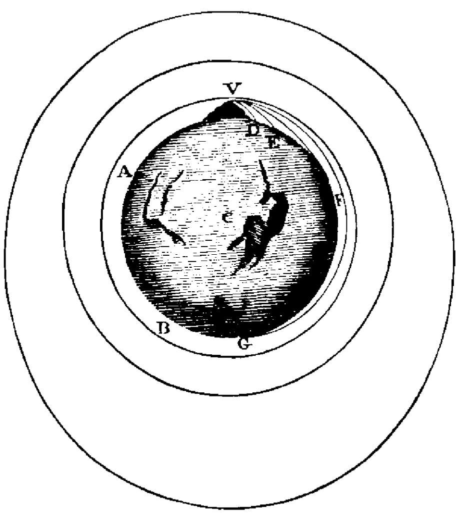
The Awful Truth About Zero-Gravity

Space Acceleration Measurement System; Orbital Acceleration Research Experiment

Earth's gravity holds the Shuttle in orbit, as it does satellites and the Moon. The apparent weightlessness experienced by astronauts and experiments on the Shuttle is a balancing act, the result of free-fall, or continuously falling around Earth.

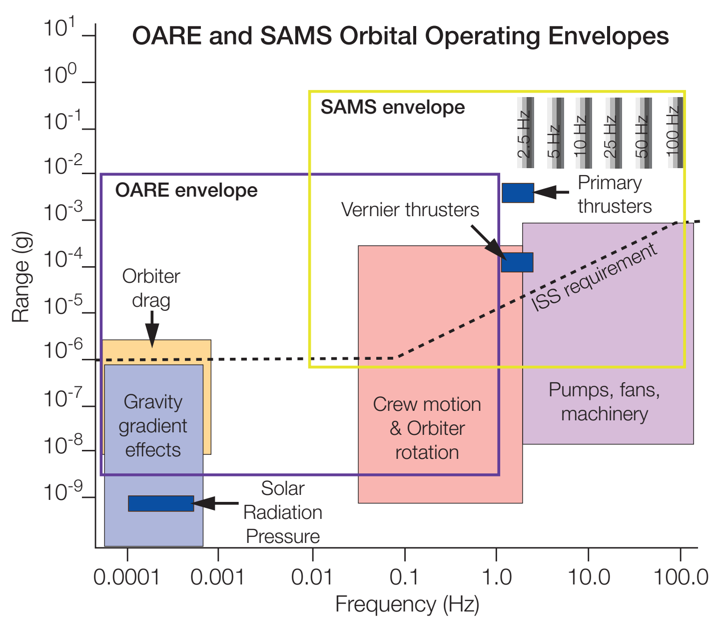
An easy way to visualize what is happening is with a thought experiment that Sir Isaac Newton did in 1686. Newton envisioned a mountain extending above Earth's atmosphere so that friction with the air would be eliminated. He imagined a cannon atop the mountain and aimed parallel to the ground. Firing the cannon propels the cannonball forward. At the same time, Earth's gravity pulls the cannonball down to the surface and eventual impact. Newton visualized using enough powder to just balance gravity so the cannonball would circle Earth. Like the cannonball, objects orbiting Earth are in continuous free-fall, and it appears that gravity has been eliminated.



Newton's Thought Experiment: A cannonball fired with enough force could fall endlessly around (or orbit) the Earth.

Yet, that appearance is deceiving. Activities aboard the Shuttle generate a range of accelerations that have effects similar to those of gravity. The crew works and exercises. The main data relay antenna quivers 17 times per second to prevent 'stiction,' where parts stick then release with a jerk. Cooling pumps, air fans, and other systems add vibration. And traces of Earth's atmosphere, even 200 miles up, drag on the Shuttle.

While imperceptible to us, these vibrations can have a profound impact on the commercial research and scientific experiments aboard the Shuttle. Measuring these forces is necessary so that researchers and scientists can see what may have affected their experiments when analyzing data. On STS–107 this service is provided by the Space Acceleration Measurement System for Free Flyers (SAMS-FF) and the Orbital Acceleration Research Experiment (OARE). Precision data from these two instruments will help scientists analyze data from their experiments and eliminate outside influences from the phenomena they are studying during the mission.



SAMS and OARE will record data in two separate areas of the vibration spectrum, and with a modest amount of overlap. Different activities have different effects on sensitive payloads on the Shuttle, and the broad range that each has. Frequency (Hz) indicates vibrations per second. Notice that "0-g" is never reached.

SAMS Shuttle Project Manager: Ronald J. Sicker, Glenn Research Center, Cleveland, OH
PIMS Project Manager: Kevin M. McPherson, Glenn Research Center, Cleveland, OH

Background Information

The primary means for scientists to learn more about the microgravity conditions affecting their research is from the Space Acceleration Measurement System (SAMS). The SAMS system is produced by the Microgravity Environment Program (MEP) at the NASA Glenn Research Center. The MEP produces a variety of microgravity measurement hardware for on-orbit spacecraft (the *International Space Station* (*ISS*) and the Space Shuttle) and ground-based flights (drop towers, parabolic aircraft, and sounding rockets). The various SAMS (SAMS, SAMS-FF (free flyer), and SAMS-II) have supported 22 shuttle missions, and the Mir space station, and provide long-term support on the ISS. STS–107 will use a SAMS-FF. This is the second Shuttle mission for the SAMS-FF, which is a third-generation SAMS system. It uses industrial-grade components to provide a flexible, modular system that is easily customized for each particular mission.

Space Acceleration Measurement System-Free-Flyer

SAMS-FF consists of a control and data acquisition unit (CDU), three remote acceleration sensor heads, and a fiber-optic gyroscope (FOG). The CDU is similar to a desktop computer packaged to meet the rigors of spaceflight. It controls the operation from the ground and process data from the sensors through a telemetry data stream, which can be seen on NASA computers on the ground. This lets experimenters view the data collected during the mission so they can correlate their science results with the SAMS data in real time. Three accelerometers are precisely mounted at right angles to form a triaxial sensor head (TSH). This allows the sensor head to detect vibrations in three different directions of movement: what would be on Earth up and down, forward and backward, and side-to-side (called X, Y, and Z axes). The data are processed to provide the resultant vector of the magnitude and direction, as well as the frequency content, of various time intervals. The TSH is a microcontroller-based data acquisition system capable of measuring the microgravity accelerations of the Shuttle. Sensitive inertial grade accelerometers are used to resolve the very low forces experienced during quiet periods and have the dynamic range to measure the larger vibration disturbances.

SAMS-FF includes the control data unit (left), a triaxial sensor head (center) and the fiber-optic gyroscope (right). Two additional triaxial sensor heads will be remotely mounted with payloads.

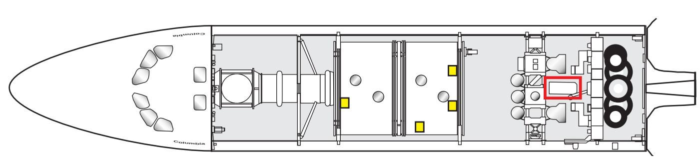
A new sensor on STS–107 is a fiber-optic gyroscope (FOG). To fully capture the motion of the vehicle, not only are the forces examined in three linear directions, but also the rotation of the vehicle is measured to understand the torque forces. FOG has no moving parts and is used to measure precisely the roll, pitch, and yaw of the shuttle. It does this by comparing the phases of beams of light traveling in opposite directions around a very long coil of fiber. If there is no rotation, the beams recombine at exactly the same phase. However, if the coil is rotated in a particular direction, travel takes longer in the opposite direction before it exits the coil. This difference is detected by sensitive electronic circuits to determine the rate at which the rotation occurs. Lower grade versions of FOG gyroscopes are used in automobiles, combined with GPS data for electronic positioning displays.

Orbital Acceleration Research Experiment

In addition to SAMS, the OARE accelerometer system characterizes (measures) the quasi-steady acceleration environment. OARE measures very low frequency microgravity accelerations caused by upper atmospheric drag (as the shuttle passes through the upper atmosphere), rigid body inertial rotations, gravity-gradient effects, shuttle's mass expulsion, and crew activities. OARE acceleration data complement that of SAMS by providing the scientists a more thorough understanding of the various accelerations that can affect the experiments onboard the shuttle or any orbiting spacecraft in a low Earth orbit.

Principal Investigator Microgravity Services

The PIMS group at NASA Glenn is responsible for processing, analyzing, and archiving the acceleration data measured by the two accelerometer systems previously described. During STS–107, acceleration data will be transmitted to the ground via telemetry links for real-time processing and analysis so that the scientists can assess the impact of the reduced-gravity environment in near real time on their experiments. Specialized displays are developed by the PIMS group to help the scientists make near real-time decisions in order to lessen the impact of the reduced-gravity environment on their science results, thereby maximizing good science data collection. PIMS will prepare an STS–107 mission microgravity characterization summary report which will highlight the reduced-gravity environment during the STS–107 mission to help the scientists take into account the adverse impact of the environment on their science results. PIMS will provide real-time support and post mission support to the Combustion Module–2 (CM–2) facility.


Approximate locations of this payload aboard STS–107.

Picture credits. NASA.

FS-2002-06-073-MSFC