What is Microgravity?

- A condition of reduced gravitational effects
- An environment “isolated” from most gravitational forces
- An opportunity to explore events and processes impossible to study on Earth

During many Space Shuttle missions, the word microgravity is used to refer to the apparent absence of gravity that allows the crew to float around and perform unique experiments that cannot be done on the ground. But what is microgravity?

The National Aeronautics and Space Administration (NASA) uses the term microgravity to describe a condition of free-fall within a gravitational field in which the weight of an object is significantly reduced compared to its weight at rest on Earth. The effects of gravity are reduced by allowing an object to fall; as it does, the object and anything in it are falling with an acceleration caused almost exclusively by gravity, so they “float” in relation to each other as if there were no gravity. This reduced-gravity environment can only be created by free-fall because, to find natural microgravity conditions similar to those experienced by astronauts orbiting the Earth, one would have to travel more than 6 million kilometers into space — 17 times farther away than the Moon.

At the height the Shuttle orbits, the pull of Earth’s gravity is still almost as strong as it is at ground level. In fact, if it were possible to drop a ball from the top of a tower that reached to the same altitude at which the Shuttle circles Earth, the ball would fall toward Earth just as it would if it were dropped from a tall building. An experiment canister dropped down a tube from a tower, called a drop tower by scientists, 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 is 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 the Shuttle stays in orbit.

While in free-fall, the Shuttle and its contents are “isolated” from the effects of gravity. Aboard the orbiter, even the heaviest objects no longer fall “down,” and spilled liquids form balls that float rather than forming puddles that flow across the floor. The free-fall environment provides unique opportunities to researchers. Subtle and complex phenomena, normally hidden by the stronger force of gravity, can be revealed for detailed study. For example, the way a fire starts and spreads can be studied without the interference of gravity, giving scientists a better understanding of the processes involved and, perhaps, leading to improved fire safety. Mixtures that separate on Earth, because of the different densities among their components, can be evenly mixed and processed in microgravity. This allows scientists to study the processing of such materials and to create advanced materials for study and comparison. Without the pull of gravity, more perfect crystals can be produced, which may eventually lead to the creation of advanced computer chips and semiconductors. The growth of near-perfect protein crystals will enhance our understanding of protein molecular structures and may speed the development of improved drugs. Also, scientists can use the microgravity environment to learn how the presence or absence of gravity affects living organisms. This will aid long-term space efforts and also will provide a better understanding of life on Earth.

Exploring the Opportunities

Microgravity research covers five major areas. Fluid Physics research seeks to improve scientists' understanding of the behavior of fluids and to apply that understanding to processes of scientific and technical importance. Combustion Science research aims to improve our understanding of the basic combustion process, to learn how that process is affected by gravity, and to use that information to advance combustion science and technology on Earth and enhance fire safety in spacecraft. Materials Science research increases our understanding of the relationships between the structure, processing, and properties of materials. Biotechnology research seeks not only to grow protein crystals of sufficient size and perfection that scientists can determine their structure and how they form, but also to investigate the benefits of microgravity for growing cells and tissues. Technology Demonstrations help develop the hardware necessary for future microgravity research.

NASA has long been committed to studying the microgravity environment and the opportunities it offers for research. In preparing for the first spaceflights, drop towers and aircraft were used to test systems for moving fuel and other fluids in the absence of gravity. As space exploration progressed, researchers began testing theories and performing basic materials science studies on Apollo spacecraft. NASA's microgravity research began in earnest on Skylab, our first space station. Much of our understanding of the physics underlying semiconductor crystal growth, for example, comes from research begun on Skylab. The experiments performed there allowed equipment and procedures to be refined for the advent of modern microgravity research using the Shuttle and Spacelab. Spacelab is a system of interchangeable pressurized modules and pallets that fit in the Shuttle's cargo bay.

The different components can be arranged to provide the best possible laboratory for any given set of experiments. From the early Spacelab missions, scientists determined that more capable instruments were needed, along with a greater amount of ground-based research, to support and refine space-based experimentation. Congress gave strong support to these findings and began the United States Microgravity Laboratory Program as the first major step in building a mature U.S. microgravity research program on the international space station and other advanced platforms.

The United States Microgravity Laboratory Program links researchers in government, colleges and universities, and private industry in an unprecedented effort to push back the frontiers of fluid physics, combustion science, materials science, and biotechnology and to develop the hardware and procedures needed for more advanced research on space station and other advanced platforms. Combining the strengths of these different communities allows for more extensive ground-based research, improved microgravity experimentation, and a wider distribution of the knowledge gained in the process. The involvement of U.S. industry also means that the results of ground-based experimentation and the knowledge gained from operations on the Shuttle can be "brought down to Earth" in a timely and practical manner.

With the Extended Duration Orbiter kit, missions flown as a part of the program are able to stay on orbit for more than 2 weeks, allowing microgravity research in a laboratory environment to continue for more than 7 days for the first time since Skylab. Such extended missions will allow scientists to explore the microgravity environment, to learn better how to use microgravity for research, and to conduct a variety of unique experiments. As a result, they will also gain a better understanding of how to live and work in microgravity and to improve the equipment and procedures used in their research.

The Second United States Microgravity Laboratory builds on the foundation of the very successful first mission, using the knowledge gained to enhance procedures and operations and to expand and refine data. Where possible, hardware has been refined to take advantage of the lessons learned. The mission also benefits from advances in technology to improve operations; for example, the Hi-Pac video downlink system that increases the amount and quality of downlink video available to researchers will make its first flight on this mission.

The First United States Microgravity Laboratory provided a monumental start for the program. One of the most successful NASA scientific missions ever, this mission provided a wealth of data and samples that are still being analyzed. Highlights of the first mission include:

- This was the first flight of four major facilities: the Surface Tension Driven Convection Experiment apparatus, the Drop Physics Module, the Crystal Growth Furnace, and the Glovebox. These facilities not only returned important scientific data but also provided engineering data that are allowing even more advanced facilities to be designed for use on the international space station and other platforms.

- Data from the Surface Tension Driven Convection Experiment have allowed development of a complete description of fluid flows that remained steady over an extended period of time. Preliminary analysis of data from the experiment also contradicts current beliefs about the causes of thermocapillary oscillations in fluid systems with flat and curved free surfaces.

- Theoretical models of liquid drop rotation and separation of one drop into two (bifurcation) have been confirmed from data obtained in the Drop Physics Module. In addition, the data were compared with that obtained on Spacelab 3 in the Drop Dynamics Module, allowing differences to be determined and explained and also allowing the accuracy of the experiment results on the First United States Microgravity Laboratory to be improved.

- Combustion studies shed new light on the role of gravity in ignition and flame spreading. Data from the first mission have resulted in significant findings for spacecraft safety and may lead to a better understanding of the complex dynamics of candle flames. While small candles — burned in microgravity without air flowing over them —rendered smoke detectors ineffective because they emitted almost no soot, burning insulation on wires was extinguished as soon as air flow stopped. The explosive flaming that took place on hot wire insulation before airflow started may be a safety hazard unique to the microgravity environment.

- Materials science studies carried out in the Crystal Growth Furnace have provided new fundamental information on the role of gravity in crystallization. The experiment on defect formation in cadmium zinc telluride semiconductor crystals demonstrated greatly improved structural quality in the samples processed in microgravity, where sample container contact is greatly reduced. Furthermore, the removal of the first set of processed samples from the Crystal Growth Furnace using an airtight glovebox and insertion of additional samples for study demonstrated an important operational concept for materials science experiments on the International Space Station Alpha.

- Numerous protein crystals were grown, including several that scientists have never been able to crystallize on previous missions. Data collected from crystals grown on the first mission, alone or in conjunction with data from crystals grown on the ground, have allowed scientists to determine the structure of several proteins. One of these, malic enzyme, has potential use in antiparasitic drugs and produced the best crystals of this protein ever grown. Another crystal, reverse transcriptase from HIV, had never been crystallized in microgravity. Factor D, an immune system protein, produced the longest crystal of this protein ever grown. These are only a few examples of the results from the first mission, but the knowledge gained from these experiments is allowing investigators on the second mission to proceed with confidence in continuing efforts to increase our knowledge and understanding of basic physical processes on Earth and in space and to prepare for more advanced operations on future space platforms.

Mission Characteristics

Mission Objectives:

- To conduct scientific and technological investigations in microgravity on Earth orbit
- Materials processing and fluids processes experiments
- Medical experiments on effects of zero-gravity on humans
- Government, commercial, and academic participation
- Development of basis for future Spacelab and Space Station applications
- Exploration of potential applications for commercial products and processes

Launch:	September 1995
Launch Site:	Kennedy Space Center
Flight Number:	STS-73
Orbital Altitude/Inclination:	145+3 nmi circular/28.5 degrees
Mission Duration:	16 days nominal
Science Operations:	Around-the-clock
Crew Size:	7