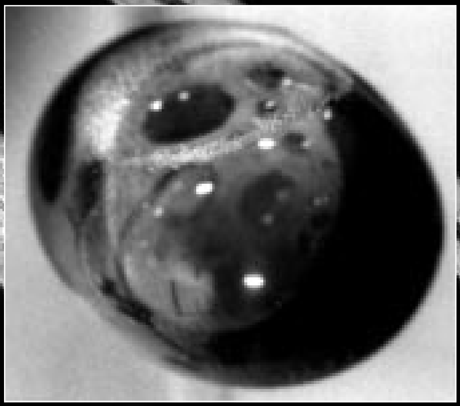
National Aeronautics and
Space Administration

Educational Guide	
Educators	Grades 3-12

EG-2001-01-12-MSFC

Microgravity: Earth and Space

An Educator's Guide with Activities in Technology, Science, and Mathematics Education



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Microgravity: Earth and Space

An Educator's Guide with Activities in Technology, Science, and Mathematics Education

National Aeronautics and Space Administration

Office of Biological and Physical Research
Physical Sciences Research Division

Office of Human Resources and Education
Education Division

EG-2001-01-12-MSFC

On the cover (clockwise from top left): 1) Students watch the video replay of a fluid demonstration that was run on the drop tower demonstrator to the right of the monitor. 2) Bubbles crowd a cola droplet floating in the middeck of the Space Shuttle during the Spacelab 2 (STS 51-F) mission in 1985. In orbit, the air and water have no apparent weight (although mass remains unchanged), so the water does not settle to the bottom and the air does not float to the top. This is a fundamental aspect of many experiments in orbit and can be a help or hindrance depending on the work to be done and our intelligence in meeting the challenges. 3) A similar effect is seen inside a sphere filled with colored water in the Fluid Acquisition and Resupply Experiment on the Space Shuttle (STS-53) in December 1992. 4) Two young visitors to NASA's Marshall Space Flight Center try out a training model of a glovebox used aboard the Space Shuttle and space station *Mir*.

Background image: *International Space Station* is seen in December 2000 after addition of the first U.S.-built solar array and battery system. Early 2001 will see the addition of the Destiny lab module (to the docking port at the front of this image) where NASA and its affiliated researchers will conduct experiments in microgravity research.

Microgravity: Earth and Space
An Educator's Guide with Activities in Technology, Science, and Mathematics Education

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Connections to Academic Standards

The activities presented in this guide address national standards in technology, science, and mathematics education. The standards for each are identified in the charts below.

Technological Literacy Standards International Technology Education Association 2000	Project Team Activity, 3-12	Way to Grow, 3-5	It's Crystal Clear, Glovebox, 3-5	It's Crystal Clear, Crystal Growth, 3-5	Bubble Technology, 6-8	Sim Satellite, 6-8	Hold That Satellite, 6-8	A Drop in the Bucket, 9-12 Drop Tower Activity	A Drop in the Bucket, 9-12, Experiments
Scope of Technology	●	●	●	●	●	●	●	●	●
Themes of Technology	●	●	●	●	●	●	●	●	●
Relationships Among Technologies & Other Fields	●	●	●	●	●	●	●	●	●
Effects on Society		●		●		●			
Effects on the Environment		●	●	●	●	●			●
Impact of Society on Technology	●	●	●	●		●		●	
History of Technology						●		●	
Attributes of Design	●	●	●	●	●	●	●	●	●
Engineering Design	●	●	●	●	●	●	●	●	●
Problem Solving, Other Approaches	●	●	●	●	●	●	●	●	●
Apply Design Processes	●	●	●	●	●	●	●	●	●
Use and Maintain Products and Systems		●	●	●	●	●	●	●	●
Assess Impacts of Products and Systems	●	●	●	●	●	●	●	●	●
Medical Technologies		●	●	●					
Agricultural, Related Biotechnologies		●	●	●	●				
Energy and Power Technologies						●			●
Information and Communication Technologies	●						●	●	●
Transportation Technologies						●	●		
Manufacturing Technologies		●	●		●	●	●		
Construction Technologies			●		●			●	

National Science Education Standards National Research Council, 1996	Project Team Activity, 3-12	Way to Grow, 3-5	It's Crystal Clear, Glovebox, 3-5	It's Crystal Clear, Crystal Growth, 3-5	Bubble Technology, 6-8	Sim Satellite, 6-8	Hold That Satellite, 6-8	A Drop in the Bucket, 9-12 Drop Tower Activity	A Drop in the Bucket, 9-12, Experiments
Science as inquiry									
Abilities to do inquiry	●	●	●	●	●	●	●	●	●
Physical science									
Properties and changes of matter		●	●	●	●	●	●	●	●
Properties in matter		●	●	●	●	●	●	●	●
Motion and forces		●	●	●	●	●	●	●	●
Transfer of energy		●	●	●	●	●	●	●	●
Interactions of matter and energy		●	●		●	●	●	●	●
Life science									
Structure and function in living systems		●			●				
Earth and space science									
Earth in the solar system		●					●		●
Science and technology									
Abilities of technological design	●	●	●	●	●	●	●	●	●
Understanding about science and technology	●	●	●	●	●	●	●	●	●
Science in personal and social perspectives									
Populations, resources, and environments	●	●	●	●		●	●	●	●
Risks and benefits		●	●	●		●	●	●	●
Natural and human induced hazards			●		●	●	●		●
Mathematics Content Standards National Council of Teachers of Mathematics, 1989*									
Problem solving	●	●	●	●	●	●	●	●	●
Communication	●	●	●	●	●	●	●	●	●
Reasoning				●	●	●	●	●	●
Connection	●	●	●	●	●	●	●	●	●
Estimation	●	●	●	●	●	●	●	●	●
Algebra					●	●	●	●	●
Geometry			●	●	●	●	●	●	●
Measurement		●	●		●	●	●	●	●

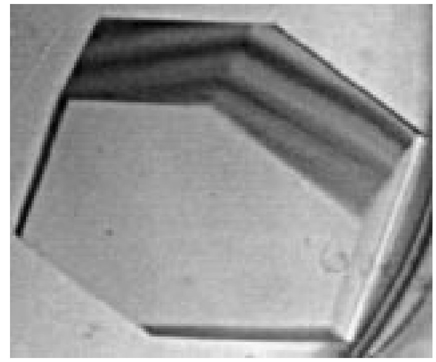
*Note: Grade levels 4-8 and 9-12 are combined.

Technology Education and Microgravity

Grade 3-12 Introduction

Introduction

This integrated guide provides teachers and students with a variety of opportunities to explore what microgravity is, what NASA scientists and others are discovering about what happens in the microgravity environment, and how all of it affects us. The goal of this guide is to offer ways to apply technology to microgravity and make it more real. Students will have hands-on opportunities to simulate activities in a microgravity environment using problem solving strategies, critical thinking skills, and a team approach. Each activity reinforces national technology, science, and mathematics content standards.



This space-grown crystal of lysozyme, an antibacterial protein found in eggs and our noses, is a thing of beauty under a microscope, and an instrument of knowledge when X-rays shine through to reveal its structure. Growing proteins in orbit allows greater clarity that leads to a better understanding of their structure and role in life.

How to Use This Guide

This guide contains general information about microgravity, classroom activities, and student worksheets for you to use. You might start with the overview of what microgravity is and how it affects us.

Other information about microgravity research is located in the specific activity that addresses key ideas or concepts. Students can research concepts and explain the research in their own words as part of the information gathering and problem solving process.

This box means there is background information provided that will help you explain a process or concept to the students. It may be new information to you, or a review of familiar ideas. Call-out boxes give brief explanations of a term, mathematical expression, or science concept.

μ**g** **stands for microgravity**

Some of the technology activities in this guide are ones you may already do as part of your technology education or science class. The difference is that you and your students will apply technology concepts to explore how the microgravity environment affects people and processes.

Each technology activity presents a **design brief** that describes what problem your students are going to solve. The goals and objectives are specific but the problem solving and design process is open-ended to allow for many designs, materials, and solutions. An example or illustration is included in each activity to give you one idea for a design solution. Your students will have many other original ideas or modifications.

The activities are meant to be done by **project teams**, similar to the ones NASA forms for science and engineering projects. The first activity suggests how to establish project teams in your laboratory-classroom and presents a sample proposal and materials budget. Reproducible proposal sheets are included along with team and individual evaluation forms for your use in each activity. After the project teams activity, the activities are grouped by grade levels 3-5, 6-8, and 9-12. Each section and corresponding design brief activity addresses a different area of microgravity research.

What is Microgravity?

Microgravity literally means very little **gravity**. Another way to think of *micro-* is in measurement systems, such as the metric system, where micro- means one part in a million or 1×10^{-6} g. Scientists do not use the term microgravity to accurately represent millionths of 1 g. The microgravity environment, expressed by the symbol **μg**, is defined as an environment where some of the effects of gravity are reduced compared to what we experience at Earth's surface. We refer to gravity at Earth's surface as a one-gravity (**1 g**) environment. Let's explore gravity first.

The prefix, micro-, comes from the Greek word *mikros*, "small."

What Gravity Does

Your body is accustomed to a one-gravity (1 g) environment and feels different if that gravitational force is changed. We take gravity for granted on Earth. You have probably heard the adage "What goes up, must come down" and you have probably experienced the effects of gravity when you fell off a bike or a snowboard. We expect a football or snowflake moving through the air to eventually fall to the ground. So what happens when we change the force of gravity? How the concept of gravity is presented to students makes a difference in how they conceptualize the effects of this force at Earth's surface and in the space environment. Many physics and science books refer to gravity as a fundamental force or attraction between any two masses. Gravity is often simply defined as a force, or a "pull." It pulls us to the ground, keeps the Shuttle and the Moon in **orbit** around Earth, and keeps the planets in orbit around the Sun.

If you ask most students what gravity does, they will say that gravity pulls you "down." In truth, gravity pulls you toward the center of Earth. Earth's surface stops us from moving freely, just as a chair or the floor stops us. We use Earth's gravitational pull on us to define "up" and "down."

Sir Isaac Newton (1642-1727) described gravity as a force that governs motion throughout the universe, not just on Earth. It is the attraction between all masses in the universe. That means there is a gravitational attraction between you and this page. So why don't you feel it? The reason is that the force of gravity depends on the mass of the objects involved and the distance they are from each other. Because Earth is so massive, its force of attraction is much greater than the other gravitational forces around us. Newton mathematically described the attractive force between two objects, as shown in the box. Sir Henry Cavendish (1731-1810) modified Newton's law to include a gravitational constant, thus producing the familiar equation still in use today.

Newton's Law and Cavendish's modification mean that the greater the masses of the objects, represented by $\mathbf{m_1}$ and $\mathbf{m_2}$, the greater the force of attraction, or **F**, between them. Also, the

Newton's original law

$$F \propto \frac{m_1 m_2}{r^2}$$

F = force

$\propto$ = "proportional to"

m_1 = mass of the first object

m_2 = mass of the second object

r^2 = distance between the objects

Henry Cavendish's modification

$$F = G \frac{m_1 m_2}{r^2}$$

G = 6.67×10^{-11} Nm^2/kg^2

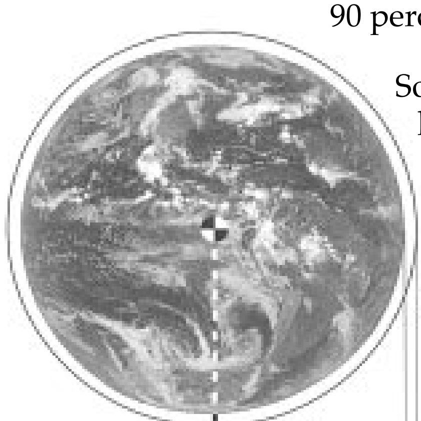
Cavendish added G, the universal gravitational constant. Note that multiplying the two masses cancels the $1/kg^2$ in G, and the $1/r^2$ cancels the m^2 in G, leaving just Newtons (N) as the final result.

farther apart the objects are from each other, a distance represented by **r**, the less the attraction.

Here is a way you can determine how much gravity changes as you move away from Earth's surface. When you are standing on Earth's surface, you are at 1 gravity or 1 g, the acceleration of an object toward the center of Earth. Your mass and the force of gravity determine your actual weight where you are at that moment. At Earth's surface, the acceleration is approximately 9.8 meters per second squared (**m/s^2**) or 32 feet per second squared (**ft/s^2**).

Earth's gravitational pull on you is reduced as you move away from Earth. How much gravity's effects change as you move away from Earth is easy to figure out using this simple relationship: **$1/r^2$**. **r** stands for the distance (radius) from Earth's center to the surface, 6,378 km (3,963 mi). Where you are standing now, R=1. If you travel from the center of Earth to a distance=2R, or 12,756 km from Earth's center, Earth's gravitational pull drops to $1/2^2$ or 1/4 what it is on Earth's surface. At an altitude of 343 km (212 mi), where the Space Shuttle often orbits, the astronauts and the Shuttle are still under the influence of about 90 percent of what they would experience on Earth's surface.

So why don't they fall back toward Earth? You have no doubt heard that the astronauts can move freely in space because they are so far from Earth that gravity has little effect, or that there is no gravity. Now you know that is not true. Astronauts in space are moving freely. Any time you are able to move freely in a gravity field with nothing to stop you from accelerating or decelerating with it, you are in free fall. How do the astronauts reach the condition of free fall? They are traveling at just the right speed (more than 27,000



Proportional gravitational pull at height (h) above Earth's radius (R) $= \left(\frac{R}{R+h}\right)^2$

1R — 6,378 km $= \left(\frac{6{,}378}{6{,}378+0}\right)^2 = \left(\frac{6{,}378}{6{,}378}\right)^2 = (1.0)^2 = 1.0$

1R + Shuttle orbit — 6,721 km $= \left(\frac{6{,}378}{6{,}378+343}\right)^2 = \left(\frac{6{,}378}{6{,}721}\right)^2 = (0.949)^2 = 0.901$

2R — 12,756 km $= \left(\frac{6{,}378}{6{,}378+6{,}378}\right)^2 = \left(\frac{6{,}378}{12{,}756}\right)^2 = (0.5)^2 = 0.25$

Note: Earth's equatorial radius in British units is 3,963 miles. The Shuttle orbit here is 212.75 statute miles. The equations will produce the same results in either system because these are simple ratios.

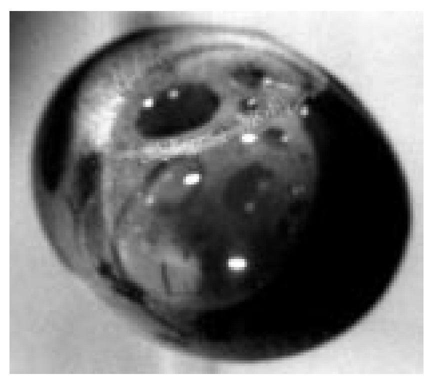
km/h [17,000 mph]) and the right altitude along with the Shuttle so they are constantly falling around Earth in orbit. The trajectory, or path, is caused by the Shuttle speed along with the downward acceleration of gravity, producing a curve that follows the curvature of Earth. Because the Shuttle is free falling in orbit around Earth and the upper atmospheric friction is low, a microgravity environment is established. The condition of microgravity occurs whenever an object is in free fall.

Japanese astronaut Chiaki Mukai sails through the entrance of the Space Shuttle's Spacelab module.

A round balloon filled with water can be used to explain some effects of gravity. What shape does a balloon take when it rests on a table or is held in your hand? The water-filled balloon is flattened on the table. The table, or your hand, is exerting a force to keep the balloon from falling. If you hold the balloon by the knotted end, gravity stretches it downward. In free fall however, it assumes a spherical shape because neither gravitational effects nor the table disturbs it.

If you drop a baseball on Earth, it accelerates toward Earth's surface at 9.8 m/s^2 (32.2 ft/s^2). This acceleration is what we refer to when we talk about a 1g environment. If an astronaut drops a baseball inside the Shuttle, it falls, too, but to the astronaut it just doesn't look like it is falling. That is because the baseball, astronaut and the Shuttle are all falling together around Earth. The Shuttle and everything in it are kept in orbit around Earth by gravity. Because they're all falling together, objects move freely in a state we call microgravity.

You can better understand this concept by exploring Sir Isaac Newton's hypothesis on how a satellite could be made to orbit Earth. If you placed a cannon at the top of a very tall mountain (see page 43) and then fired a cannonball parallel to the ground it would arc and fall to Earth because of the presence of gravity. If you added more energy so the cannonball had greater speed, it would travel farther before landing. But if the cannonball was fired with the proper speed, the cannonball would achieve a state of continuous free fall, or orbit, and would fall entirely around Earth. Provided no force other than gravity acted on the cannonball's motion, it would keep circling Earth in orbit. The same principle applies to the Shuttle.



Soft drinks don't fizz in space since the bubbles don't rise to the surface, as shown by this cola droplet. Eventually the bubbles coalesce into larger bubbles and escape.

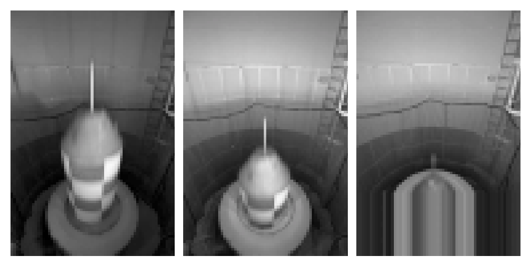
Once we achieve free fall we have a microgravity environment. What can we do in a microgravity environment that is different from normal gravity conditions? In some instances, the behavior of granular solids, liquids, and gases are affected by gravity. If you tried to melt two different metals then mix them to form a new metal (called an alloy), the process would only work if both metals had similar densities. On Earth, the less dense metal would always float to the top once you stopped mixing them, like Italian salad dressing after it is shaken.

In orbit, because of microgravity, the two metals could more easily form a metal alloy with particular properties. NASA scientists are doing microgravity research in areas such as biotechnology, combustion science, fluid physics, fundamental physics, and materials science. Microgravity can help us learn more about how free fall conditions affect our bodies. It also gives us unique opportunities to investigate new materials such as alloys, crystals, and medicines.

How Do We Create Microgravity?

Orbiting spacecraft provide the best laboratories for long periods of microgravity research. Scientists also use drop towers, aircraft, and rockets to achieve short periods of microgravity. Experiments lasting for more than two weeks are possible with the Shuttle right now. Once the International Space Station has a permanent crew aboard and is ready for research, experimentation time can be extended to months. An important advantage of having longer periods of time available is that scientists have the ability to do research like it is done on Earth. Experiments can be performed multiple times with different parameters. Thus scientific researchers will be able to gather comprehensive data.

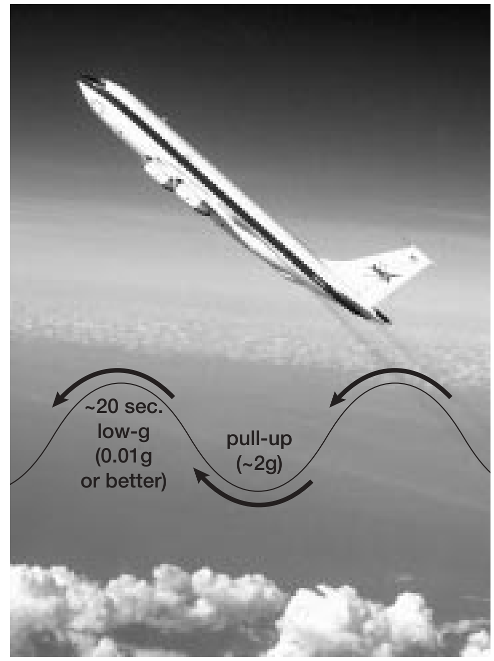
Dropping an experiment down a deep hole on Earth also creates free fall conditions for a brief time. Researchers in NASA and other facilities around the world use drop towers and drop tubes to create microgravity environments. NASA's John H. Glenn Research Center in Cleveland, OH, has two drop facilities. The 132-meter (430-ft) drop tower creates a microgravity environment for about 5.2 seconds while the 24-meter (79-ft) drop tower provides 2.2 seconds of microgravity per drop. Experiments in the 2.2-second Drop Tower are assembled on a drop frame structure and enclosed in an aerodynamically shaped box, called a drag shield, that protects the experiment. The drag shield/experiment assembly is hoisted to the top of the tower and released. The entire assembly falls freely in the open environment of the tower. The experiment is isolated from aerodynamic drag because it is contained within the drag shield but not attached to it. During the drop, the entire assembly falls 24 meters, and the experiment freely falls a distance of 20 cm (0.65 ft) within the drag shield. The package is slowed and stopped by a 3-meter (10-ft) tall air bag. Battery packs provide onboard power to the experiment. High speed motion picture cameras, video cameras, and onboard computers collect data for the investigator. The 5.2-second Zero-Gravity Facility drops larger packages in a deep vacuum chamber. The longest drop time (10 seconds) is in Japan where a vertical mineshaft was converted to a 490-meter (1,607.2-ft) drop facility.



An experiment package plunges into the decelerator in the Zero-Gravity Facility at NASA's John H. Glenn Research Center. This facility provides about 5.2 seconds of microgravity conditions for experiments.

In these drop facilities, experiments are dropped, not people! You could experience the same sensation as an experiment in a drop tower by going on a roller coaster in an amusement park or jumping off a diving platform into a swimming pool.

You can also create a reduced gravity environment in an airplane as it flies in a roller coaster trajectory or parabolic path. NASA astronauts train for orbital missions in a modified KC-135 (a military tanker version of the Boeing 707 passenger jet), also called the Vomit Comet! A typical flight lasting from 2 to 3 hours gives crew members about forty 20-second periods of microgravity. The plane does a series of pull-up and push-over segments as it moves along its roller coaster path in the air to produce temporary free fall. Many people get airsick, as you might imagine. While the conditions of microgravity are limited in an airplane because of turbulence and flight-control limitations, the advantage is that researchers can ride along with their experiments.



The roller-coaster ride of the KC-135 (*aka* the Vomit Comet) is another technique for providing brief periods of low-g to test experimental hardware and to train astronauts (below).

Small sounding rockets are another way to create microgravity. Sounding rockets experience free fall conditions for 6 to 7 minutes as they follow suborbital parabolic paths. Free fall exists during the rocket's coast above Earth's atmosphere, where it is free of drag.

Now Let's Put Microgravity in the Curriculum

You have been introduced to the concepts of gravity and microgravity. This Guide offers a variety of learning activities that will involve students exploring microgravity. For more in-depth physical science information or mathematical integration, check the resources at the end of each activity. The NASA resource, *Microgravity—A Teacher's Guide with Activities in Science, Mathematics, and Technology,* (NASA, 1997) is a good companion resource as well as the following on-line microgravity resources:

Spacelink
http://spacelink.nasa.gov
NASA Microgravity Research Program Office
http://microgravity.nasa.gov
John H. Glenn Research Center..*http://microgravity.grc.nasa.gov*
George C. Marshall Space Flight Center ....*http://www.msfc.nasa.gov*
National Center for Microgravity Research *http://www.ncmr.org/education/k12.html*

These resources can provide a framework for teaching the concepts through integrated activities that give students a variety of opportunities to explore microgravity. The discovery learning and peer collaboration activities in this guide are designed to develop critical thinking and problem-solving skills as well as increased scientific and mathematical knowledge. To make access easier, the URLs in this guide are also on a web site:

Microgravity education links .... *http://microgravity.nasa.gov/ed_links*

Project Team Activity

Microgravity Teamwork
Grades 3-12

Teacher Information

It is never "too soon" to get students to work in cooperative teams or to develop career awareness. The technology design briefs in this guide suggest that students should be placed in teams whenever possible and assigned a career role. At the elementary level, students may need help understanding their role in a team. Also, they may need extra time to work out solutions to problems. At times, you may decide to be the principal investigator in order to get the activity started more efficiently. At the middle and high school levels, students will benefit from initial guidance concerning teamwork and increasing responsibility for carrying out their career roles. The careers used in the following activity simulate NASA project teams.

All space missions are the result of teamwork, starting with small groups like the one working out procedures for glovebox experiments (above) to large teams like the mission managers directing the ASTRO-2 Spacelab mission (below).

Introduction

Many professional projects require people to work together effectively in teams. The success of the design and engineering activities students will do in each microgravity unit depends on teamwork. To have a good team, every member needs to do his or her assigned tasks well and on time. Students will work as a project team member in each of the activities in this guide. Students will set up project teams, assume career roles according to the project team member descriptions, and write a project proposal.

The laboratory-classroom activities will simulate the process of project approval at NASA. Each student in the class will be a member of a team. A class can have several teams working at the same time. Each team will be responsible for preparing a project proposal, and presenting the proposal to a peer review panel; the entire class or student committee may serve as the peer review panel.

Project Team Roles

To simulate project team activities, students can be given specific career roles described in the next section. You may assign a student a different role for each activity. In this instructional approach, students will learn what it is like to fulfill major career roles on a NASA project team.

Principal Investigator

In this leadership role, students will need to understand what a project goal is, write a proposal for funding the project, and present the idea to the class. A proposal is a statement of what problem a team is going to work on, how they are going to work on it, and the materials needed to do the project. Scientists in any field can be the principal investigator (PI) for a project.

Scientist

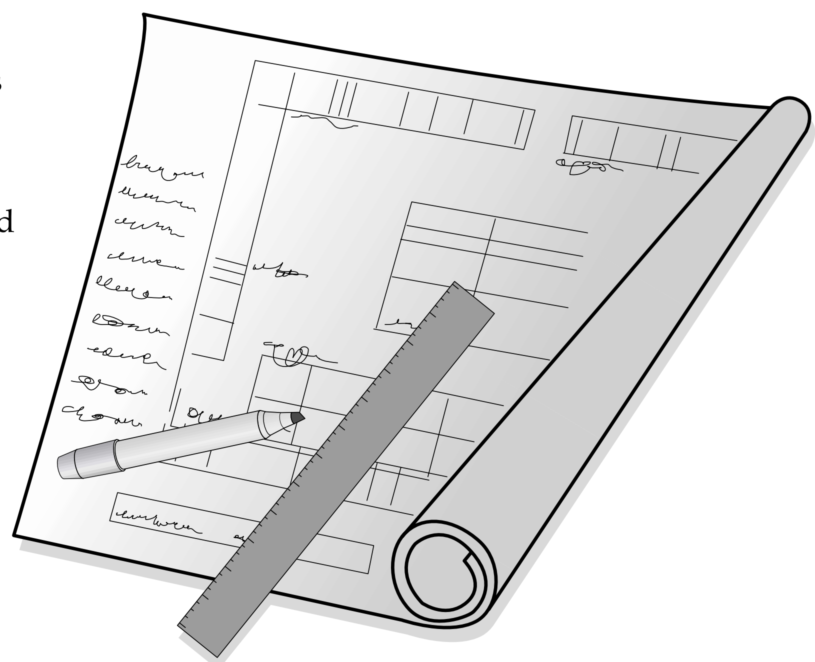
Scientists usually specialize in a specific field of study or investigation. For these activities, you can introduce students to careers. Scientists specialize in specific fields of study such as:

- Biology
- Microbiology
- Chemistry
- Organic chemistry
- Biochemistry
- Nuclear physics
- Physics and optical physics

Engineer

Engineers use mathematics and scientific principles to solve technology-related problems. Engineers specialize in many different engineering fields such as:

- Mechanical
- Electrical
- Chemical
- Civil
- Aerospace
- Systems
- Structural



Technician

Technicians use a variety of machines and materials. They take working drawings and build experiment hardware and parts that cannot be ordered from catalogs. Technicians often specialize in specific areas such as:

- Mechanical
- Electrical
- Fluid, hydraulic/pneumatic
- Heating, ventilation, and air conditioning
- Welding
- Automation, robotics

Astronaut/Test Subject

In these activities, everyone will be able to perform scientific tests in the field of microgravity. Shuttle missions consist of the following people:

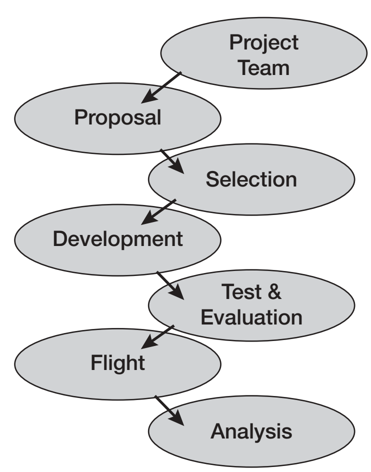
- Mission commander
- Pilot
- Mission specialist(s)
- Payload specialist(s)

The mission commander and pilot who fly the Space Shuttle are qualified jet pilots. Quite often they also are experienced test pilots. Mission specialists are engineers and scientists working full time as astronauts. They are trained to operate experiments in a wide range of disciplines. Both pilot astronauts and mission specialists also take part in designing future human spacecraft. Payload specialists are engineers and scientists, but are trained to fly on one or two missions to conduct specific activities.

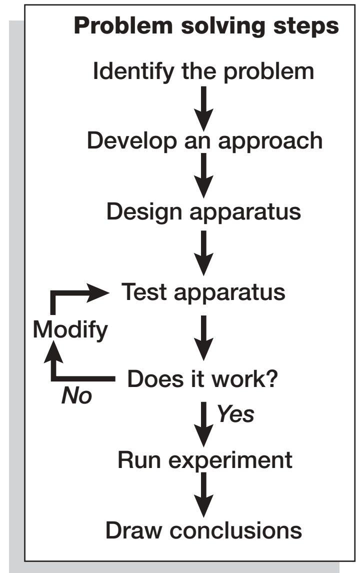
Project Proposals

All projects must have a **principal investigator**, or **PI**, the lead scientist who devises a plan to investigate a problem. This plan becomes the experiment. The PI sets up the activities for the team members, and supervises the writing, or actually writes, a Project Proposal. In the first activity, you as the teacher might be the Principal Investigator just to show how it works. Principal Investigators can put together a project team to help write the proposal. You might give the teams a materials list to use and a proposal form that requires them to write certain information or you can let them develop the proposal format themselves. Proposals include:

- Design brief statement,
- Written description of the problem,
- Written description of the planned approach to investigating the problem, including necessary steps to complete it,
- Materials list/cost spreadsheet,
- Appropriate illustrations or drawings, and
- Steps involved in solving the problem.



In studying the proposed problem, the steps shown here can be used. First, students express the problem to be addressed in a clear and concise statement. Next, students gather information and ideas relevant to the problem. In the activities in this guide, students will review some background information and resources. In addition, students brainstorm possible solutions to the problem. Next, students select the most feasible and effective solution to develop. The solution will be constructed and tested by the students. Finally, students evaluate the results to determine the extent to which they addressed the initial problem and the effectiveness of their solutions, and recommend the next step. In the next section, a sample proposal is presented as a guide for addressing microgravity activity problems. A blank project proposal form is included for use in other activities on page 12.



The student team project proposal must include a visual representation of the solution, such as a sketch, drawing, or CAD (computer-aided drafting) illustration. It should show details such as the materials, measurements, and placement of parts. A sample of a design sketch is at the end of this section in the sample proposal (see pages 13-14).

Peer Review Panel

All projects must be reviewed by a peer review panel. The review panel evaluates the merits of the proposal and the benefits of the project. In the real world, peer review uses scientists not directly involved in a project. This helps ensure that the best investigations are selected. In our activities, the entire class will be the peer review panel. The project team should prepare an oral or multimedia presentation for the panel that will quickly describe the proposal. The class should offer suggestions or comments about each team's proposal.

Each team will want to share what they are doing. Here are some ideas to help the students develop their presentations:

- Use the overhead projector to show your designs on a large screen,
- Share your project design on a computer connected to a television,
- Make large charts, drawings, graphs,
- Build a model of your proposed project, and
- Take video clips that illustrate key concepts.

Public speaking is an important skill. Students need to know that they might have the best idea ever thought of, but it needs to be effectively communicated to others to make it happen.

Safety Configuration Management

A proposal must be given the "go ahead" from the peer review panel and the teacher, and it must meet safety standards. NASA considers safety to be a very important part of every project decision. Every material and piece of equipment must be researched and tested before it receives flight approval. Configuration management specialists check every material and trace its manufacturing history down to the types of cleaners used on the material. Even cleaners can contaminate materials and contribute to problems in space. Safety issues can be excellent research and class discussion topics. Each project team member must consider the safety of everyone involved in the use and construction of projects. The teacher will be the safety manager in charge of approving plans or recommending changes based on safety issues. All project members should follow the rules assigned for the safe use of materials, tools, and equipment.

Team Evaluation

Each team and individual team member should be evaluated according to how well team members worked together to complete the microgravity project (see the forms on the next page; feel free to modify as needed for your grade level or class). The Project Team Evaluation can be used to evaluate team effectiveness. Also, individual team members should be evaluated, using the Project Team Member Evaluation form, for their contributions to the total project effort.

Project Team Evaluation

Project Team Members: **Date:** ____________________________

____

____

____

____

1.	All team members actively participated in the problem-solving strategy	5	4	3	2	1
2.	Team members performed assigned career roles responsibly	5	4	3	2	1
3.	All team members contributed ideas before selecting the final design	5	4	3	2	1
4.	The team was able to work together to resolve issues	5	4	3	2	1
5.	The team completed the assigned project goals successfully	5	4	3	2	1

Project Team Points______ / 25 possible points

Scoring key:
5 Absolutely true of this team
4 Described the team for the most part
3 Description fitted the team about half the time
2 Only marginally describes the team
1 Does not describe the team at all

Project Team Member Evaluation

Team member: ____

Each student will be evaluated on the following:

1.	Problem solving strategy (Followed the problem solving steps)	5	4	3	2	1
2.	Project construction (Found materials, helped build apparatus)	5	4	3	2	1
3.	Testing, experimenting (Tried to modify or improve designs)	5	4	3	2	1
4.	Safety/Clean up (Helped keep area clean and safe)	5	4	3	2	1
5.	Extensions (Tried new ideas)	5	4	3	2	1

Total Points______ / 25 possible points

Scoring key:
5 Absolutely true of this individual
4 Described the individual for the most part
3 Description fitted the individual about half the time
2 Only marginally describes the individual
1 Does not describe the individual at all

PROJECT PROPOSAL TITLE: *Working in a Simulated Microgravity Environment*

DESIGN BRIEF: *Design and build the most cost-efficient neutrally buoyant satellite model.*

PROJECT TEAM MEMBERS:
Principal Investigator: *T. Smith*

- **Scientists:** *Elli Whitney, Albert Stein*
- **Engineers:**
  Mechanical Engineer *Stan Diego*
  Aerospace Engineer *George Jones*
  Industrial Engineer *Hanna Hanson*
  Structural Engineer *Doug Walrath*
- **Technicians:** *Bob Upndown, Craig Waters*
- **Astronauts/Test Subjects:** *Gillian Island, Jarid Jones*

PROJECT DESCRIPTION
Simulating microgravity on Earth is hard. We are going to figure out how to make a helium balloon satellite become neutrally buoyant. This means the satellite does not sink or rise, but stays level so we can simulate working in space as astronauts.

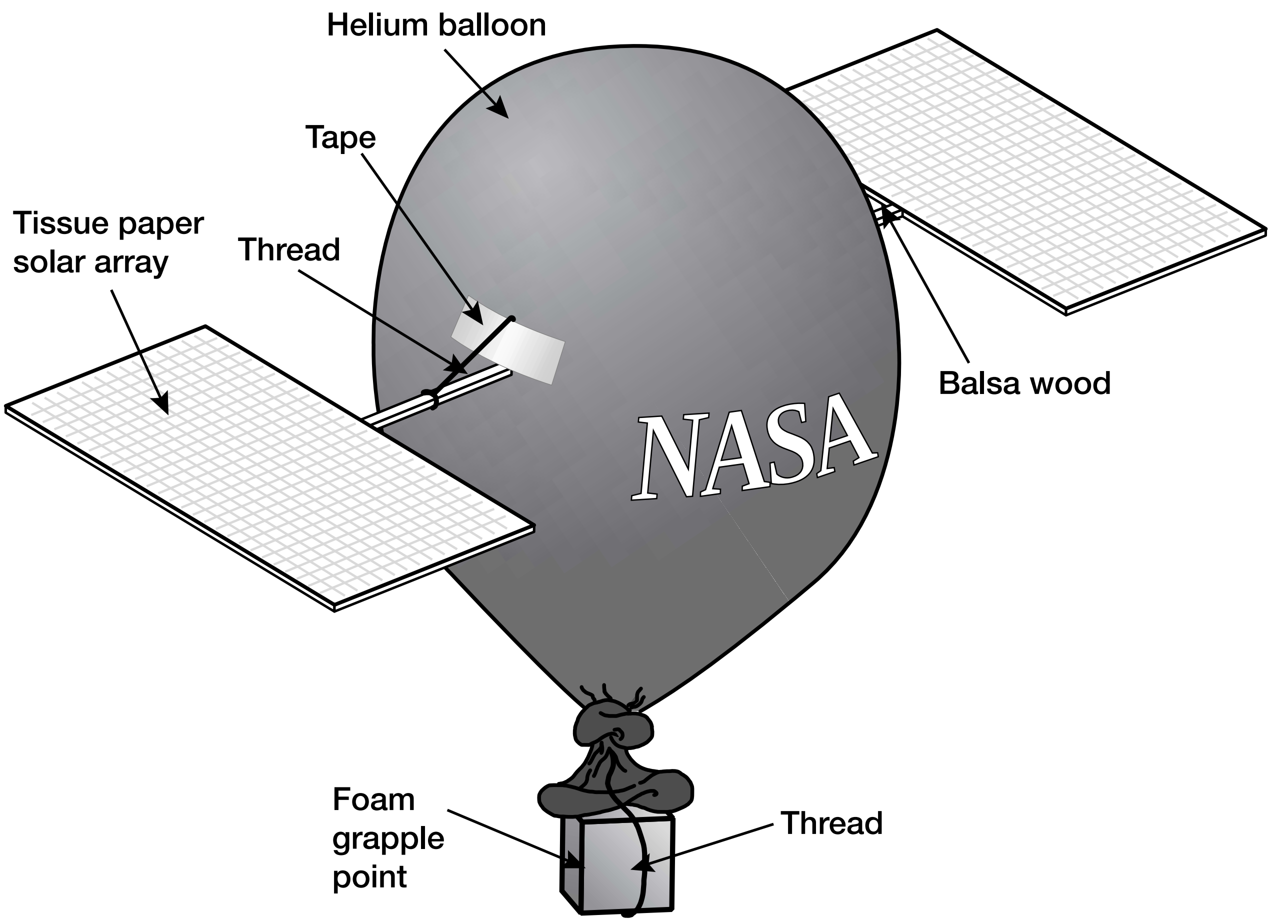
MATERIALS LIST

Item	Description	Quantity	Cost ea.	Approx. total
Balloon	Standard 12-inch	3	1.00	3.00
Helium	Small canister, party pack size	1	20.00	20.00
Balsa wood	1/16 x 1/16 x 26 in.	1	0.80	0.80
Tape	Any type, 6 in.	1	0.00	0.00
Thread	Sewing thread, 18 in.	1	0.00	0.00
Foam	Low density bead board, 4 cu. in.	1	0.00	0.00
Glue	Wood or hot glue, 2 oz.	1	0.15/oz	0.30
Paper clips	Small or large	6	0.00	0.00
Straws	Plastic drinking straws	4	0.00	0.00
Tissue paper	Tissue wrapping paper, 40 sq. in.	1	0.25	0.25
TOTAL				**24.35**

Note: Prices listed through this guide are for the purposes of illustration to indicate the order of magnitude of expenses. Prices will vary with region, city, and store. Measurements are given in English units because that is how most U.S. stores measure goods.

Project details
Sketch/drawing

PROJECT DESIGN SKETCH: A balloon satellite
TEAM MEMBERS:
Principal investigator: *T. Smith*
Science Group: *B. Jones, S. Brown, L. Williams, P. Anderson*



Approval
Peer Review Panel ________________________________

Safety Inspection (Teacher) ________________________________

PROJECT PROPOSAL TITLE:

DESIGN BRIEF:

PROJECT TEAM MEMBERS:

Principal Investigator:

- **Scientists:**
- **Engineers:**

  Mechanical Engineer

  Aerospace Engineers

  Industrial Engineer

  Structural Engineer
- **Technicians:**
- **Astronauts/Test Subjects:**

PROJECT DESCRIPTION

MATERIALS LIST

Item	Description	Quantity	Cost ea.	Approx. total
TOTAL				

Project details
Sketch/drawing

Approval

Peer Review Panel ______________________________

Safety Inspection (Teacher) ______________________________

Project Teams Design Brief
Microgravity Teamwork
Grades 3-12

Design Brief

Set up a microgravity project team and prepare a project proposal to address a microgravity problem or investigation.

Objectives

In this activity, students will:

- Carry out a specific career role on the team.
- Develop a project proposal.
- Present a proposal for peer review.

Two astronauts practice installing new equipment on the Hubble Space Telescope (top). While all attention is focused on them, they are just a small part of the team that makes it possible. In addition to the astronauts, this team includes utility divers to help the astronauts, safety divers to make sure no one gets in trouble, and more than a dozen engineers and technicians monitoring the whole operation in a nearby control room. An important (sometimes overlooked) part of teamwork is saying "Thanks" to the team members who made success possible. After the successful Hubble repair mission, the astronauts visited several NASA centers (below) to talk with employees and sign autographs, one of several ways to thank all involved.

Procedure

1. Assign students to teams and review the career roles of each team member.
2. Identify a problem to be solved. You may use a problem in this guide or one provided by the teacher.
3. Gather background information. Brainstorm possible ideas for solutions.
4. Prepare the proposal, to include a description of the problem, sketch of the solution, and materials needed.
5. Discuss and record safety considerations for this project.
6. Prepare a presentation for the peer review committee.

Discussion Questions

- What are advantages of working in project teams?
- Why does NASA use project teams?
- What did you learn from your assigned career role?
- How will you use the recommendations from the peer review panel to improve your proposal?

Way to Grow!

Growing Plants in a Simulated Microgravity Environment
Grades 3-5

Teacher Introduction

Have you ever tasted astronaut food? It may not be quite as good as your meals at home but food served on the Space Shuttle and aboard the International Space Station has really improved since astronauts had to eat out of squeeze tubes! Today they get to choose their own menus from prepared foods such as spaghetti and meatballs or chicken. Astronauts can even eat sandwiches. Some food is dehydrated like camping foods where you add water before you eat it. Other food is just normal Earth food like you would buy at a supermarket. Astronauts eat peanut butter, cookies, cans of pudding, and even fresh fruit the first few days in orbit. It is important for the astronauts to eat enough of the right foods while in orbit so they can do their jobs properly. Taking enough food for a few weeks in space works right now, but if people are going to stay in orbit for longer periods of time, we need to find ways to produce some of the food in space.

Wheat grown in the Astroculture facility aboard the Space Shuttle shows a number of changes from wheat grown normally on Earth. Although it lacked cues from gravity, the wheat did have an overhead light in the chamber to help direct its growth.

There is a problem, however, with growing plants in microgravity. Plants have developed in a 1 g environment and have adapted to detect the force of gravity. On Earth, roots grow downward with gravity. This plant response is called **geotropism** or **gravitropism**. Stems and leaves grow toward the light in a process called **phototropism**. In a microgravity environment they seem to get mixed up. In microgravity, the roots grow in all directions. Sometimes they get tangled with the stem and the leaves. Even the stems get tangled. So to grow plants in microgravity conditions, you have to use a membrane to separate the stem and leaves from the roots as well as keep the growth media in place.

> Did you know that astronauts get to chew gum? Chewing gum in orbit is the same as chewing gum on Earth. One thing that is different is using salt or pepper to spice up your meal. If you tried to shake either one onto your food while in orbit, it would float everywhere. So salt and pepper are added to water in small squeeze bottles to put on your food.

In space, some plants will probably be grown **hydroponically**. That means they will be grown without soil. It makes sense because you can grow more plants in a smaller area. In addition, the plants grow faster and produce more results. Scientists are experimenting with designing artificial gravity greenhouse environments. By slowly rotating a greenhouse unit, artificial gravity is created. The rotation pushes everything outward so the plant stems and leaves grow "up" towards the center, and the roots grow "down" away from the center through thousands of tiny holes on the sides of the rotating unit. A special plant medium can be used for some plant roots. Other plants can just be sprayed with a plant food solution and they grow. Of course, plants need light which they get from grow lights in each greenhouse unit. In these units, we can grow plants that do not grow freely in microgravity.

Growing our own food in space will become a necessity for long-term space missions where frequent supply missions are impractical. Besides, the plants (when under light) use the carbon dioxide humans breathe out, and return oxygen in its place, just like on Earth.

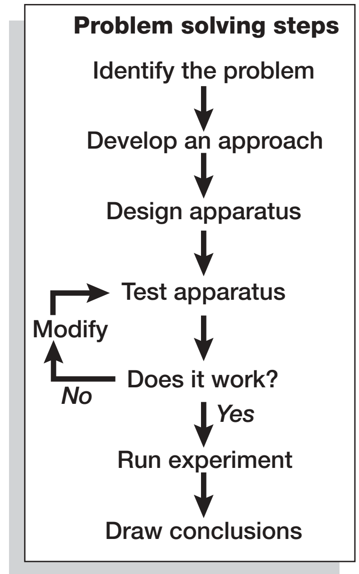
Payload specialist Leonid Kadenyuk of Ukraine prepares (top) then conducts experiments to pollinate and grow *Brassica rapa* plants aboard the Space Shuttle in 1997.

Way to Grow!

Growing Plants in a Simulated Microgravity Environment
Grades 3-5

Design Brief

Using a problem solving strategy, design and make a plant wheel that can be used to simulate growing plants in a microgravity environment.



Objectives

In this activity, students will:

- Learn the parts of plants and how they grow in a 1 g environment.
- Investigate how plant growth will differ in a microgravity environment.
- Grow plants and observe what happens as the direction of gravity is changed relative to the plant.
- Work in teams to successfully complete goal.

Procedure:

1. Set up a class team using the Project Team Activity in this guide. The teacher will be the principal investigator for this activity. Explain to students how this is a special project in which they will be studying how plants might grow in orbit. Discuss parts of plants and what plants need to grow.

2. The sample proposal shows you one idea of how to make a plant wheel. In this example, an old record turntable is placed in a vertical position and the arm removed. A cardboard wheel is placed on the turntable and the plant/seed bags are taped to the wheel. The turntable needs to be near an electrical outlet so it can be turned on to rotate.

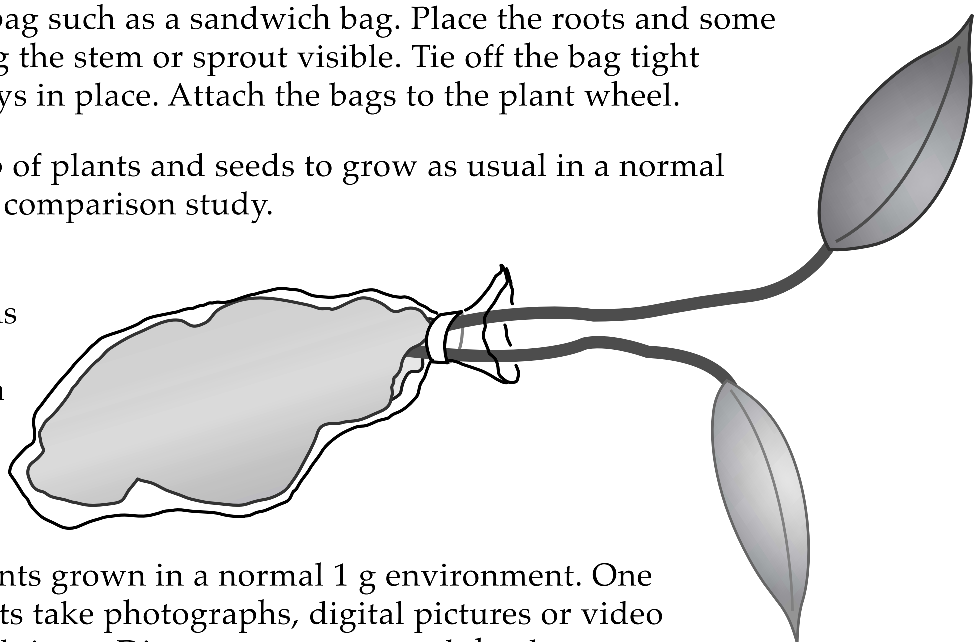
> **Safety**
> - Students should follow established safety procedures for using equipment and materials.
> - Wear safety goggles/glasses for construction activities.
> - Wash hands after setting up the activity.

3. Prepare the plant/seed bags. If you want to start with seeds, select ones that germinate quickly in your area. You might start with bean seeds that have been soaked overnight or radish seeds that normally sprout within two to three days.

4. Seeds can be placed on wet crumpled paper towels inside a plastic bag. Be sure to punch air holes in the bag. The plant bags should separate the stem from the roots. Try

using a small plastic bag such as a sandwich bag. Place the roots and some soil in the bag, leaving the stem or sprout visible. Tie off the bag tight enough so the soil stays in place. Attach the bags to the plant wheel.

5. Set up a second group of plants and seeds to grow as usual in a normal 1 g environment for a comparison study.
6. Student teams should measure what happens to the seeds or plants (stop the wheel once a week for measurements.)



7. Compare the plants on the wheel with plants grown in a normal 1 g environment. One idea is to have students take photographs, digital pictures or video segments at scheduled times. Discuss ways to record the data.

Evaluation

At this level, the teacher may use the discussion questions to evaluate student understanding. Students will benefit from visual evidence of plant changes over time using digital or 35mm photos and video segments. Teachers can begin to address career awareness through roles assigned to students. Asking "What does an engineer do?" or "What does a scientist do?" will stimulate interest in careers. Have students draw and label part of a plant and discuss what plants need to grow.

A rose flown in space was found to have a new fragrance after it was returned to Earth.

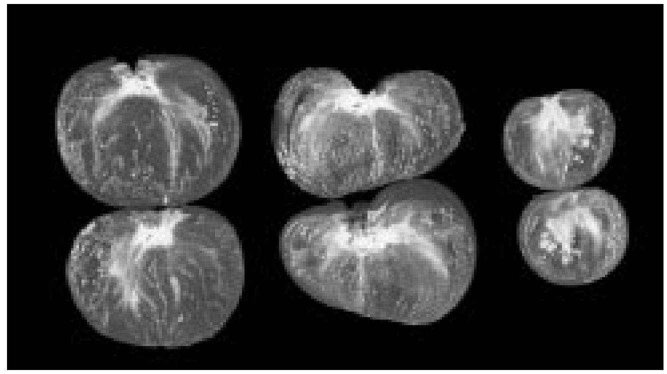
Discussion Questions

- How did the device you designed change the way your plants or seeds grew?
- Compare the sizes of your control plants (1 g) with the experimental plants. Do you think being in microgravity will make it more difficult to grow plants?
- How is it possible to grow plants without soil? What are some advantages to growing plants in space?

Extensions

- Test plant phototropism and geotropism by designing and constructing a plant maze (like a maze for a mouse to run in search of cheese).
- Design a hydroponic system for plants for students to study.

Teacher Notes


Tomatoes grown in orbit (center , right) overproduce a valuable hormone. Now they are being cultured for this ef fect.

It takes time to grow plants, and then more time to observe what happens to them as they grow. Find a good place to keep the plant wheels or plant boxes. You might want to make a large wall chart with teams and plant observation information. That way, students can share each team's experience. Starting the activity with seedlings helps. Be sure to use seeds that grow quickly in your area. Hydroponics kits are available at most technology education and science supply companies. You can also check with your local nurseries for information and supplies.

Further Research

More information on growing plants or seeds in a microgravity environment can be found on-line or in these resources:

Bosak, Susan V. Science is… Ontario: Scholastic Canada, 1991.

McKay, David E. and Bruce G. Smith. Space Science Projects for Young Scientists. New York: Franklin Watts, 1992.

Mullane, R. Mike. Do Your Ears Pop in Space?: And 500 Other Surprising Questions About Space Travel. New York: John Wiley & Sons, 1997.

NASA. Microgravity-A Teacher's Guide with Activities in Science, Mathematics, and Technology. EG-1997-08-110-HQ, 1997. Also available on-line at *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity*

Smolders, Peter. Living in Space: A Handbook for Space Travellers. Blue Ridge Summit, PA: Aero, 1986.

Stellar Hydroponics. *http://stellar.arc.nasa.gov/stellar*

Fast Plants. *http://www.fastplants.org*

Welty, Kenneth. "Desk-top farming." *Technology and Children*, **3**:1, pp. 3-6, 1998.

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Sample Proposal

PROJECT PROPOSAL TITLE: *A Revolving Seed/Plant Wheel*

DESIGN BRIEF: Design and build a revolving seed/plant wheel to simulate growing plants in microgravity.

PROJECT TEAM MEMBERS

Principal Investigator: *I.A. Smart*

- **Scientists**: *Al Einstein*
- **Engineers**:

  Hank Ford, Polly Linus, Bo Eing, Sam Steel

  Bucky Fuller, Sally Dressing, Brigette Quickly

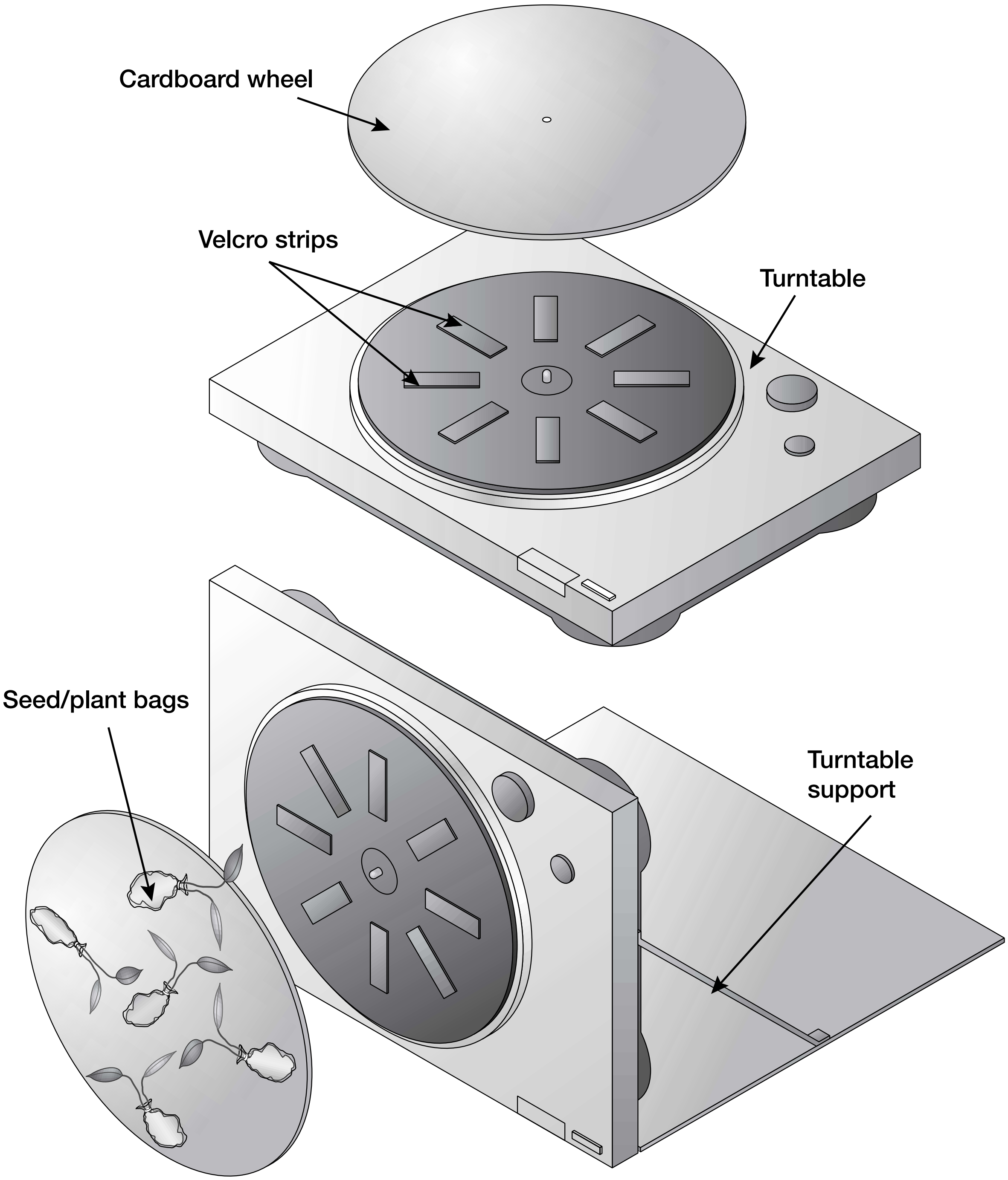
- **Technicians**: *I.M. Thumbs, A.C. Fast*
- **Astronauts/Test Subjects**: *G. Jettson, B. Rogers*

PROJECT DESCRIPTION: *Seeds and plants grow in a certain way on Earth. In orbit, in a microgravity environment, they grow in unusual ways. The roots often get tangled with the stems. Our team designed a seed/plant wheel that revolves to simulate a way to help seeds or plants growing in microgravity. We are using an old turntable to keep the wheel constantly rotating.*

MATERIALS LIST:

Item	Description	Quantity	Cost ea.	Total cost
Record turntable	Revolving base	1	0.00	.00
Cardboard wheel	12” Diameter circle	1	0.00	.00
Plastic bags	Small sandwich size	8	0.20	1.60
Seeds	Radish or beans	1 pk	1.40	1.40
Soil	Potting soil	1 pk	2.50	2.50
TOTAL				**5.50**

Project details
Sketch/drawing



Approval

Peer Review Panel ______________________________

Safety Inspection (Teacher) ______________________________

It's Crystal Clear!

Crystal Growth Glovebox Activity
Grades 3-5

Teacher Information


An engineer demonstrates the workspace inside the large Microgravity Science Glovebox that will be available on the International Space Station.

Growing crystals on Earth is fun! You can learn how buoyancy, density, and convection currents affect crystal growth. In a microgravity environment, crystals grow differently because these effects of gravity are reduced. In this activity, you will use a **glovebox** to observe crystal growth.

The glovebox is a device used by NASA to do some experiments in orbit. In a microgravity setting, objects tend to float around and could be a problem to the astronauts or to equipment on the Space Shuttle. Sometimes there are materials that people shouldn't touch and so the glovebox is a good place to work with these objects. The glovebox is a self-contained box with attached gloves. Astronauts and scientists can work with items in the box by putting their hands in the gloves. This way they do not touch the objects with their bare hands.

The glovebox can also be used when scientists want to control or limit what affects their experiment, such as strong air currents or extra movement. In this activity, student teams will first design and construct simple gloveboxes. Then they will grow crystals and observe what happens to them as a result of gravity.

Microgravity and How It Affects Crystal Growth

The microgravity environment gives scientists a good place to study materials and how they are produced. We need to know more about what happens when a material changes from one phase — gas, liquid, or solid — to another. This is what happens when water changes to ice or a metal is melted to a liquid from a solid phase. In orbit, it is easier to understand some of the processes because gravity does not get in the way. For example, some new metal **alloys** can be made in orbit where the effects of gravity are reduced. On Earth, materials that are more dense than others tend to settle or are pulled by "down" gravity's effects. This is called **sedimentation**. In microgravity, it is possible to mix molten metals of different density so they will stay together.

Alloys are metals made by melting two or more metals together. An example is brass, made by mixing molten copper and zinc.

Microgravity researchers observe how **buoyancy-driven convection** and sedimentation affect the ways materials are made. Buoyancy-driven convection occurs when a fluid such as a gas or liquid starts moving because of a density difference.

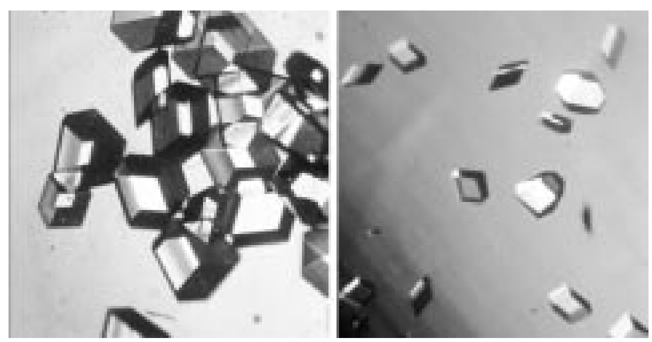
For example, when you heat water, the heated water expands slightly in volume. The cooler, more dense water sinks and the warmer, less dense water rises. Less dense means the water weighs less than cold water with the same volume. Thus, it rises because it is more buoyant. It sets up a movement pattern where the heated water and the cooler water eventually mix together. Sedimentation occurs when solid materials settle out of a solution to the bottom of the liquid. In this activity you will observe how both buoyancy-driven convection and sedimentation affect the way your crystal grows on Earth.

You have seen **sedimentation** at work in a bottle of salad dressing. When you shake up a bottle of oil and vinegar dressing and then let it sit for a few minutes, it forms layers with the oil on top, the vinegar in the middle, and solids (like peppers) at the bottom.

Both biotechnology researchers and materials scientists use a microgravity environment to see how crystals form. In biotechnology, scientists focus on protein crystal growth. You have over 100,000 different proteins in your body that do important jobs, such as fight disease, or carry oxygen and other chemicals in the blood. Many proteins can be made to form crystals, an important step in studying their structure. Scientists want to find out more about these proteins and their structure. A microgravity environment gives us the chance to grow more uniform, orderly crystals.

Buoyancy is a net force that lifts against the force of gravity. Any object—whether it is a grain of sand or a gas bubble immersed in a fluid—has a buoyant force acting on it. A boat floats on the water because of the buoyant force.

Researchers want to design new drugs that work by changing a protein's activity in some way. For example, scientists grow insulin crystals in orbit to see more details in the three-dimensional crystal structure. Crystal growth experiments may lead to new and improved forms of products.



Insulin crystals grown in space (left) are larger and structured better than those grown on Earth (right).

Materials scientists want to be able to improve materials and make new ones. Silicon crystals such as the ones we use in computers and other electronic equipment need to be very pure and uniform or they will not work correctly.

In a microgravity environment scientists can gain a new understanding of how gravity affects the solidification and crystal growth of materials by eliminating buoyancy-driven convection and sedimentation. Even in orbit, there are still tiny accelerations that affect experiments the same way gravity does depending on how far away from the Shuttle's center of mass an object is. Sometimes the scientists ask that the Shuttle be pointed in a certain direction during an experiment to reduce these acceleration effects as much as possible!

You can get more information from the on-line NASA microgravity resources located at NASA's George C. Marshall Space Flight Center, Huntsville, AL (*http://microgravity.nasa.gov*) and John H. Glenn Research Center, Cleveland, OH (*http://microgravity.grc.nasa.gov*).

It's Crystal Clear!

Crystal Growth Glovebox Activity
Grades 3-5

Introduction

This activity may be done in two parts. The first part is a technology team design brief. Student teams will design and build a glovebox to do a crystal growing experiment. The glovebox can be used for many other experiments in your classroom where you want to contain an activity or give students a chance to work as scientists do on Earth or as astronauts do in orbit. Growing and observing crystals is the second part of the design brief activity.

Students try out the Middeck Glovebox used aboard the Space Shuttle.

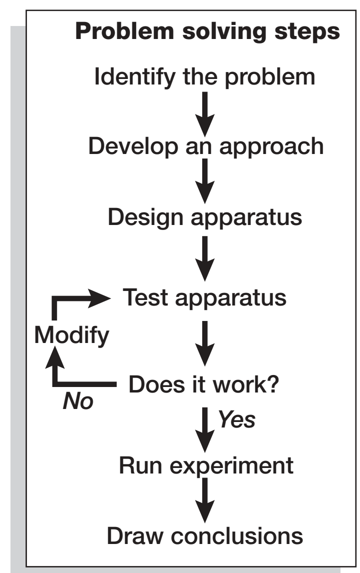
Design Brief

Design and construct a glovebox that will be used to observe crystal growth.

Objectives

In this activity, students will:

- Work in project teams to solve a problem.
- Design and build a glovebox for experiments.
- Prepare a crystal solution in the glovebox.
- Observe, measure, and record data (either on paper or on a computer) on crystal growth.



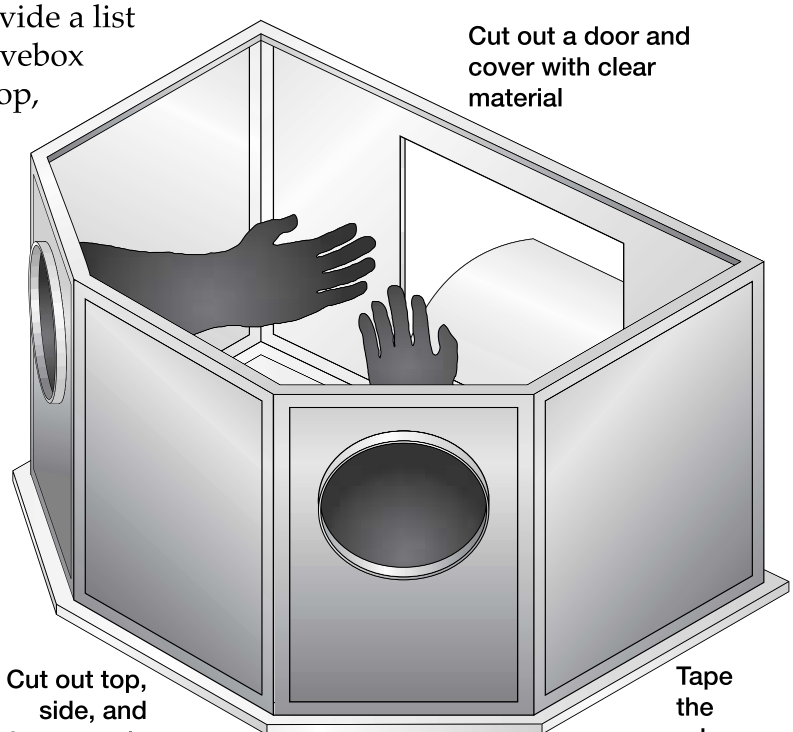
Project Teams

People often work in teams to solve problems. In this activity, students will work in a cooperative team setting just as NASA engineers and scientists do to design and then build a glovebox for their experiment. You may assign student teams to do each part of this project or do the activity as a whole team approach. For example, two or three teams can design and build the gloveboxes and then other groups can be responsible for preparing the crystal solution in the gloveboxes. The observation, measurement, and recording should be done by every member of the team. See the Project Team Activity to set up your teams.

Procedure Pt. 1: Design and build the glovebox

1. Assign students to teams and review team roles.

2. Discuss the design brief. Brainstorm possible ideas and materials for a glovebox or provide a list of materials students can use. A glovebox needs to have a clear, see-through top, so you can see what you are doing. The gloves need to be securely attached to the box and positioned so your hands can work together. The gloves need to go inside the box.



3. Student teams, or the whole class acting as a team, should design a glovebox on paper or computer. Students should label materials, parts, etc. Illustrated is an example of a glovebox made from a cardboard box.

4. The teacher must approve the design before assembly starts.

5. The top can be hinged or removable so you can place the experiment materials inside. You can also make a hinged opening in the back.

6. Use duct tape to tape the gloves facing into the box.

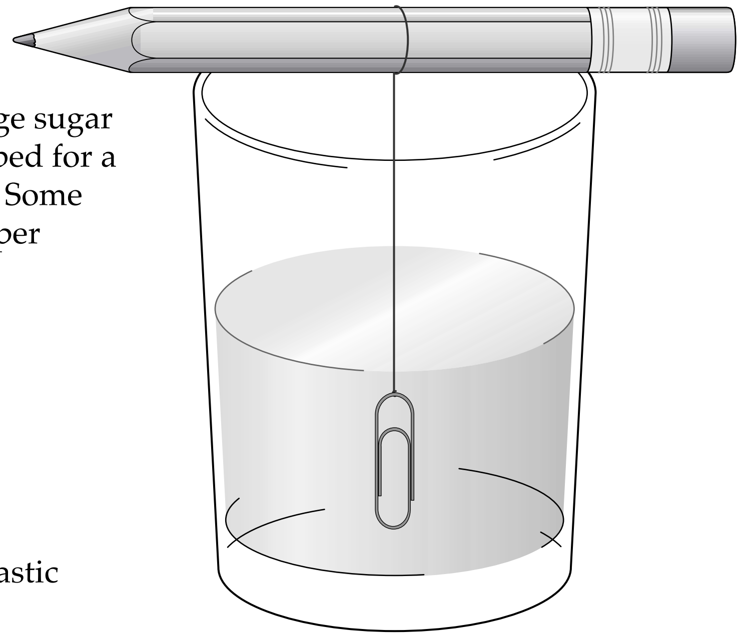
7. Place an aluminum or foam tray inside to contain spills and help with clean up. Line with contact paper or plastic to protect the glovebox.

Astronaut Ron Sega conducts an experiment inside the Middeck Glovebox in the SPACEHAB module aboard Space Shuttle mission STS-76.

Safety
- Review safe use of materials and equipment such as scissors, pencils, utility knives, etc. involved in this project.
- Wear safety glasses when mixing crystal solutions.
- Do not allow students to taste crystals.
- In some instances, crystal materials should not be touched. Check instructions if you are using materials from special crystal growing kits.
- Students should wash hands before and after using the glovebox.

Procedure Pt. 2: Crystal growth

You can grow crystals from many different materials. In this activity, we will grow crystals using sugar or salt. If you want to try different crystals, you can purchase crystal kits at retail stores that will work well in this activity.



If you have a never-fail crystal solution for this activity, you can use it. The crystal solution provided here will make fairly large sugar or salt crystals if the glovebox is not disturbed for a couple of days. *Follow all safety instructions*. Some materials are not safe to touch without proper protective clothing or equipment.

Crystal Solution Materials:

- ❏ Eye protection and gloves
- ❏ Boiling or hot water
- ❏ Measuring cup
- ❏ Thermometer
- ❏ Clear, colorless drinking glass, jar, or plastic container
- ❏ Spoon or stirring tool
- ❏ Sugar or salt
- ❏ Clean string
- ❏ Paper clip
- ❏ Pencil, piece of dowel rod, bamboo skewer, or a straw
- ❏ Paper towels
- ❏ Magnifying glasses
- ❏ Observation log, one per student or team

Making Crystals in the Glovebox

As a safety precaution, the teacher should pour the boiling water into the container and place it in the glovebox for each team. Because transporting any liquid in a container involves a spill hazard, it is best if the hot water can be carried in a covered, insulated container if it cannot be made in the classroom. Working in the gloves can be difficult until students get the feel for it. The other materials should be placed in the glovebox prior to starting the crystals. You will need a "permanent" place for the gloveboxes during this experiment. Students should be able to use the box, then observe the crystals growing for several days without moving the glovebox. Each student as part of a team should have a chance to assist in making the crystal solution in the glovebox.

Procedure for Making Crystals

1. Place hands into the gloves. Fill the glass about 1/3 full of boiling water. Stir in sugar until no more will dissolve. You will need about 2 parts sugar to 1 part water. If you are using

salt, the ratio is 1 part salt to 1 part water. Your solution should end up as a thick syrup with a few grains of either sugar or salt floating in it.

> **Math idea:** This is a great place to have students work with ratios. You can have them figure out how much water you would need if you were going to use 4 cups of sugar or how much sugar you would use if you have 3 cups of boiling water in a container.

2. Tie one end of a piece of string to the middle of a pencil or straw and the other end to a clean paper clip.
3. Wet the string and paper clip. Drag both through dry sugar or salt so grains stick to the string and paper clip.
4. Let the solution cool to 38 ˚C (100 ˚F). Otherwise the seed crystal will melt away.
5. Place pencil or straw across the rim of the container so the paper clip is suspended halfway into the solution.
6. Place a piece of plastic wrap loosely over the container opening.
7. Remove hands from gloves. Leave glovebox and container undisturbed for several days until crystals appear.
8. Keep an observation log in which you record temperature, solution clarity, crystal size, and anything of interest.

After several days the crystals will form along the string and on the paper clip. The glovebox environment will reduce evaporation and keep the solution from being disturbed. The teacher might give the teams specific observation questions that can be answered orally or in written form along with drawings of the crystals as they grow.

Evaluation

Students will need to observe their crystal growth over a number of days. You can evaluate them as teams in the glovebox design as well as the crystal solution preparation and observation phase. A sample evaluation form is in the proposal writing activity section.

Discussion Questions

- Compare the shape of your crystals to the shape of some sugar or salt grains. Use a magnifying glass to observe shapes.
- How does gravity affect the way crystals grow on Earth? Predict how your crystals would grow differently in microgravity.
- Predict what your crystals would look like if grown in a microgravity environment.

Extensions

- Design other experiments that you can do best in the glovebox, where you can control certain variables such as temperature, air currents, or movement.

- Try growing other kinds of crystals in the glovebox, such as monoammonium phosphate or Epsom salts (available at drug stores) or from crystal kits in the science section of a toy store. Observe the difference in crystals grown from different solutions. Make a chart or computer slide show to share student information and crystal formations.

- Grow a seed crystal (a small "starter" crystal) and then suspend it in its crystal solution to watch it grow. What will happen if the temperature of the solution changes?

Further Research

More information on crystal growth and glovebox experiments can be found on these NASA Internet web sites and other reference resources:

NASA Microgravity Research Program, *http://microgravity.nasa.gov*

John H. Glenn Research Center Microgravity Science Division, *http://microgravity.grc.nasa.gov*

Bosak, Susan V. Science is… Ontario: Scholastic Canada, 1991.

Doherty, P. and D. Rathjen. Exploratorium Science Snackbook. San Francisco: Exploratorium Teacher Institute, 1991

McKay, David E. and Bruce G. Smith. Space Science Projects for Young Scientists. New York: Franklin Watts, 1992.

Mullane, R. Mike. Do Your Ears Pop in Space?: And 500 Other Surprising Questions About Space Travel. New York: John Wiley & Sons, 1997.

NASA. Microgravity-A Teacher's Guide with Activities in Science, Mathematics, and Technology. EG-1997-08-110-HQ, 1997. Also available on-line at *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity*

NASA. Student's Glovebox: An Inquiry-Based Technology Educator's Guide. EG-2000-09-004-GRC, 2000. Also available on-line at *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/NASA.Student.Glovebox*

Teacher Notes

Growing good crystals takes time and patience. You might grow seed crystals ahead of time and then have students watch the continued growth in the glovebox. Older students can observe convection currents by suspending a seed crystal in its solution. Use a clear, colorless plastic container. Let the solution rest until any stirring motion dies out. Place it inside the glovebox and shine a light directly on the crystal. Place white paper behind the crystal container to act as a screen. The light passing through the container solution will produce shadows on the white paper showing the convection currents affecting the crystal's growth. These may rise or fall, depending on the type of solution used. This activity is described in NASA's publication, *Microgravity—A Teacher's Guide with Activities in Science, Mathematics, and Technology*.

Crystal Growth Observation Log

Day 1

Temperature	Solution clarity	Crystal sizes (select 10 to 20, measure, then calculate average size)

Other observations

Day 2

Temperature	Solution clarity	Crystal sizes (select 10 to 20, measure, then calculate average size)

Other observations

Day 3

Temperature	Solution clarity	Crystal sizes (select 10 to 20, measure, then calculate average size)

Other observations

Day 4

Temperature	Solution clarity	Crystal sizes (select 10 to 20, measure, then calculate average size)

Other observations

Day 5

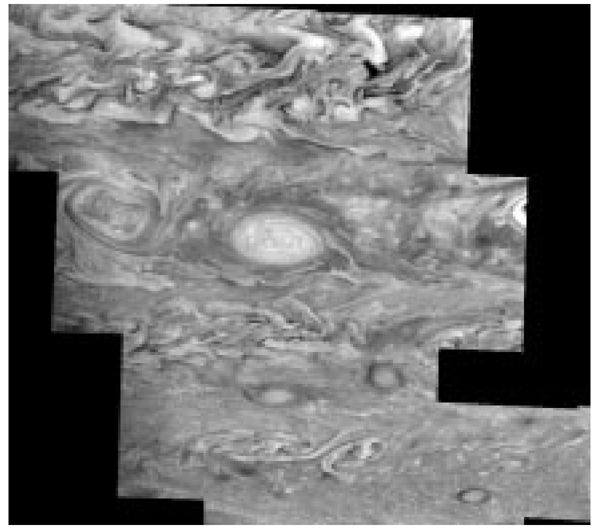
Temperature	Solution clarity	Crystal sizes (select 10 to 20, measure, then calculate average size)

Other observations

Bubble Technology

Building and Using a Fluid Flow Demonstrator
Grades 6-8

Teacher Introduction



Vortexes can be seen across our solar system, from the atmosphere of Jupiter swirling around the Great Red Spot (above) to air rolling off the wingtips of an airplane (as in the crop duster used in NASA tests, below). You can also see it as cream is poured into a cup of coffee that has just been stirred.

Soap bubbles are great for experimentation and for fun. In this activity, you will learn what bubbles can teach us about surface tension and gravity's effect on **fluids**, such as water.

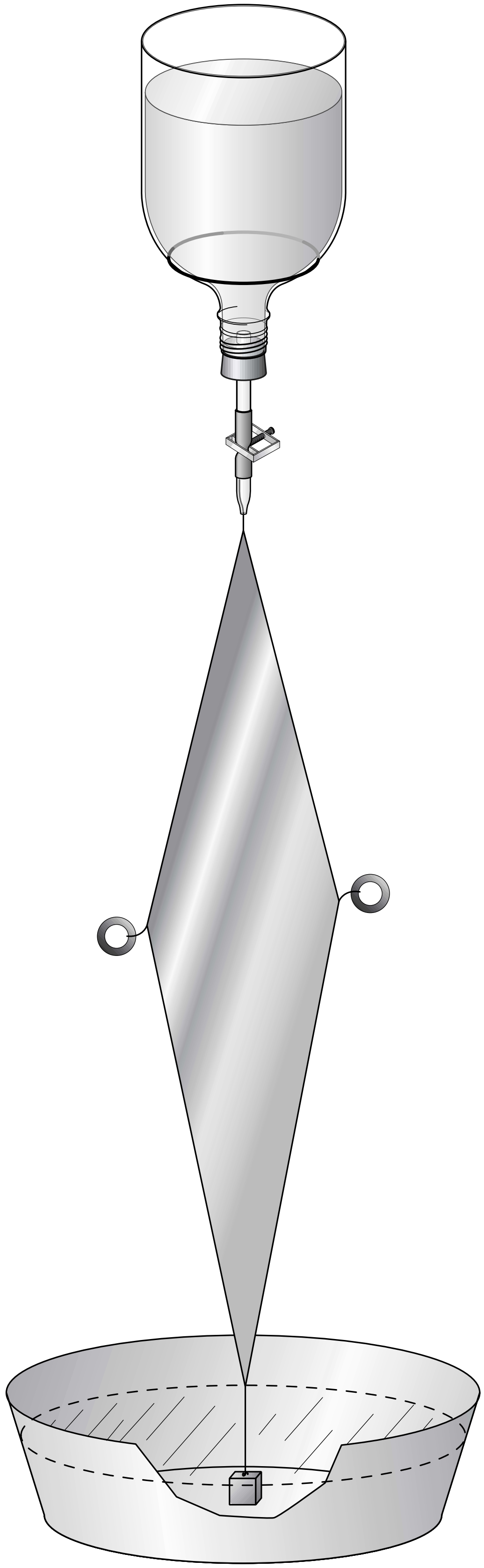
Each of us is accustomed to living in an environment where we rely on gravity to make many things work correctly. For instance, water systems on Earth work against gravity (to pump water uphill) or with it (letting it flow downhill). However, water stored in a tank behaves much differently in microgravity. In orbit, fluids like water tend to "float" in a blob. Scientists study the reaction of fluids—even molten metals—in microgravity to be able to predict their behavior and to be able to design safe and dependable fluid systems for space and to improve how we make materials on Earth.

It is difficult to analyze fluids as they move through a pipe or in a tank. You can investigate fluid flow by making a very thin film.

A soap film is really just a thin slab of water sandwiched between two layers of soap molecules. A soap film is 98% water and 2% soap. These films can show fluid patterns and turbulence in the flow. Studies of the turbulent patterns in soap films can even give us a chance to simulate turbulence in the atmospheres of giant planets (like the Great Red Spot of Jupiter).

Soap films are very thin, so thin that they can be considered just two-dimensional (having height and width, but no depth). Studying two-dimensional films can give us a way to predict how fluids flow through pipes and small nozzles called *orifices*. Understanding fluid flow can help to improve the efficiency of products such as car engines and home heating and cooling systems. Studies may lead to a method of modeling fluid flow in a computer for design and engineering simulations.

Bubbles are held together through **surface tension**. Molecules in a droplet of water are slightly attracted to each other. At the surface, with no water molecules outside, this pull is stronger.



It’s as if they try to stick together. This is why water forms droplets, or sheets of water have rounded edges. If the molecules want to stick together too much, bubbles will not form very easily. That’s why we add soap. Soap decreases the surface tension to about 1/3 of what it usually is and that makes it easy to form bubbles (and so the water can get into and under dirt to clean dishes, clothes, and us).

To make bubbles last longer, you need to add something to a bubble solution to keep the water from evaporating too fast. Glycerin is a substance that is commonly used for this purpose. Substances such as glycerin that have water-holding properties are called **hygroscopic liquids**. Glycerin can be found in the laxative aisle of a drug store.

In this activity, you can explore making different bubble solutions as well as different metal forms to make bubbles. As an introductory lesson on changing the surface tension of water, you can have students shake pepper over the surface of water in a shallow container, such as a pie pan. Dip the tip of a toothpick in liquid soap, then touch the toothpick to the center and watch what happens to the pepper. Have the students predict what will happen if you touch the toothpick to the water at the edge of the container. More suggestions for exploring surface tension are included in the extension at the end of the activity. Note: You can only do this once because the soap breaks the surface tension. You will have to clean the container thoroughly, or have additional containers, to repeat this experiment.

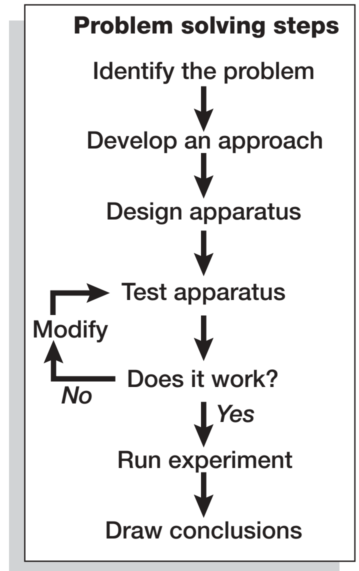
If this is the first time your students have explored bubbles, have them make enclosed shapes from wire clothes hangers or other pipe cleaners. You can make bubble frames from straws and short segments of pipe cleaners. Check the reference list at the end of this activity for more ideas.

Bubble Technology

Building and Using a Fluid Flow Demonstrator
Grades 6-8

Introduction

In this activity, you will design a device to make bubble films and learn about surface tension.



Design Brief

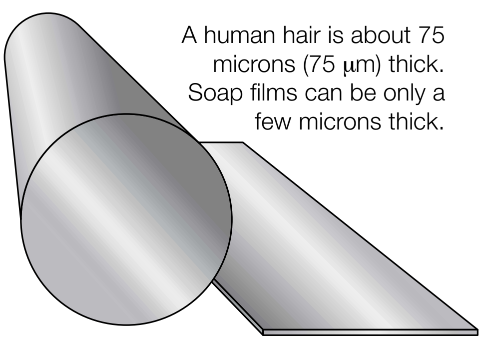
Using the steps in a problem solving strategy, design and build a bubble film apparatus to study fluid flow.

Objectives

In this activity, students will:

- Work in teams to design, build, and test a fluid flow demonstrator.
- Experiment with different light sources to carefully study the flow of fluid around objects.

A *fluid* is often thought of as a liquid, but fluids can be either liquids or gases. A fluid is matter whose shape (under gravity's effects) is determined by the shape of the container. Granular materials can act like fluids even though the individual grains are solid. The fluid flow demonstrator makes it possible to form a continuous soap film that flows from a reservoir onto two strings and into a drip pan. When the strings are pulled apart, a large, thin sheet bubble, called a *film*, is formed. The sheet of soap film can be made very large so that many students can see the demonstration. Soap films are very thin. On Earth, gravity makes the film thicker at the bottom than the top. The films range from a few *microns* (millionths of a meter) to several tens of microns in thickness.


A human hair is about 75 microns (75 μm) thick. Soap films can be only a few microns thick.

Although they are so thin, soap films can have lengths and widths that are several meters in size. The soap molecules form a surface layer on both sides of the film. The soap is called a **surfactant** (*surf*ace *act*ive *agent*) because it creates a surface over the water without dissolving. When objects are coated with the soap solution and placed into the film, patterns can be seen downstream of the object. The brightest parts of a soap film are the thickest areas. A swirling pattern in the film is called a **vortex**. The vortex flow seen in the soap film liquid is similar to the tornado-like vortex of air created at the tips of airplane wings. A vortex will also create a bright area on the soap film. Colors on the film can be indicators also. Red indicates counterclockwise swirling; blue, clockwise.

Procedure

1. Follow the Project Team Activity to organize into groups and prepare a proposal for peer review. See the Sample Proposal.

2. Thoroughly rinse a 2-liter drink bottle with water. Leftover drink can contaminate the solution.

3. Carefully cut off the bottom of the bottle with sharp scissors.

4. Assemble the apparatus illustrated in the sample proposal or design a better method using available materials and equipment. The goal is to have a steady drip from your solution container.

5. Design and build a way to hang the soap container from the ceiling or other high point. This could be a ladder with an extension off the side. You might use the basketball stands in the gymnasium.

6. Place old carpet squares under and around the drip pan to catch any splashed solution and reduce slip hazards.

7. Mix a bubble film solution using 1/2 cup of dishwashing detergent (Dawn® or Joy® work best), 1/4 cup of glycerine and 1 gallon of water. You can also try other solution mixtures. Letting the solution sit overnight makes bigger bubbles.

8. Experiment with different light sources (a low-power laser pointer, a slide projector, polarizing sunglasses) and different angles of incidence to get the best view of the flow pattern.

9. Wet various shaped waterproof objects in the bubble film solution and place them one at a time in the film flow. Observe the downstream patterns created by the objects.

10. **Important**: Clean up any spilled bubble film solution immediately to prevent slipping on the floor or surrounding area.

Discussion Questions

- How would your experiment work in microgravity?
- What would happen to liquid oxygen or liquid hydrogen inside a tank in a microgravity environment?
- Observe and describe differences in colors that appear at the top and bottom of the film.
- Describe three things that you have learned about bubble and fluid flows.
- What is surface tension? What are characteristics of fluid flows?
- Compare a soap film vortex to some other kind of vortex that occurs in nature.

- What happens when dry objects are placed in the fluid flow? Explain.

Extensions

- Describe what would happen to a water balloon if it popped in microgravity. View the MPEG videos on-line at *http://microgravity.grc.nasa.gov/balloon/blob.htm.*
- From what you know about how fluids act in microgravity, explain what might happen to the stomach contents of astronauts.
- Can you predict where the film will pop based on the color patterns?
- Experiment with a different soap solution formula to find a mix that makes the biggest bubbles. Try various soap concentrations, distilled water, water temperature, or other variables.
- Design a tank that would force water out under pressure in microgravity.
- Design a soap film apparatus to make the largest possible film area. Get teacher permission before attempting the experiment.
- Research the effects of microgravity on the circulatory system of astronauts. Why do the faces of astronauts look puffy in microgravity?
- Place a paper or cloth backdrop behind the bubble flow and videotape the experiment for future evaluation.
- Observe the effect of a helium-neon laser on the soap film. (**Follow the safety rules** that come with the laser. **Never look** directly into the beam or reflected beam of even a low-power or "eye-safe" laser.)
- Experiment with different string materials.

Further Research

American Institute of Physics, soap film physics, *http://www.aip.org/physnews/graphics/html/soapfilm.htm*

Ohio State University, soap film physics, *http://www.physics.ohio-state.edu/~maarten/work/soapflow/soapintro/basicsoap.html*

Bosak, Susan V. <u>Science is…</u> Ontario: Scholastic Canada, 1991.

Doherty, P. and D. Rathjen. <u>Exploratorium Science Snackbook</u>. San Francisco: Exploratorium Teacher Institute, 1991.

Lawrence Hall of Science. Great Explorations in Math and Science. Bubbleology and Bubble Festival, 1986. *http://www.lhs.berkeley.edu/GEMS/gemsguides.html*

Isenberg, Cyril. The Science of Soap Films and Soap Bubbles. New York: Dover Press, 1992.

McKay, David E. and Bruce G. Smith. Space Science Projects for Young Scientists. New York: Franklin Watts, 1992.

Teacher Notes

The fluid flow experiment is easy to set up as a demonstration and simple enough to have small groups build their own. The materials are inexpensive and easily acquired. Special attention should be paid to the following:

- A possible slipping hazard exists after prolonged use or accidental spills. A mop and a bucket should be available to clear up slippery areas immediately. A tarp or inexpensive backyard plastic swimming pool might be used to contain spills. A piece of old rug can help prevent slips.
- Students will want to try to place their fingers or hands into the bubble film. This is possible if they wet their hands in the bubble solution before putting them into the flow. A supply of paper towels should be available to help clean off after the experiment. Locating the experiment near a sink will aid in clean up and provide an easy place to rinse off the solution. Use a spray bottle of vinegar to cut the soap and speed clean up.
- Students should be encouraged to experiment by trying a different formula for the bubble solution. Changing the concentration of soap, the addition of glycerin to the solution, or the use of distilled water instead of tap water can often improve results.
- Although the chemicals involved in the activity are very safe, students should be required to wear safety goggles while experimenting. These can be purchased at hardware or lawn and garden stores.
- Make sure the weight and fishing line are submerged in the fluid at the bottom before pulling the nylon lines apart. Otherwise, a a fluid sheet will not form.
- A class competition to create an apparatus that will make the largest bubble film surface will stimulate creative ideas. Each idea must be reviewed by the teacher with regard to safety.
- **Important**: If a laser is used, **observe all safety rules** that come with it. **Never look** directly into the beam or reflected beam of even a low-power or “eye-safe” laser.

Sample Proposal

PROJECT PROPOSAL TITLE: *Fluid Flow Demonstrator*

DESIGN BRIEF: *Design and build a bubble film apparatus to study fluid flow.*

PROJECT TEAM MEMBERS:
Principal Investigator: *Ashley Firestone*

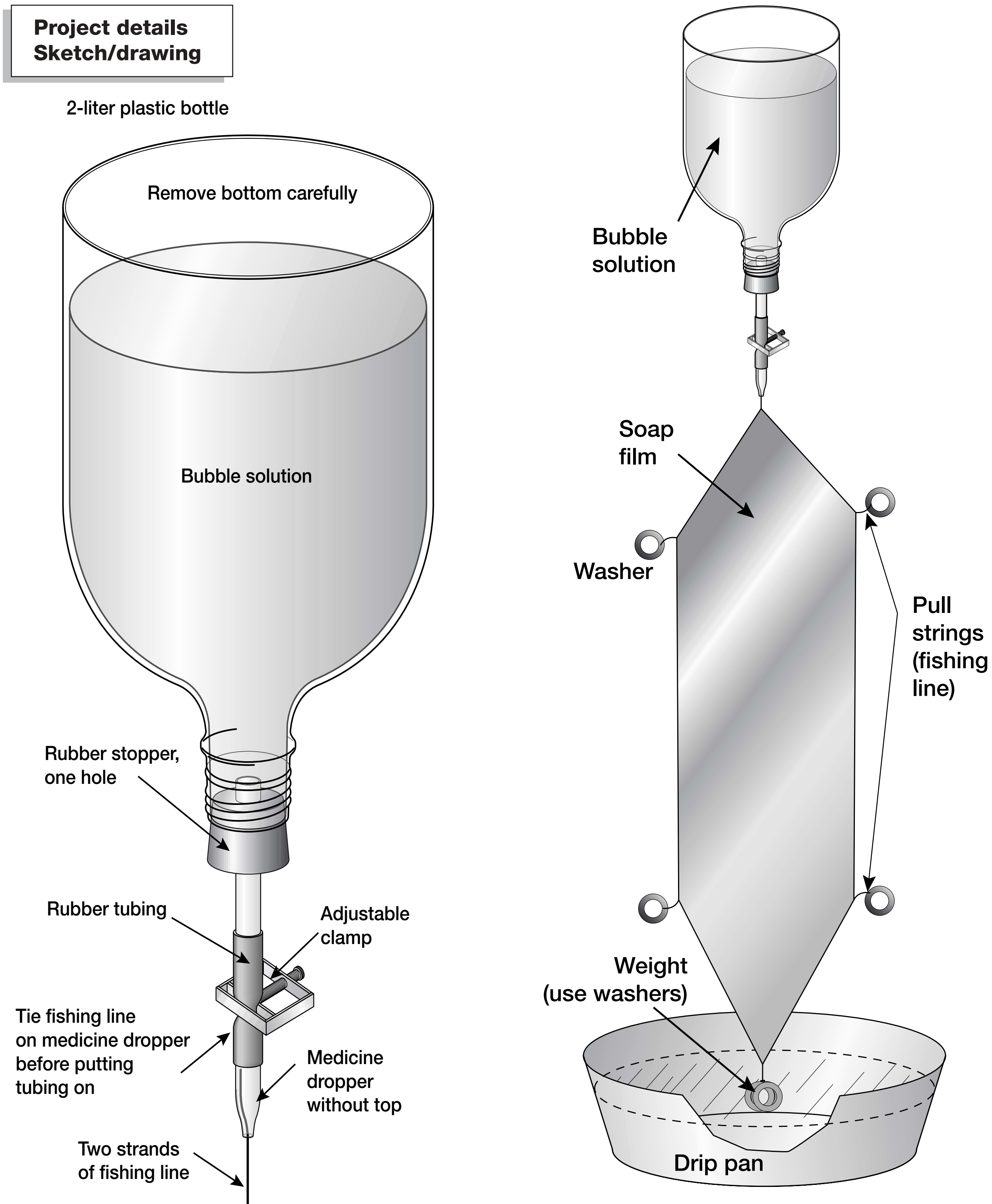
- **Scientists:** *Elli Whitney, Albert Stein*
- **Engineers:**
  Mechanical Engineer *Stan Diego*
  Chemical Engineer *Pam Cookingspray*
  Aerospace Engineer *George Jones*
  Industrial Engineer *Hanna Hanson*
  Structural Engineer *Doug Walrath*
- **Technicians:** *Bob Upndown, Craig Waters*
- **Astronauts/Test Subjects:** *Gillian Island, Jarid Jones*

PROJECT DESCRIPTION
This project will let bubble solution drip out of a 2-liter plastic bottle onto strings. A rubber stopper and adjustable clamp will regulate flow. The strings will be tied to a weight at the bottom and pulled apart to make a bubble film. Extra bubble solution will be caught in a drip pan or bucket. A bubble solution made of Dawn® or Joy® (1/2 cup), glycerine (1/4 cup) and water (1 gallon) will form a film between the strings. Objects will be put into the film and the flow below it will be observed.

MATERIALS LIST

Item	**Description**	**Quantity**	**Cost ea.**	**Total cost**
Plastic Bottle	2 liter	1	0.00	0.00
Medicine Dropper	(Possible donation)	1	.25	.25
Rubber Tubing	1/4” inside diameter, 3” long	1	.15	.15
Dish washing soap	(Possible donation from home)	1	1.98	1.98
Fishing line	(Possible donation)	1	2.49	2.49
Adjustable Clamp	Adjusts fluid flow	1	2.99	2.99
Goggles	Lawn or shop safety goggles	3	2.00	6.00
Washers (1/4 or 1/2 in)	Hardware store	2	.25	.50
Glycerin	Drug store	1	2.50	2.50
Rubber Stopper	Drug store	1	.30	.30
Total				**17.16**

Project details
Sketch/drawing



Approval

Peer Review Panel ______________________________

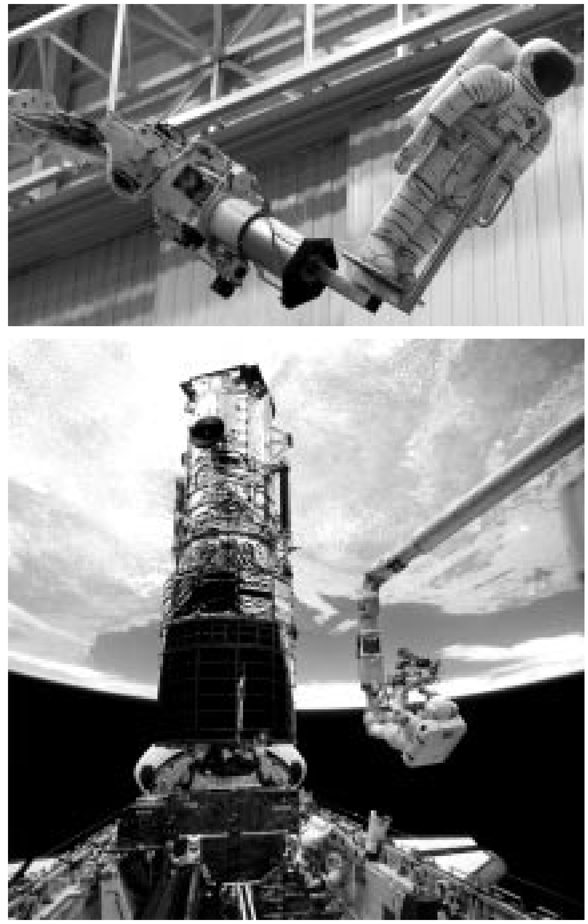
Safety Inspection (Teacher) ______________________________

Sim Satellite!

Simulating Microgravity
Grades 6-8

Introduction

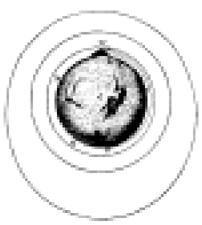
Working in space is a real challenge for the astronauts. Before the astronauts go into orbit, they have to spend many hours practicing how to use special tools and equipment. Remember, they will be in a microgravity environment once they are in orbit. That means some effects of gravity will be reduced compared to effects on Earth. In space, the astronauts and other objects are in free fall as they orbit Earth. Without the effects of gravity to pull them and other objects down against the floor or a table, there is no resistance and the slightest push can send an object — or you — floating away.



A balloon shaped like an astronaut stands in for the real thing at the end of a mockup of the Shuttle robot arm (top). This helped the crew train for flight operations when they repaired the Hubble Space Telescope (bottom).

Many people think that astronauts and other objects in space move freely because there is no gravity. That is not the case. It takes gravity to keep the Shuttle and other objects orbiting Earth. Sir Isaac Newton figured this out over 300 years ago. He imagined placing a cannon on top of a very high mountain. If he fired the cannon, the cannonball would eventually fall to the ground. If he increased the energy by using more firepower, the cannonball would go out farther before it fell, but it would still fall to the ground.

With just the right amount of energy applied to the cannonball, its speed and direction (or velocity) plus the pull of gravity would cause the ball to curve along Earth's surface. The ball would never hit the ground but would stay in orbit. Like the cannonball, the Shuttle and its astronauts are constantly falling toward Earth; they move forward to match gravity's pull in an arc around Earth. The Shuttle and astronauts are in free fall and so experience microgravity. If gravity did not exist, the Shuttle would keep moving away from Earth in a straight line with constant speed.



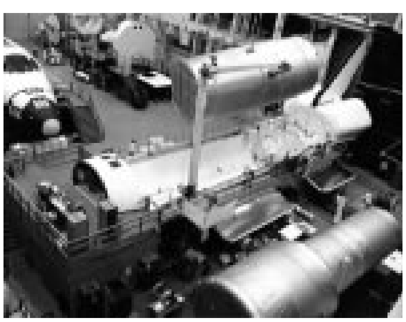
A thrown stone, propelled by its own weight [inertia], is deflected from a straight-line course, follows a curve in the air, and ultimately falls to Earth. If it is thrown with a greater velocity, it will go farther. It is conceivable that if the velocity were increased enough, the stone would ultimately shoot beyond the borders of Earth and not fall back again.

Sir Isaac Newton

Astronauts perform some very specialized jobs while on space walks. They service and repair satellites in low Earth orbit or build structures like connecting parts on the International Space Station. Anytime you are working in orbit, you have to think about how microgravity will affect your job. In the microgravity environment, you have to be careful how you move. Any sudden movement can send you off in a direction you might not want to go. An astronaut might spend 10 minutes on a job in a microgravity environment that she could easily do in 2 minutes on Earth. That means astronauts have to plan more time for simple tasks on space walks. In addition, astronauts must wear bulky space suits that make using small tools and equipment even more difficult. They have to be careful not to let go of objects or the gentlest push might make the tool—or themselves—just float away!

You can see that practicing for a space walk and knowing how your tools and equipment work before you go in orbit are very important. Astronauts train for some special tasks underwater. Being underwater does not place you in free fall. But if you can be made *neutrally buoyant* underwater—if your density is the same as the density of the water, so you neither sink nor rise—then what happens moving and using certain tools is a lot like what happens in microgravity. (To achieve neutral buoyancy, engineers attach weights to the astronaut's space suit, or plastic floats to heavy tools.) Just suppose you tried to fix a satellite during a space walk without using the special foot restraints located around the payload bay. Every time you tried to exert a force your body would move in the opposite direction. As you used a wrench to tighten a bolt (a clockwise movement), your body would move in the opposite (counterclockwise) direction. In the underwater facility, your body would move almost as it would in orbit. The underwater facility lets the astronauts get the feel of microgravity and what working in a bulky suit feels like. In addition, the underwater facility lets engineers see if the tools they have designed work correctly and if the foot restraints and handholds are in the right places.

Buoyancy is a net force that lifts against the force of gravity. Any object—whether it is a grain of sand or a gas bubble immersed in a fluid—has a buoyant force acting on it. A boat floats on the water because of the buoyant force.



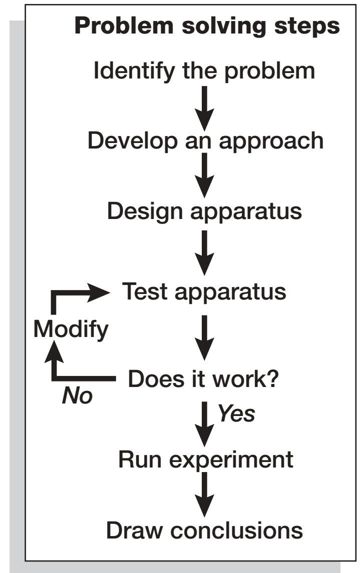
In the Manipulator Development Facility, a balloon model about the same size as a module for the International Space Station is held over the Shuttle mockup for deployment. A balloon model of the Hubble Space Telescope lies on the ground to the right.

Some training for using the Shuttle robot arm is done with balloons in a large building, not under water. One of the Space Shuttle mockups has the flight deck where the crew works, the payload bay, and a working model of the robot arm. To practice grappling payloads like the Hubble Space Telescope, or moving astronauts around the Hubble or International Space Station for maintenance work, the astronauts handle balloons shaped like satellites or an astronaut. The balloons are filled with enough helium to balance the balloon's weight and make them neutrally buoyant. This way the fragile model of the robot arm isn't lifting any real weight. But the crew goes through all the right motions so they'll know what to do in orbit.

Sim Satellite!

Simulating Microgravity
6-8

Introduction



This design brief has two microgravity simulation activities. The first activity addresses making things "float" on Earth using the principle of neutral buoyancy. The second activity simulates working in a microgravity environment. In both activities, you will be using neutral buoyancy but without the swimming pool! (Think about it: this is how the Goodyear blimp floats, without rising or sinking, during football games.)

Design Brief

Using a team problem solving strategy, design and construct a neutrally buoyant helium satellite model.

Objectives

In this activity, students will:

- Work in teams to design, construct, and test a helium satellite model for neutral buoyancy.

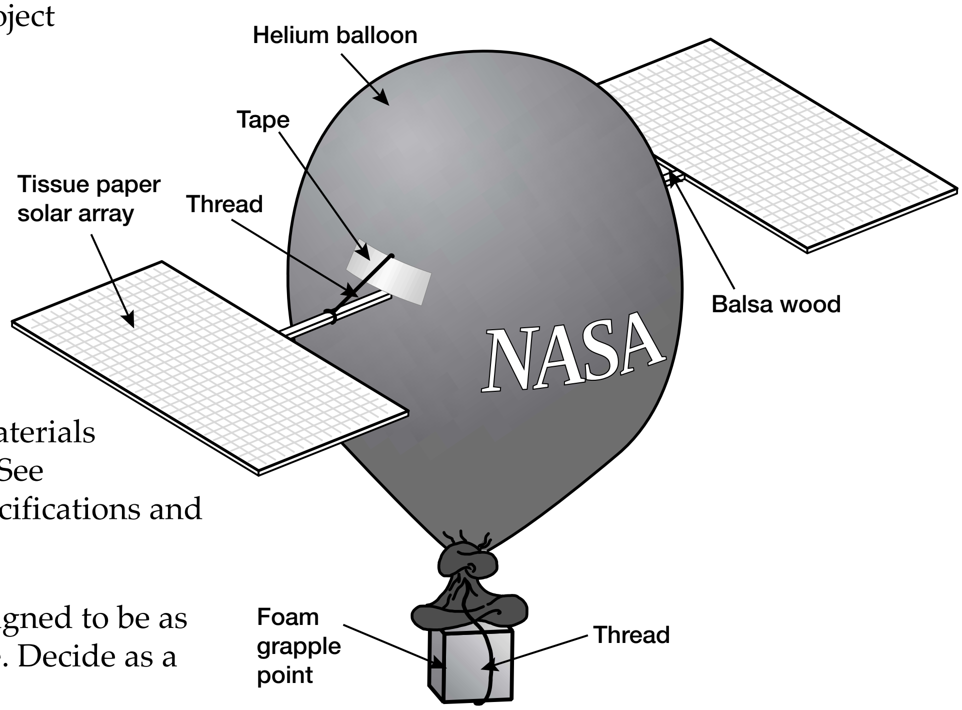
Procedure

1. Research the parts and design of various satellites and how they work.

2. Divide the class into project teams. See the Project Teams Activity for ways to develop a team.

3. Each team needs to write a proposal for the design of their satellite. Students will research satellite designs and possible materials to use for construction. See construction design specifications and sample proposal.

4. Satellites should be designed to be as cost efficient as possible. Decide as a



class what materials should cost or set up a materials list as shown in the sample. Students can use spreadsheet software on a computer to keep track of their total costs.

5. Students submit a proposal to the teacher for approval. Have teams build and test their designs. Modify as needed. The helium balloon will not have the same buoyancy from day to day (helium leaks through the rubber of a balloon) so they will need to have all the components ready at the same time.

6. When the satellite model is able to float for 10 seconds without going up or down, it has reached neutral buoyancy. Teams should test their designs in a room free of air currents, if possible.

Design Specifications

There are many possible designs that will work to make a neutrally buoyant satellite. Encourage teams to find different designs. The final design must meet the following minimum specifications:

- Float without moving up or down for at least 10 seconds. A test will be conducted in a room free of air currents.
- Be constructed of approved materials and quantities. See sample materials list on page 49.
- Have a designated grapple point (a reinforced area where you grab hold of the balloon).
- Have a minimum of 6 square inches of solar array area.

Each team should design the least expensive satellite simulator that will still work. Small helium canisters (usually used for blowing up party balloons) can be purchased at discount and retail stores. Also, you can obtain inflated balloons that meet your specifications.

Safety

- Follow all general safety rules established for your classroom when working with materials, tools, and machines.
- Do not allow students or adults to inhale helium. It is a suffocation hazard if inhaled in significant quantities.

Testing

When construction is complete, test each satellite to see if it has achieved neutral buoyancy. That means it must float without moving up or down for at least 10 seconds in a place where air currents are low or absent. Compare costs of the different satellites (including cost of materials) and then allow time for minor changes. Test again. Student teams should share successful ideas with other teams as well as possible modifications for more efficiency. Select the most cost-efficient designs that achieve neutral buoyancy to use in the next activity.

Evaluation

Use the team evaluation sheets in the Project Team chapter to evaluate the teams and each individual member. You can videotape the activity and respond to what happened in the simulated work experience.

Discussion Questions

- What design problems did you have in your neutrally buoyant satellite simulation?
- What team job did you have and how did you help the team?
- What would your team do differently if you could do this activity again?
- How could you make your design more cost efficient (less expensive)?
- Why does a helium balloon float?
- Where do astronauts use neutral buoyancy when training?

Extensions

- Design and construct neutrally buoyant satellites from other sizes and shapes of balloons.
- Construct a "staging area" to control your helium balloon while you adjust it to make it neutrally buoyant.

Further Research

Bosak, Susan V. Science is… Ontario: Scholastic Canada, 1991.

NASA. Microgravity-A Teacher's Guide with Activities in Science, Mathematics, and Technology. EG-1997-08-110-HQ, 1997. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity*

NASA. Mathematics of Microgravity. EB-1997-02-119-HQ, 1997. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Mathematics.of.Microgravity*

Smolders, Peter. Living in Space: A Handbook for Space Travellers. Blue Ridge Summit, PA: Aero, 1986.

"Do-it-yourself" instructions for making a model of the Hubble Space Telescope. *http://sol.stsci.edu/~mutchler/HSTmodel.html*.

NASA's Great Observatories Kit. *http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Technology/Models/NASA's.Great.Observatories.Kit/.index.html*

Iceberg paper model links. *http://www.peterjvisser.demon.nl/links.html*

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Sample Proposal

PROJECT PROPOSAL TITLE: *Sim Satellite*

DESIGN BRIEF: *Design and build a satellite mockup that floats to simulate satellite handling and retrieval in space.*

PROJECT TEAM MEMBERS

Principal Investigator: *Itsa Goodyear*

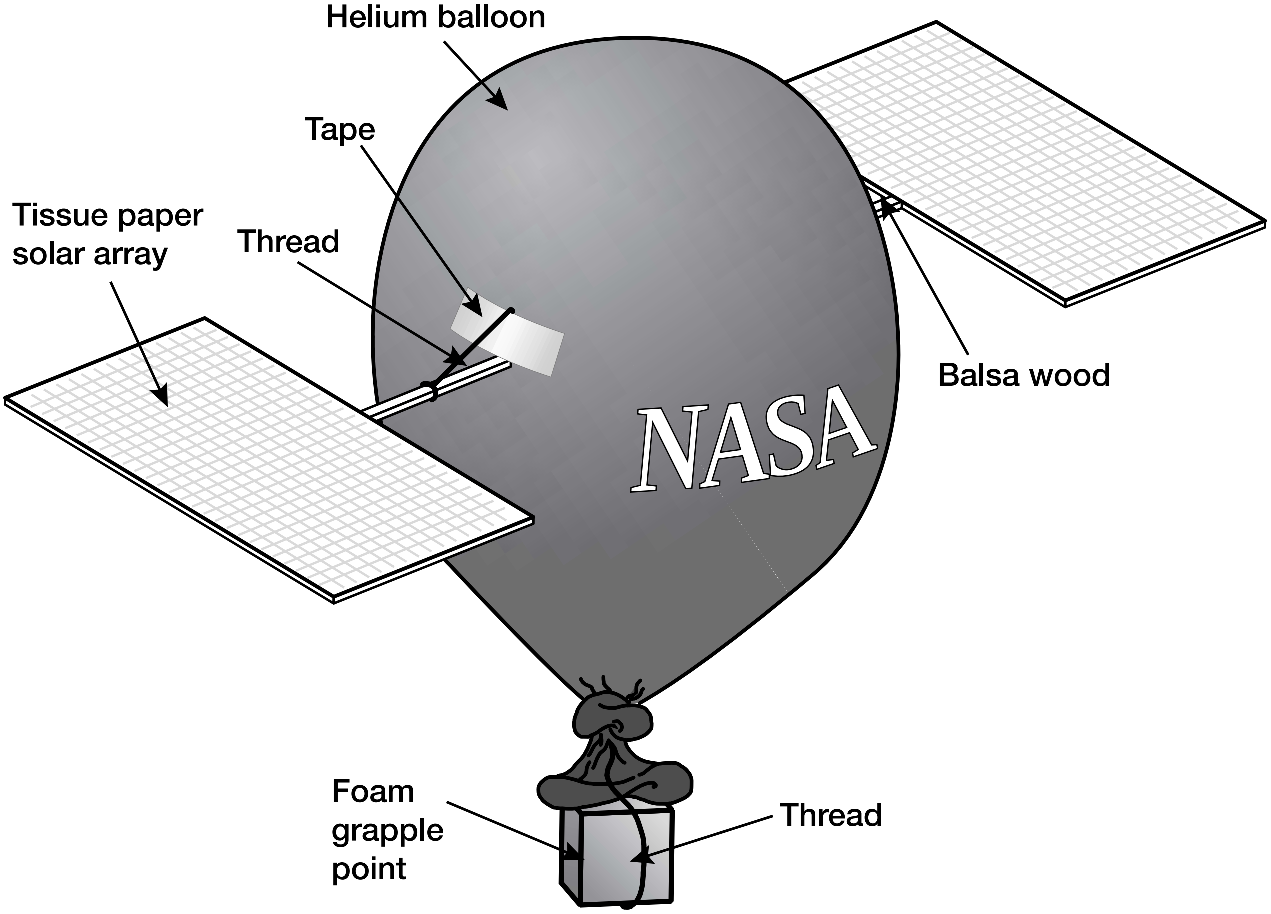
- **Scientists**: *I. Sikorsky*
- **Engineers**: *G. Zeppelin*
- **Technicians**: *Heloise Helios*
- **Astronauts/Test Subjects**: *D. Bowman, F. Poole*

PROJECT DESCRIPTION: *Neutral buoyancy simulates how objects float in the microgravity environment. A helium-filled balloon will float away. With enough weight added it will neither float nor sink. If the weights are shaped like parts of a satellite, we can simulate handling a satellite with the Space Shuttle's robot arm.*

MATERIALS LIST:

Item	Description	Quantity	Cost ea.	Total cost
Balloon	Standard 12-inch	3	1.00	3.00
Helium	Small canister, party pack size	1	20.00	20.00
Balsa wood	1/16 x 1/16 x 26 in.	1	.80	0.80
Tape	Any type, 6 in.	1	0.00	0.00
Thread	Sewing thread, 18 in.	1	0.00	0.00
Foam	Low density bead board, 4 cu. in.	1	0.00	0.00
Glue	Wood or hot glue, 2 oz.	1	0.15/oz	0.30
Paper clips	Small or large	6	0.00	0.00
Straws	Plastic drinking straws	4	0.00	0.00
Tissue paper	Tissue wrapping paper, 40 sq. in.	1	0.25	0.25
TOTAL				**24.35**

Project details
Sketch/drawing



Approval

Peer Review Panel ______________________________

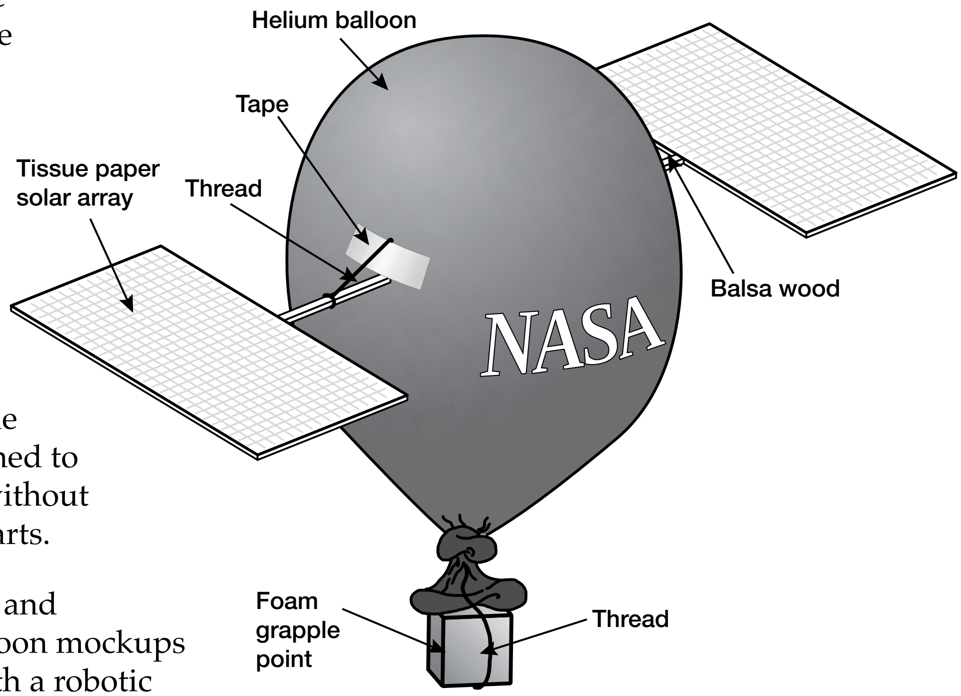
Safety Inspection (Teacher) ______________________________

Hold That Satellite!

Working in a Simulated Microgravity Environment
Grades 6-8

Introduction

Now that the students have had an opportunity to make a neutrally buoyant satellite, they are ready to go to work in a simulated microgravity environment. The teams must grapple and dock an orbiting satellite for repair. They have to grab it by its grapple point with the robotic arm. The grapple point on a satellite is designed to be strong enough to grab without causing damage to other parts.



Astronauts practice raising and lowering helium-filled balloon mockups of satellites or payloads with a robotic arm in the NASA Manipulator Development Laboratory. This prepares them to use the robotic arm effectively on the Space Shuttle. For the robotic arm, one team member can act as the robot or use an existing mechanical robotic arm. (Balloon mockups are used because even lightweight mockups would be too heavy for the robot arm mockup to lift. In the NASA lab, the balloons are not released to float and then be recaptured. They are picked up from the ground or inside the Shuttle mockup.)

Design Brief

Grab a satellite with a robotic arm in a simulated microgravity environment.

Objectives

In this activity, students will:

- Successfully grab a neutrally buoyant model satellite with a robotic arm.
- Work in a team environment to solve a problem.

Project Team

People often work in teams to solve problems. Each student in the class will be a member of the team. In this activity, students will be asked to choose a career role from the following list:

Principal Investigator is the team leader and must understand all aspects of the problem and present it to the group. As team leader, the P.I. carries the greatest responsibility for the project.

Scientists usually specialize in a specific field of study or investigation. This activity needs scientists familiar with microgravity and neutral buoyancy.

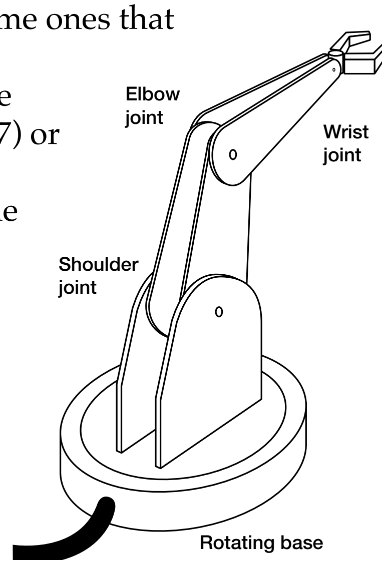
Engineers use mathematics and scientific principles to solve technology-related problems. In this activity the engineer will work closely with the technicians to design robot commands that will move the robotic arm.

Technicians must work with a variety of machines and materials. He or she should be able to read and follow written directions and understand working drawings.

Astronauts perform the actual operation. In practice, several test subjects develop the procedure for the astronauts to refine and then rehearse on Earth before flight. In this activity, students will take turns trying to grapple the neutrally buoyant balloon satellite.

Procedure

1. Divide the class into teams of five. The teams may be the same ones that were set up in Sim Satellite to make the neutrally buoyant satellites, or they may be changed. Team members should be assigned a specific job. See the Project Teams chapter (page 7) or you can do the activity as a whole class “team” approach. If they are not doing this activity during the same period as the previous one, they may need to make another neutrally buoyant satellite.



2. Each team needs to develop a plan and generate robot commands to be used in this exercise.

3. Define an area that will be used for the satellite maneuver and the **work envelope** of the robot. The *work envelope* is the maximum distance that each part of a robot arm can move. They’ll want to be sure the neutrally buoyant satellite stays in that area.

4. Identify the moving parts of a robotic arm:

   - Shoulder: moves in and out and rotates (or, robot base rotates),
   - Elbow: moves up and down,
   - Wrist: pitches up and down, and rotates,
   - End effector: opens and closes to grip objects.

5. Match the moving parts of a mechanical robotic arm with the human arm. Teams can make up a command list to move a human “robotic” arm properly. For example, try commands

Can you imagine trying to lift an object that is as fragile as a glass ornament, big as two buses, and costs tens of millions of dollars? To learn how to do this, astronauts practice in a special place called the Manipulator Development Facility, or MDF, where there is a simulated robotic arm. On the real Shuttle, the Remote Manipulator System (RMS) is the mechanical arm used to move payloads in and out of the payload bay in space. It has three joints — shoulder, elbow, and wrist— that work much like the joints on a human arm. At the end of the wrist is a special end effector that grabs the grapple on free-flying payloads.

such as “End effector close” or “Elbow up” on a team mate. If you are using a mechanical robot arm, use the control commands that work for that robot model.

6. If you are using a person to be the robotic arm, blindfold the person. Team members take turns giving commands to the robot arm as they try to grab the grapple point of the neutrally buoyant balloon satellite. Be sure you remember to make a “stop” command so the human “robotic” arm can stop movement at the proper time. If you are using a mechanical model, team members should take turns at the controls. A challenge or extension might be to set up a video camera to view the robot arm and satellite from a remote location (or with a lightweight camera atop the robot arm). Try to grab the grapple point by watching it on a TV monitor.

7. Have teams time how long it takes to grab a free-floating satellite with their “robotic” arm.

Evaluation

Use the team evaluation sheets in the Project Team activity to evaluate the teams and each individual member. You or the students might video tape the activity and respond to what happened in the simulated work experience.

Discussion Questions

- How would you change the satellite design to make it easier to grab the grapple point?
- How do you know helium is less dense than air?
- How are satellites powered?
- What was the most difficult part about controlling your robotic arm?
- What team job did you have and how did you help the team?

Extensions

- Use walkie-talkie radios to communicate between someone watching the satellite/robot and another student controlling the robot but unable to see it.

- Design a robotic arm to use for this activity.
- Dock the satellite in a payload bay mockup without damaging the solar arrays.

Further Research

More information on neutral buoyancy, density, robotics, and working in a microgravity environment can be found in the following resources.

"Canadarm: The Background." Article in *Science Dimension* magazine. *http://www.ieee.ca/millennium/canadarm/canadarm_background.html*

NASA. Cool Robot of the Week at the NASA Telerobotics web site. *http://ranier.hq.nasa.gov/telerobotics_page/coolrobots.html*

NASA. Space Shuttle News Reference, Payload Deployment and Retrieval System. *http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts-caws.html#sts-deploy*

NASA. Microgravity-A Teacher's Guide with Activities in Science, Mathematics, and Technology. EG-1997-08-110-HQ, 1997. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity*

NASA. Mathematics of Microgravity. EB-1997-02-119-HQ, 1997. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Mathematics.of.Microgravity*

NASA. Liftoff to Learning Series Videotape: Let's Talk Robotics. EV-1998-04-015-HQ, 1998. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Let's.Talk.Robotics*

Microgravity News and Research, on-line at *http://microgravity.nasa.gov*.

Mullane, R. Mike. Do Your Ears Pop in Space?: And 500 Other Surprising Questions About Space Travel. New York: John Wiley & Sons, 1997.

Smolders, Peter. Living in Space: A Handbook for Space Travellers. Blue Ridge Summit, PA: Aero, 1986.

Sample Proposal

PROJECT PROPOSAL TITLE: *Hold That Satellite!*

DESIGN BRIEF: *Develop the procedures for recovering a balloon satellite mockup to simulate satellite handling and retrieval in space.*

PROJECT TEAM MEMBERS

Principal Investigator: *Itsa Goodyear*

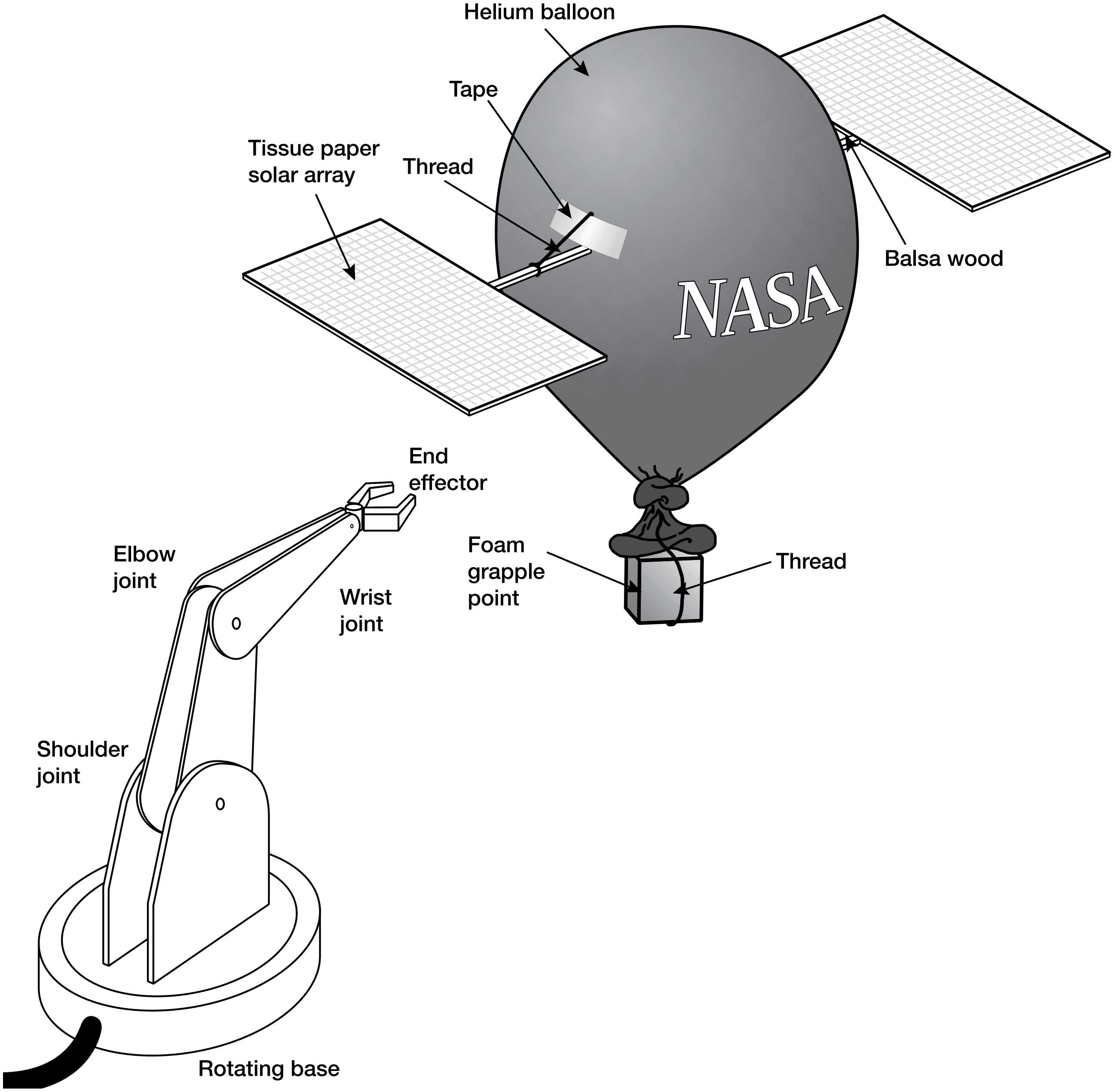
- **Scientist**: *I. Sikorsky*
- **Engineer**: *Itsa Goodyear, Griff Zeppelin,*
- **Technician**: *Heloise Helios*
- **Astronauts/Test Subjects**: *D. Bowman, F. Poole*

PROJECT DESCRIPTION: *Satellites must be handled with care because they are fragile and cost a lot of money. In microgravity, small motions can make a satellite move away from the Space Shuttle. We will develop procedures for safely capturing and storing a satellite mockup.*

MATERIALS LIST:

Item	Description	Quantity	Cost ea.	Total cost
Sim Satellite	Developed in earlier exercise	1	0.00	.00
Robot arm	Possible donation or loan	1	0.00	.00
TOTAL				0.00

Project details
Sketch/drawing



Approval

Peer Review Panel ______________________________

Safety Inspection (Teacher) ______________________________

A Drop in the Bucket

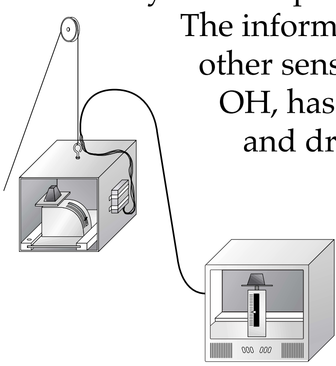
Microgravity Drop Tower Activity
Grades 9-12

Introduction

An experiment package is readied for a 24-meter drop in the 2.2-second Drop Tower Facility at NASA's John H. Glenn Research Center.

Astronauts experience microgravity because they are actually falling toward Earth while their horizontal velocity keeps them at the same altitude. Free fall on Earth is like being in orbit with one exception: on Earth whatever you drop will eventually reach the ground.

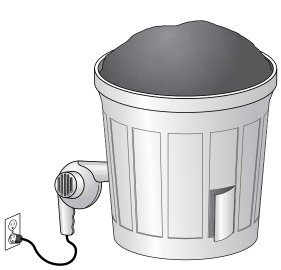
Scientists use special facilities called **drop towers** to perform experiments in areas such as combustion (burning) and fluid flow. Many people are surprised to hear that scientists, engineers, and technicians spend months designing and building experiments just to drop them from a high point. The experiments are not destroyed, however, they land in a special bag or in a deep basin of foam beads.



Many scientific experiments last for hours, days, weeks, or even years. Drop tower experiments only last a few seconds. The information is recorded by video camera and other sensors to be analyzed later. NASA's Glenn Research Center in Cleveland, OH, has two drop towers. The 24.1-meter (79-foot) high tower is designed to lift and drop experiments for 2.2 seconds. A larger, 131-meter (430-foot) drop chamber provides a 5.2-second microgravity environment in a vacuum.

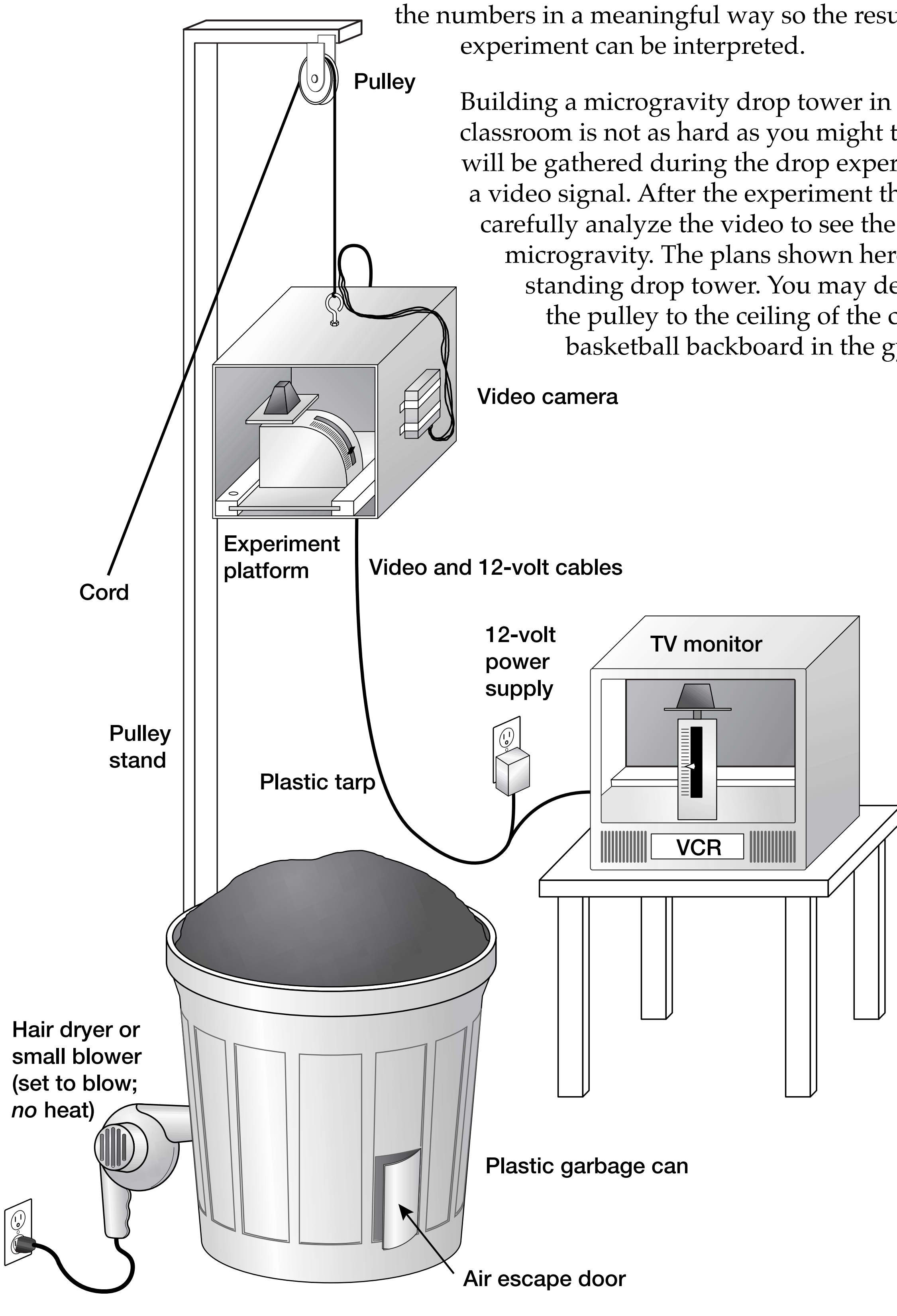
In this activity, you will design and build a drop tower to videotape a series of experiments and investigate microgravity conditions on Earth.

Drop tower experiments are performed to investigate the effects of a microgravity environment on experiments. NASA's microgravity drop towers use a thin *optical fiber* cable, or sometimes a small transmitter, to send video and data to computers. Gathering information in an experiment is called *data acquisition*. A video signal can carry a great deal of information very quickly. The time of the drop experiment is only a few seconds, so the data are recorded and analyzed carefully later. This communication link between the experiment and the computer is similar to the phone lines that you might use. The information is carried on a very thin glass thread. The glass fiber is so thin that it is very flexible. Laser light carries the data through the very pure glass fiber. The laser light can go long distances without becoming weak.



Sensors gather information during the experiment. *Sensors* or *transducers* can take a very small sample of information such as temperature, light strength or voltage and give scientists and technicians the ability to measure very accurately. The data gathered during the experiments are often a long series of numbers representing sensor measurements taken during the experiment. Computer software is used to graph the numbers in a meaningful way so the results of the experiment can be interpreted.

Building a microgravity drop tower in a laboratory-classroom is not as hard as you might think. The data will be gathered during the drop experiment through a video signal. After the experiment the students will carefully analyze the video to see the effects of microgravity. The plans shown here are for a free standing drop tower. You may decide to attach the pulley to the ceiling of the classroom or the basketball backboard in the gym instead.



A Drop in the Bucket

Microgravity Drop Tower Activity
9-12

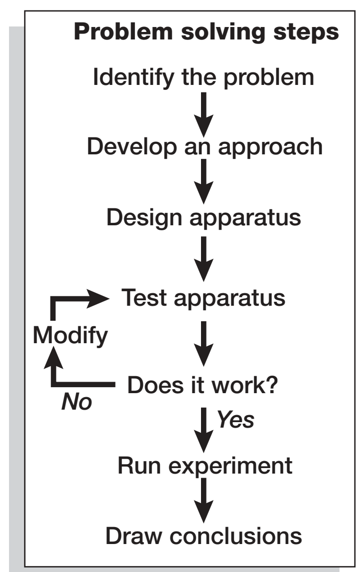
Design Brief

Using the problem solving steps, design and build a drop tower to perform microgravity experiments.

Objectives

In this activity, students will:

- Design and construct a microgravity drop tower system.
- Design and build a pulley stand to raise a test chamber to the highest point in your classroom or design another pulley attachment to go on a ceiling.
- Connect a video camera from a drop chamber to a VCR and monitor.
- Design and build a catch device for the drop chamber.
- Build an experiment apparatus to use in the drop tower.
- Conduct drop experiments to assess effects of microgravity.



Procedure

1. Divide the class into project teams (see Project Team Activity). There will be a separate team for the following tasks:
    - Pulley stand or ceiling mount
    - Test chamber
    - Catch device
2. Prepare project proposals for each part of the drop tower.
3. Have students use the sample proposals in this guide or design their own methods and experiments.
4. Teams must get the approval of the peer review committee and the safety inspector (teacher) before proceeding.
5. Have teams gather the materials needed for the project.
6. Teams should build the drop tower apparatus following the approved plans. If changes are needed, they should be approved by the safety inspector (teacher).
7. Pretest the design. Inspect parts for rough edges. Make sure all the parts work together.

8. Conduct experiments and record observations.

9. Teams should report the results of their experiments to the class.

Note: The Microgravity Drop Tower is a large project that relies on all students working as a team. Many real-world projects are much more complicated than this classroom activity. Project managers often create a timeline to schedule all of the subprojects so they are completed on time. Project management is an important skill for students to master as they get involved with more complex activities.

Extensions

- Design a part of the experiment so that special equipment available in the laboratory-classroom can be used.
- Use CAD software, if available, to make the drawings.
- Use a frame-accurate VCR to determine the drop time. (Standard speed is 30 frames per second.)
- With teacher supervision, design and build a drop tower system that could be placed at the highest point of the school's gym. Remember that a longer drop means greater speed at impact, so a larger, more robust catch system may be needed.
- Create a timeline for the completion of all of the subprojects related to the construction of the microgravity drop tower.
- Create a spreadsheet to chart findings for the entire microgravity drop tower project.
- Design a taller drop tower that could be moved outside of the school. What type of experiments could take place outside without being affected by the wind? Again, an even larger catch device may be needed.
- Design and sketch a different type of catch device that uses packing material to cushion the fall of the test chamber.

Evaluation

Use the team evaluation form in this guide to evaluate the team and individuals in solving the design problem.

Discussion Questions

- Sketch a drop tower that could be safely mounted to the ceiling in the highest part of the school gym.
- How could the design of the test chamber be improved?

- Research the properties of selected materials for impact strength. Which materials are best suited for the drop tower apparatus?
- How would the microgravity drop tower work differently on the Moon?
- Why do scientists use drop towers for research?

Further Research

More information can be found in the following web sites and resources:

2.2-second Drop Tower. *http://microgravity.grc.nasa.gov/facility/_DTOWER.HTM*

NASA Microgravity Research Program Office. *http://microgravity.nasa.gov/*

Discussions of gravity at NASA's Ames Research Center
http://spaceprojects.arc.nasa.gov/Space_Projects/SSBRP/gravity.html
http://spaceprojects.arc.nasa.gov/Space_Projects/SSBRP/microgravity.html

National Center for Microgravity Research. *http://www.ncmr.org/education/k12/overheads.html*

NASA. The Microgravity Demonstrator. EG-1998-12-49-MSFC, 1998; and videotape.

NASA. Microgravity—A Teacher's Guide with Activities in Science, Mathematics, and Technology. EG-1997-08-110-HQ. 1997.
http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity

NASA. Mathematics of Microgravity. EB-1997-02-119-HQ. 1997
http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Mathematics.of.Microgravity

Teacher's Notes

The microgravity drop tower is a high-tech activity that is easy to build and use. Teachers with limited resources can modify the materials and construction suggestions given in the sample proposals to suit available equipment and materials. As with every laboratory-classroom activity, it is important that every student knows and follows the general lab and the specific safety rules related to each piece of equipment. A safety zone should surround the drop tower catch device. Students should follow the procedure outlined in the *A Drop in the Bucket* activity when using the tower.

The tower can be made in many different ways. Schools with mezzanine areas may have a natural location for the tower. A temporary tower could be quickly set up using a stepladder with a pulley attached to its top.

The part of the experiment that can be somewhat confusing is the attachment of the wires to the small video camera. Teachers should be careful to observe the polarity of the 12 volt DC connections. Cameras come with a wiring diagram that should be followed. An AC/DC transformer power supply should be ordered as an option if available. The wires from the power supply can easily be spliced to longer leads for the drop chamber. Care should be taken to leave enough slack in the 12-volt DC wires and the video cable to prevent tangling with the cord used to raise the chamber. To keep the cables from dragging on the experiment package (for example, through a pulley at the top of the stand), coil the cable atop the package so the two fall together. Make sure the cables are a little longer than the distance the package will drop. This way the package will fall away from the cables rather than pulling them.

Small, inexpensive video cameras are widely available and can be found at mail-order and e-commerce sites on the web. Some are priced as low as $100.

Due to the delicate nature of the electronics, it is recommended that the camera be ordered with a protective case. The camera can be attached to the drop chamber using a combination of adhesive hook and loop tape and plastic cable ties. The wires should be attached to the chamber at a different point than the camera connections to provide some stress relief. The cord used to raise the chamber should be 1/8 inch nylon or other strong abrasion resistant material. Hardware items such as bolts, nuts, pulleys, cord, plastic tarp, and plastic trash can, can be purchased locally.

Sample Proposal

PROJECT PROPOSAL TITLE: *Microgravity Drop Tower Stand*

DESIGN BRIEF: *Design and build a stand to lift a microgravity test chamber to the highest possible point in the classroom.*

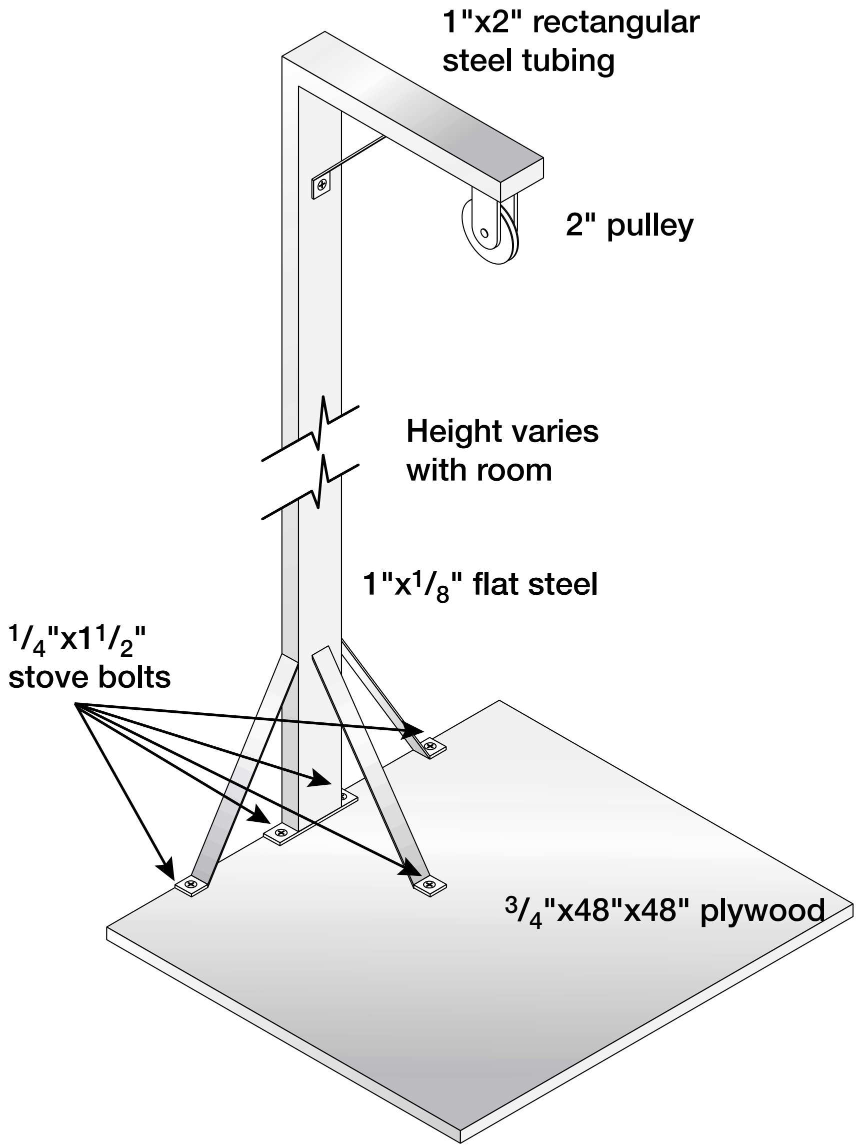
PROJECT TEAM MEMBERS:
- **Principal Investigator**: *Pat Yourhead*
- **Scientists**: *Rob Abank, Don Alduck*
- **Engineers**:
  Mechanical: *Rhonda Bend*
  Aerospace: *Cam Shaft*
  Structural: *Frank Leespeaking*
- **Technician**: *Linda Hand*

PROJECT DESCRIPTION: *This project will provide a mounting point for a pulley that will lift a microgravity drop tower test chamber. The stand will be made of 1" x 2" rectangular steel tubing. Oxyacetylene welding (to be done in a school machine shop) will be used to fasten the parts. The height will be determined by the ceiling height of the classroom. The plywood floor platform should be large enough to hold the trash can catch device. After the test chamber is completed, it will be attached to a cord that runs over the pulley. An optional ceiling mount can be built for attaching to high ceilings.*

MATERIALS LIST:

Item	Description	Quantity	Cost ea.	Total cost
Steel tubing	1" x 2" rectangular	15	1.45	21.75
Pulley	2" diam	1	5.95	5.95
Flat steel x 18"	1" x 1/8"	4	0.95	3.80
Plywood	3/4" x 48"x48"	1	16.00	16.00
Stove bolt/nut	1/4" x 1-1/2"	7	0.12	0.84
TOTAL				**43.84**

Project details
Sketch/drawing



Approval

Peer Review Panel ______________________________

Safety Inspection (Teacher) ______________________________

Sample Proposal

PROJECT PROPOSAL TITLE: *Microgravity Drop Tower Test Chamber*

DESIGN BRIEF: *Design and build a microgravity test chamber*.

PROJECT TEAM MEMBERS:
- Principal Investigator: *Anna Mation*
- Scientists: *Hank O'Hare, Golda Themhills*
- Engineers:
  Mechanical: *Woody Knott*
  Structural: *Bob Sled*
  Aerospace: *Molly Thedog*

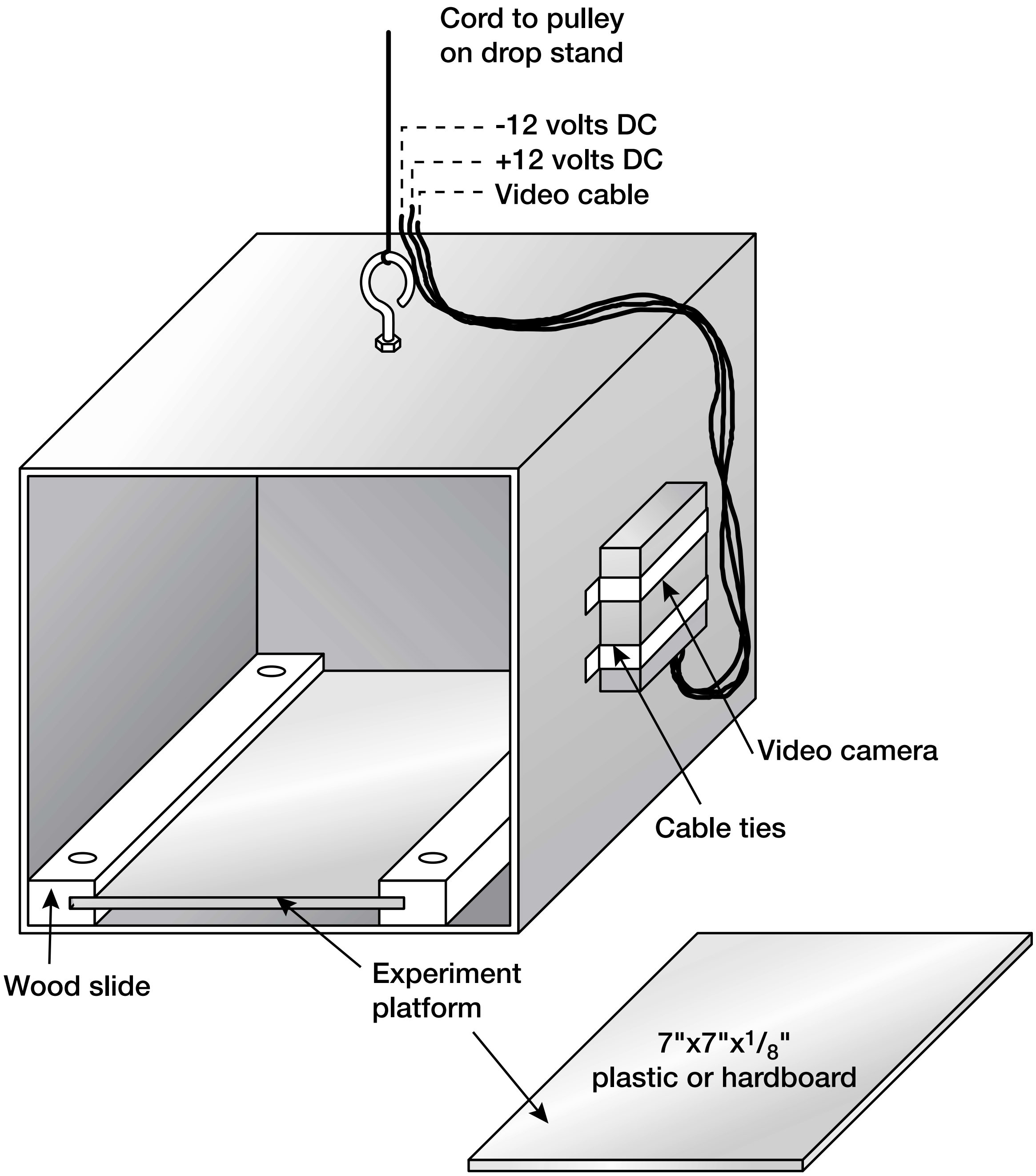
PROJECT DESCRIPTION: Th*e Microgravity Drop Tower Test Chamber is a four-sided box that holds experiments and a video camera. A standard size experiment platform is used so other students can be building experiments while the test chamber is built. The box will be 10″x10″x7-1/2″. If possible, the box will be made of polycarbonate to resist cracking and is formed on a strip heater. A 1/4″ plywood box with reinforced corners would work as well if a strip heater is not available. The material used will be subjected to repeated drops. Every precaution should be taken to avoid rough edges or sharp points that could puncture the inflated plastic tarp on the catch device. The experiment platform should slide easily out of the test chamber so different experiments can be tested quickly yet held securely.*

MATERIALS LIST:

Item	Description	Quantity	Cost ea.	Total cost
Polycarbonate sheet	1/4” x 42” x 7-1/2”	1	2.45	2.45
Polycarbonate sheet	1/8” x 7” x 7”	10	0.35	3.50
Cord	1/8” nylon x 12’	1	0.95	0.95
Video camera	9-12 volt DC chip camera	1	179.00*	179.00
VCR & TV monitor	Borrow from school library	1	0.00	0.00
Wire	22 Ga. std.	50”	2.99	2.99
Wire, coax	RG-6 video coax	50”	10.12	10.12
Wood strips	3/4” x 3/4” x15”	1	0.20	0.20
Bolts, stove	1/2”-20 x 1-1/2”	4	0.10	0.40
Bolts, stove	1/4”-20 x 1”	2	0.10	0.20
Screw eye	1/4”-20 x 1”	2	0.10	0.20
TOTAL				**200.01**

* Units are available for as little as $100.

Project details
Sketch/drawing



Approval

Peer Review Panel ____________________

Safety Inspection (Teacher) ____________________

Sample Proposal

PROJECT PROPOSAL TITLE: *Microgravity Drop Tower Catch Device*

DESIGN BRIEF: *Design and build a catch device to withstand the drop forces and impact of the test chamber without damaging the mounted camera or experiments.*

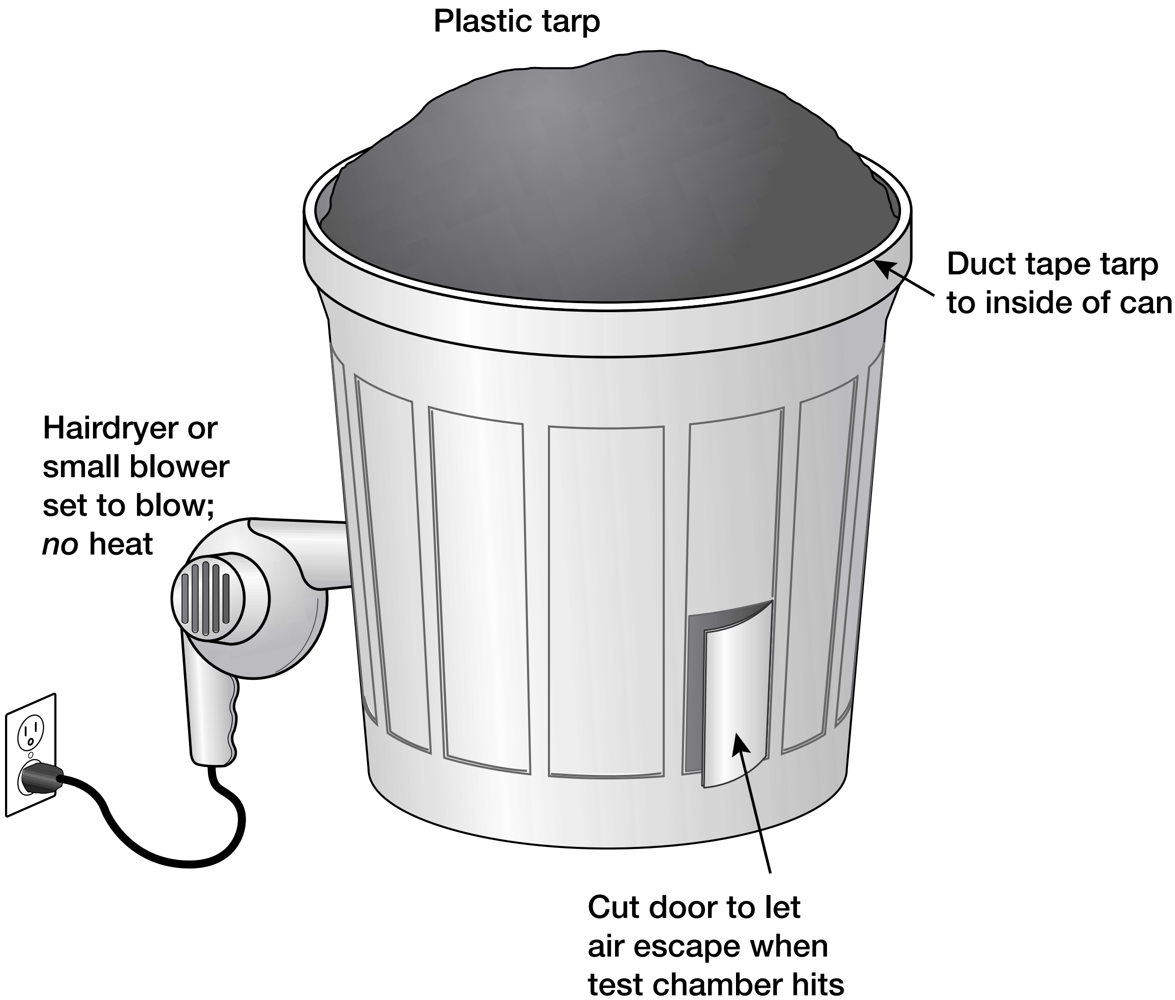
PROJECT TEAM MEMBERS:
- Principal Investigator: *Jan Uary*
- Engineers:
  Mechanical: *Herb Gardner*
  Structural: *Tina Little*
  Industrial: *Sam Playitagain*
- Technicians: *Brad Nail, Barb Morgan*

PROJECT DESCRIPTION: *The Microgravity Drop Tower Catch Device is designed to stop the fall of the Test Chamber without breaking the experiments or the video camera. The device works like an air bag. Low pressure air is blown into a plastic garbage can by a hair dryer or low power blower. The can is covered loosely by a plastic tarp duct taped to the inside of the can. An air escape door is cut into the side of the plastic can to allow the air to rapidly escape on impact. In use, the "air bag" is inflated by the blower/hair dryer. As the Test Chamber hits, the air escape door blows open to release pressure.*

MATERIALS LIST:

Item	Description	Quantity	Cost ea.	Total cost
Garbage can	Plastic	1	12.95	12.95
Duct tape	Wide	1	7.98	7.98
Blower/hair dryer	Possible donation	1	14.98	14.98
Plastic tarp	Reinforced	1	3.95	3.95
TOTAL				**39.86**

Project details
Sketch/drawing



Approval

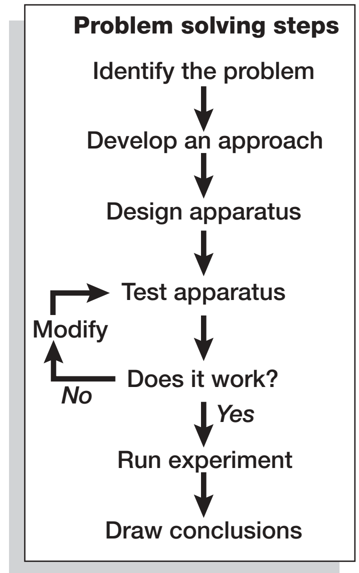
Peer Review Panel ______________________________

Safety Inspection (Teacher) ______________________________

A Drop in the Bucket

Drop Tower Experiments
Grades 9-12

Introduction



Astronauts experience microgravity because they are actually falling toward Earth while their horizontal velocity keeps them at the same altitude. Free fall on Earth is like being in orbit with one exception: on Earth whatever you drop will eventually reach the ground.

Scientists use special facilities called drop towers to perform research experiments in disciplines such as combustion (burning) and fluid flow. Many people are surprised to hear that people spend months designing and building experiments just to drop them from a high point. Drop tower experiments only last a few seconds and end in an air bag or cushion of foam beads. Even though the duration is brief, scientists can collect a lot of short-term data in preparation for space flight.

In this activity, students will develop and test selected experiments. Because the period of microgravity is very brief, students will videotape the effects that occur during testing for slow playback and study. Students will use the drop tower facility from the previous design brief to test their experiments in this activity. See the Microgravity Drop Tower Construction Activity for details.

Design Brief

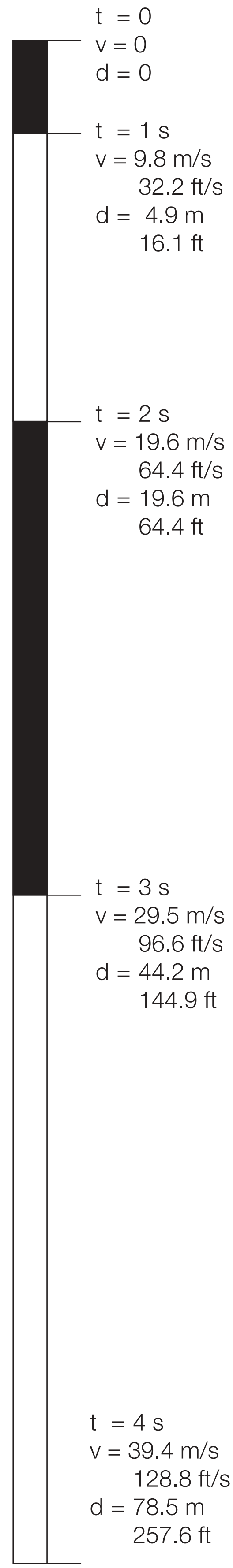
Using the steps in a problem solving strategy, design and build microgravity drop tower experiments that can be tested in a drop tower. Videotape the drop experiments and analyze the results.

Objectives

In this activity, students will:

- Use problem solving steps to design, build, and test experiments that illustrate the effects of a microgravity environment.
- Build an experiment that demonstrates their ability to plan, design, build, and test your ideas.
- Test their experiment by videotaping it during a free fall drop.
- Analyze the results of their tests using the videotape.
- Select and design an experiment that tests a property that gravity affects and that could change when dropped.

Drop towers are used to create a microgravity environment without going into orbit. When you think about the fact that human space flight is very expensive, you can see why experiments are often tried in a ground-based laboratory setting before flight. Drop tower experiments are a less expensive way to test concepts and ideas. By designing experiments that fall for even a short time on Earth, scientists, engineers, and technicians can learn a great deal about how things work in microgravity.



Drop tower experiments are unique in many ways, but one of the biggest differences from most experiments is the fact that they only last a few seconds. The time in free fall is very short. Calculate the length of microgravity time in the drop tower by using the formula in the box.

$$t = \sqrt{\frac{2h}{g}}$$

t = time of microgravity (in seconds)

h = height of drop tower (drop distance in m or ft)

g = acceleration due to gravity

Note:
If h is in feet, $g = 32\ \text{ft/s}^2$.
If h is in meters, $g = 9.8\ \text{m/s}^2$.

An alternative form is:

$$h = \frac{gt^2}{2}$$

Remember that speed increases, too:

$$v = gt$$

Check the time calculation if the VCR counts the frames of video in addition to the seconds, minutes, and hours. (The U.S. National Television Standards Committee (NTSC) standard is 30 frames of video per second. European countries use a different standard. If the VCR provides a frame counter, compare your videotape drop time to your calculation above.) Because the distance increases by the square of the time, getting longer periods of low-g means building even taller drop towers! To get a full second of microgravity means a fall of 4.9 meters (16 feet). To get 2 seconds means 19.5 meters (64 feet); 4 seconds means 78 meters (256 feet). A full minute (neglecting air resistance) would require a drop of almost 17.7 kilometers (11 miles)!

Procedure

1. Divide the class into project teams. See the Project Team Activity.

2. Each team will write a proposal for an experiment and get teacher approval. The teams will present their proposals to the peer review panel. Teams can use the proposals in this activity or devise new experiments.

3. Teams design and produce their experiments.

3. Teams conduct one or more drop tower experiments and record their observations by videotape.

4. Get final approval from the teacher. Check for the following:

   - Loose parts that could fly off on impact
   - Camera operation — viewing area, focus, background
   - VCR recording — tape ready, rewind/fast forward to recording point
   - Catch device inflated
   - Area clear of people
   - 3… 2… 1… Drop warning

5. Each team presents their results in a formal team presentation to the class.

Evaluation

- Each student writes a short paragraph describing what they think will happen to their experiment when it is dropped.

Discussion

1. How did the results of the drop test compare to the hypothesis?
2. Explain what happened in the experiment using scientific principles.
3. How long would the drop time be if the tower was twice as high?
4. How high would the tower have to be to double the drop time? Explain.
5. How would a drop of water look in microgravity? Explain.

Note: This information could be incorporated in a team or individual portfolio. Use the team evaluation form to evaluate team efforts to solve the design problem.

Extensions

- Design a safe way to drop a candle in the microgravity drop tower. Get teacher approval for the design and try it. What was the shape of the flame during free fall?
- Research the "Vomit Comet," or NASA microgravity research airplane. What types of experiments have taken place aboard the KC-135?
- Research the filming of the movie *Apollo 13*. How did the set designers make the floating astronaut scenes look so real?

- Design and build an experiment that could illustrate how fluids act in microgravity.

Teacher Notes

Students can express their creativity and use their imagination in designing an experiment in this activity. Brainstorming will reveal a long list of possible ideas, but some parameters should be placed on the actual experiments. Using live animals *should be excluded* from study. Experiments using liquids or involving open flames should be designed to be safe and teacher-tested before class.

An alternative form of these experiments is to attach a home camcorder to a board with the experiment package mounted in front of the lens (use the macro setting and check the focus). Have a student tape the experiment package while riding a swing. Observe the differences at the top of the swing's arc as compared to the bottom.

Further Research

More information can be found at the following web sites and in other resources:

KC-135 (Vomit Comet): *http://microgravity.grc.nasa.gov/kjenks/kc-135.htm*

2.2-second Drop Tower: *http://microgravity.grc.nasa.gov/facility/_DTOWER.HTM*

NASA Microgravity Research ProgramOffice: *http://microgravity.nasa.gov*

Discussions of gravity at NASA's Ames Research Center
http://spaceprojects.arc.nasa.gov/Space_Projects/SSBRP/gravity.html
http://spaceprojects.arc.nasa.gov/Space_Projects/SSBRP/microgravity.html

NASA. The Microgravity Demonstrator. EG-1998-12-49-MSFC, 1998.
http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity.Demonstrator

NASA. Microgravity—A Teacher's Guide with Activities in Science, Mathematics, and Technology. EG-1997-08-110-HQ, 1997.
http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity

Sample Proposal

PROJECT PROPOSAL TITLE: *Microgravity Drop Tower Experiment*

DESIGN BRIEF: *Design and build an experiment for the microgravity drop tower. Build the experiment to withstand the drop forces and impact of hitting a catch device without damage. Design the experiment to be within the view of the test chamber camera.*

PROJECT TEAM MEMBERS

- Principal Investigator: *June July*
- Engineers:
  Mechanical: *August Summer*
  Structural*May Spring*
  Industrial: *April Flowers*
- Technicians: *Bob Around, Candy Sweetooth*

PROJECT DESCRIPTION: *The drop tower experiments show how things work in a microgravity environment. A seven inch square piece of 1/8″ plastic or hardboard will be used as a platform. Safety will be the first consideration in each experiment. (See sample experiments.)*

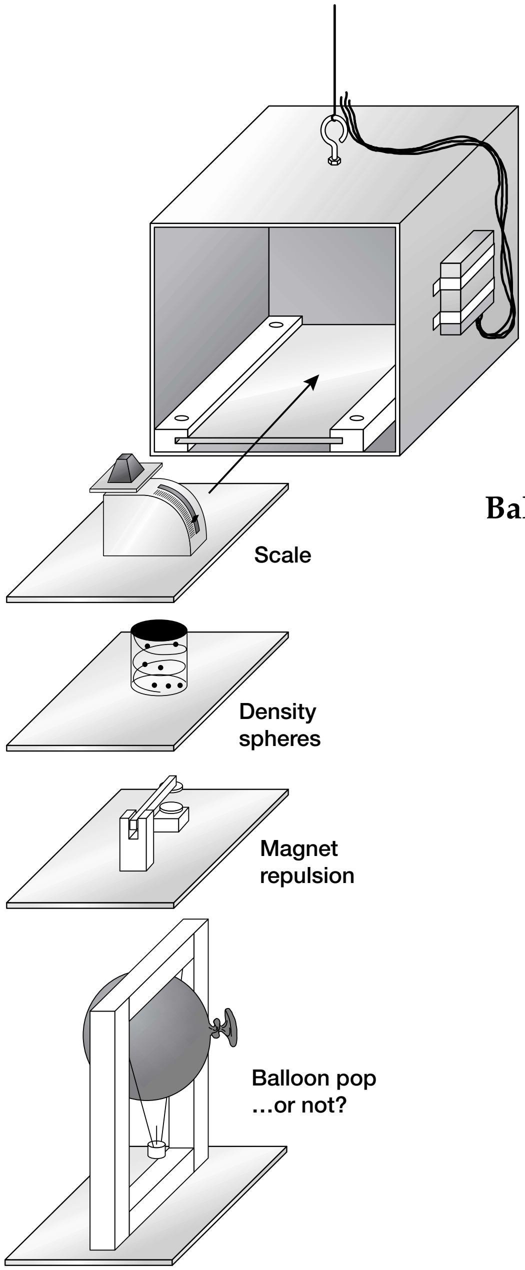
MATERIALS LIST:

Item	Description	Quantity	Cost ea.	Total cost
Plastic platform	Acrylic plastic, 7” square	1	.35	.35
Scale	Postage or kitchen	1	7.98	7.98
Tape	Two-sided	1	1.49	1.49
Weight	1 ounce	1	3.95	3.95
TOTAL				**13.77**

Project details
Sketch/drawing

SAMPLE EXPERIMENTS

Sample Proposal



Scale: Attach a small postal scale to the experiment platform. Tape a weight to the pan of the scale. Place a small piece of foam under the pan to dampen movement.

Density Spheres: Use a small toy containing liquids of different density. Observe the shape of the spheres in a microgravity environment.

Magnet Repulsion: Design a movable lever with a magnet glued to its end. Have another magnet mounted beneath with like poles facing each other to repel.

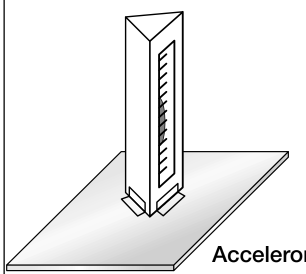
Balloon Pop... or not? Tape a partially inflated balloon to a support structure (most easily made of wood). Use rubber bands to suspend a pin attached to a weight under the balloon. The rubber bands must be weighted so they are stretched to hold the pin away from the balloon. This allows the band to return to its neutral position when the package is dropped. Try to predict what will happen when the experiment is dropped. Remember to think about the viewing area of the video camera. Repeat the experiment using string instead of rubber bands. Compare the results when using strings and rubber bands.

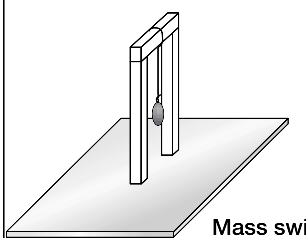
Approval
Peer Review Panel ______________________

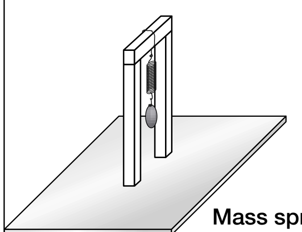
Safety Inspection (Teacher) ______________________

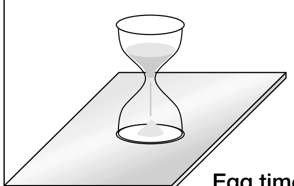
Project details
Sketch/drawing

Sample Proposal


Accelerometer


Mass swing


Mass spring variations


Egg timer

Accelerometer: Build an accelerometer as described in NASA's *Microgravity — Teacher's Guide with Activities in Science, Mathematics, and Technology*.

Mass Swing: Use a fishing sinker on a string, rubber band, or a spring to see the effects of a microgravity environment. Think of your own ideas for other ways to hang the weight.

Mass Spring Variations: What happens to a mass pulling on a spring when put into a microgravity environment? Try different masses and springs.

Egg Timer: Fasten a 3-minute egg timer to the experiment platform. Observe the movement of the sand during free fall. You might need to build a stand to place the timer in the field of view of the video camera.

Your Design Solution: Make a three-dimensional view sketch or a CAD (Computer Aided Design) drawing of a microgravity drop tower experiment. Simulate the experiment using physics simulation software to design and animate experiments on a computer. Run the experiment a frame at a time to analyze the results. Write a proposal to go along with your experiment.

Approval
Peer Review Panel ____________________

Safety Inspection (Teacher) ____________________

Project details
Sketch/drawing

Sample Proposal

Design Hints:

- Keep all experiment platforms the same size.
- Place a piece of paper on the side of the test chamber to mark the camera viewing area. Use grid paper for easy measurement. Account for parallax.
- Have all experiments approved by your teacher for safety.

Approval
Peer Review Panel ______________________

Safety Inspection (Teacher) ______________________

Appendix

References

Print

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McKay, David E. and Bruce G. Smith. Space Science Projects for Young Scientists. New York: Franklin Watts, 1992.

Mullane, R. Mike. Do Your Ears Pop in Space?: And 500 Other Surprising Questions About Space Travel. New York: John Wiley & Sons, 1997.

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NASA. Mathematics of Microgravity. EB-1997-02-119-HQ, 1997. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Mathematics.of.Microgravity*

Smolders, Peter. Living in Space: A Handbook for Space Travellers. Blue Ridge Summit, PA: Aero, 1986.

Welty, Kenneth. "Desktop farming." *Technology and Children*, **3**:1, pp. 3-6, 1998.

Videos

NASA. Liftoff to Learning Series Videotape: *Microgravity*. EV-1997-07-008-HQ, 1997. *http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity.Video.Resource.Guide*

Electronic Resources

General Microgravity Information

Microgravity Research Program, *http://microgravity.nasa.gov*
Spacelink, *http://spacelink.nasa.gov*
Glenn Research Center, Educational Programs, *http://www.grc.nasa.gov/WWW/OEP/*
Ames Research Center
gravity, *http://spaceprojects.arc.nasa.gov/Space_Projects/SSBRP/gravity.html*
microgravity, *http://spaceprojects.arc.nasa.gov/Space_Projects/SSBRP/microgravity.html*
Microgravity Newsletter, *http://mgnews.msfc.nasa.gov/site/*
National Center for Microgravity Research, *http://www.ncmr.org*

Bubble Technology

American Institute of Physics, *http://www.aip.org/physnews/graphics/html/soapfilm.htm*
Ohio State University, *http://www.physics.ohio-state.edu/~maarten/work/soapflow/soapintro/basicsoap.html*

Crystal Growth and Glovebox Experiments

Glovebox program and experiments, *http://microgravity.nasa.gov/Glov.html*

Biotechnology program, *http://microgravity.nasa.gov/Biot.html*
Materials science research program, *http://microgravity.nasa.gov/MS.html*

Drop Towers and Drop Tower Experiments
2.2-second Drop Tower: *http://microgravity.grc.nasa.gov/facility/_DTOWER.HTM*
Microgravity Man, *http://microgravity.grc.nasa.gov/ugman/*
KC-135 (Vomit Comet), *http://microgravity.grc.nasa.gov/kjenks/kc-135.htm*

Glossary

alloys: metals made from the combining of other metals.
buoyancy-driven convection: when a fluid starts moving because of a density difference.
buoyancy: an upward force exerted on a body by a surrounding fluid. If the body weighs more than the displaced fluid (*i.e.*, has greater density), it is negatively buoyant and sinks. If it weighs less (lower density), it is positively buoyant and rises. If the two are equal (equal densities), then the body is neutrally buoyant and neither sinks nor rises.
design brief: a short, concise description of what a project is to achieve and how it will be done.
drop tower: a special facility in which experiments are dropped in order to place the experiment in free fall.
fluid: matter whose shape is determined by the shape of its container in 1 g; a liquid or gas.
free fall: condition in which a body drops without being slowed by an outside force such as atmospheric drag.
geotropism: plant response to gravity in which roots grow downward and stems grow up.
glovebox: an enclosed module or box used to conduct experiments through ports usually fitted with gloves to protect the operator or experiment.
gravitropism: plant response to gravity in which roots grow downward and stems grow up.
gravity: a fundamental force or attraction between any two or more masses.
hydroponics: growing plants in water or other solution and without soil.
hygroscopic liquid: a liquid with water-holding properties.
microgravity: conditions in which the apparent gravitational pull is significantly less than that at sea level on Earth.
micron: millionth (10^{-6}) of a meter.
orbit: state of continuous free motion around a planet or star.
phototropism: plant response to light, in which plants grow toward light.
principal investigator: a scientist who is in charge of an investigation (which may include several experiments).
sedimentation: settling of materials of different densities due to gravity.
surfactant: a substance that creates a surface over water without dissolving (*surf*ace *act*ive *a*ge*nt*).
surface tension: attraction of molecules in a liquid to one another.
vortex: swirling pattern in soap film or other fluid.
work envelope: the maximum distance each part of a robot arm can move.

Microgravity: Earth and Space
K-12 Guide for Educators and Students in Technology, Science, and Mathematics Education
Teacher Reply Card

To help America achieve its goals in Educational Excellence, it is NASA's mission to develop supplementary instructional materials and curricula in science, mathematics, and technology. NASA seeks to involve the educational community in the development and improvement of these materials. Your evaluation and suggestions are vital to continually improving NASA educational materials.

Please take a moment to respond to this questionnaire. Please respond by mail. Future versions will allow you to respond through the Internet at

http://ednet.gsfc.nasa.gov/edcats/teacher_guide

The page will instruct you on how to enter your responses.

1. With what grades did you use the teacher's guide?

Number of teacher/faculty?

____ K-4 ____ Community college
____ 5-8 ____ College/university-undergraduate
____ 9-12 ____ College/university-graduate

Number of students?

____ K-4 ____ Community college
____ 5-8 ____ College/university-undergraduate
____ 9-12 ____ College/university-graduate

Number of others?

____ Administrators/staff ____ Professional groups
____ Parents ____ Civic groups
____ General public ____ Other:

2. What is your home or school 5- or 9-digit Zip code? _ _ _ _ _ - _ _ _ _

3. How was the quality of this teacher's guide?

❏ Excellent ❏ Good ❏ Average ❏ Poor ❏ Very poor

Fold along line and tape closed.

4. How did you use this teacher's guide?

❏ Background information
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❏ Group discussions
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❏ Lecture
❏ Team activities
❏ Critical thinking tasks
❏ Demonstration
❏ Hands-on activities
❏ Interdisciplinary activity
❏ Science and mathematics standards integration
❏ Other. Please specify: ____________________

5. Where did you learn about this teacher's guide?

❏ NASA Education Resource Center
❏ NASA Central Operation of Resources for Educators (CORE)
❏ Institution/school system
❏ Fellow educator
❏ Workshop/conference
❏ Other. Please specify: ____________________

6. What features of this teacher's guide did you find particularly helpful?

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7. How can we make this teacher's guide more effective for you?

____
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8. Additional comments:

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