GENESIS
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Education

Genesis Sample Return: Catching a Piece of the Sun

Science Mini-Module Overview

Target Grade Level: **Middle School, 6 – 8**

Target Content Areas: **Science, Mathematics, Language Arts**

Estimated Time: **Entire Mini-Module: 1 – 2 weeks**
Stand-alone Activities: 1 – 2 days

Objectives: The learning activities in this mini-module focus on the return of the Genesis solar wind samples, helping students to understand: a) why sample return is necessary for this mission, b) what will happen during the recovery process, and c) how mission scientists and engineers dealt with the special challenges faced in a mission to collect and return solar samples.

Learning Activities: In the Introduction section, students read and respond to texts using graphic organizers. The Investigation section features several hands-on activities in which students: a) learn about Genesis' recovery process and experiment with parachute designs, b) design and implement a model of the mid-air capture, and c) present what they have learned through a PowerPoint project.

Background Information: How was the Solar System formed? Why does life exist on Earth but not on planets like Venus? These are two of the questions that scientists will try to answer with help from the Genesis mission, launched by the National Aeronautics and Space Administration (NASA) on August 8, 2001.

The Sun contains over 99% of the matter that makes up our Solar System. Scientists believe that elemental abundances of the ***solar wind*** *(the components of the Sun that are spewed into the void of outer space)* resemble the solar nebula—a cloud of interstellar dust, gas, and ice from which the various bodies in our Solar System originated some 4.6 billion years ago. Scientists can't travel back in time to see how the Solar System formed, nor is it possible for humans to travel to the Sun and endure the intense heat in an effort to analyze the Sun's chemical composition. In order to better understand the connection between the solar wind and the evolution of our Solar System, NASA's Genesis mission set out to capture particles of the solar wind and bring them back to Earth for study.

After 2½ years of collecting elements during its solar bath, the Genesis payload will return to eagerly awaiting scientists on Earth. To protect the enclosed solar wind particles from contamination, a spectacular mid-air recovery of the Sample Return Capsule (SRC) is scheduled for the morning of September 8, 2004 above the Utah Test and Training Range.

Genesis Sample Return: Catching a Piece of the Sun provides a real-world context for learning technological design and physical science concepts. Both sections, ***Introduction*** and ***Investigation***, in this mini-module have been aligned to middle school standards; however, the activities can be adapted to the elementary and high school classroom as well. To enable educators to tap into this teachable moment in September and kick off the school year with the excitement of this NASA mission, the four activities in this mini-module have a flexible design. Each activity can be used as a one- or two-day stand-alone lesson, with the exception of the culminating PowerPoint presentation project. When presented in a sequence, the mini-module offers one or more weeks of hands-on standards-aligned lessons. For teachers who want to extend the mission-related learning further, this mini-module provides links to suggested activities presented in other Genesis modules. For more information about the Genesis modules, visit http://www.genesismission.org/educate/scimodule/moduleoverview.html.

Introduction: Why Sample Return?

Description of Activity	Teacher Materials	Student Materials	Standards Addressed
Through reading and brainstorming activities, students learn about the Genesis mission, identify challenges faced in a solar wind sample return mission, engage in problem-solving processes, and conduct a risk analysis of possible solutions.	**Why Sample Return?** • Teacher Guide (pages 4–11)	**About NASA's Genesis Mission** • Student Text (pages 12–16) **Genesis' Dramatic Recovery** • Student Text (pages 17–19)	**Science Grades 5-8** • Science and Technology • Science in Personal and Social Perspectives

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Investigation: Capture a Moving Target

Description of Activities	Teacher Materials	Student Materials	Standards Addressed
Parachute Physics: A Lesson that Drags – Part 1 Students gain an understanding about the physics concepts related to parachutes, such as mass, air resistance, friction, drag, acceleration, speed, velocity, and terminal velocity.	**Capture a Moving Target** • Teacher Guide (page 20) **Parachute Physics: A Lesson that Drags – Part 1** • Teacher Guide (pages 21–27)	**Parachute Physics: A Lesson that Drags – Part 1** • Student Activity (pages 28–34)	**Science Grades 5-8** • Science and Technology • Physical Science **Mathematics 6-8** • Number and Operations • Measurement
Model of Genesis' Mid-air Capture – Part 2 Students use common household items to construct a model of the Genesis' sample recovery process. Then they have an opportunity to reflect on the benefits and limitations of their physical models.	**Model of Genesis' Mid- air Capture – Part 2** • Teacher Guide (pages 35–39)	**Model of Genesis' Mid- air Capture – Part 2** • Student Activity (pages 40–44)	**Science Grades 5-8** • Science and Technology • Physical Science • Science in Personal and Social Perspectives **Mathematics 6-8** • Measurement
The Physics of Genesis' Sample Recovery – Part 3 Students apply their understanding of physics concepts to the Genesis' sample return and recovery process by creating a PowerPoint presentation.	**The Physics of Genesis' Sample Recovery – Part 3** • Teacher Guide (pages 45–47) • Scoring Rubric (pages 49-50)	**The Physics of Genesis' Sample Recovery – Part 3** • Student Activity (page 48) • Scoring Rubric (pages 49–50) • Presentation Graphics	**Science Grades 5-8** • Science and Technology • Physical Science **Language Arts 6-8** • Uses listening and speaking strategies for different purposes

Additional Extension Activities

Description of Activities	Teacher Materials	Student Materials	Standards Addressed
From the Genesis Science Module ***Heat: An Agent of Change*** Through the text "Heat Shields as Insulators," students are introduced to the concept of thermal protection from frictional heating during re-entry into Earth's atmosphere. In the activity "Protecting the Genesis Spacecraft from Heat," students evaluate the effectiveness of insulation materials in the design of the spacecraft. Students also build a heat transfer model from which they draw conclusions through observation and experimentation.	**Protecting the Genesis Spacecraft from Heat** • Teacher Guide	**Heat Shields as Insulators** • Student Text **Protecting the Genesis Spacecraft from Heat** • Student Activity	**Science Grades 5-8** • Science as Inquiry • Physical Science • Science and Technology
From the Genesis Science Module ***Dynamic Design: Launch and Propulsion*** In the activity "Weather or Not," students determine suitable weather conditions for launching a rocket. This activity could be adapted to have students develop weather criteria for the mid-air capture on September 8th.	**Investigating Water Rockets (on page 7)** • Teacher Guide	**Weather or Not** • Student Activity	**Science Grades 5-8** • Science and Technology • Science in Personal and Social Perspectives
From the Genesis Science Module ***Dynamic Design: A Collection Process*** In the event that the mid-air capture does not go as planned, the Sample Return Capsule has been designed to survive a land impact of 50 g's. In "All Cracked Up," students will use crackers to model the wafers and design a method for protecting the wafers from breaking up during impact.	**All Cracked Up** • Teacher Guide	**All Cracked Up** • Student Activity	**Science Grades 5-8** • Science as Inquiry • Science and Technology • Physical Science

This education mini-module, *Genesis Sample Return: Catching a Piece of the Sun*, was developed by educators at Mid-continent Research for Education and Learning in collaboration with the Jet Propulsion Laboratory and Lockheed Martin Astronautics.

Genesis Sample Return: Catching a Piece of the Sun

Introduction: Why Sample Return?

TEACHER GUIDE

Review the **Background Information** section included in the Mini-module **Overview**.

SUMMARY OF ACTIVITIES

The activities in this mini-module will focus on the return of the Genesis solar wind samples, helping students to understand why sample return is necessary for this mission, what will happen during the recovery process, and catch a glimpse of what will happen after the samples are returned to Earth. Furthermore, students will see how mission scientists and engineers dealt with the special challenges faced in a mission to collect and return solar samples.

In this section, *Why Sample Return?,* students will learn about the Genesis mission while engaging in problem-solving processes, similar to those employed by Genesis scientists, as they brainstorm all potential problems encountered by a sample return mission, and weigh the risks and benefits of potential solutions before making decisions about how to proceed. Then, after making a decision, the technology design and testing processes begin, which could, in turn, lead them back to the solution-planning phase to search for a better alternative.

Cross-Curricular Connections

The instructional activities featured in *Science as Fiction* bring the science of Genesis to the language arts classroom. Ray Bradbury's short story *The Golden Apples of the Sun*, in which a rocket is on a mission to scoop up a piece of the Sun and return it home for study, offers strong parallels to the Genesis mission.
To access *Science as Fiction,* go to: http://genesismission.jpl.nasa.gov/educate/scimodule/DestinationL1/DL1_PDFs/6_language%20arts/TG-ScienceAsFiction.pdf

MATERIALS

For teacher:

- Copies of student texts "About NASA's Genesis Mission" and "Genesis' Dramatic Recovery"
- Raw egg or cracker and plastic tarp (optional)

For each student:

- Copies of student texts "About NASA's Genesis Mission" and "Genesis' Dramatic Recovery"

PROCEDURE

1. Prior to having students read the Genesis background information, it may be helpful to provide a context and visual to help them envision how scientists might recover solar wind samples safely. One possible strategy would be to begin class by giving some general background information about the Genesis mission. Then, using a plastic tarp to protect the floor, the teacher could take something fragile, such as an egg, and heave it downward with such force that it smashes. (Alternative: For less mess, use a cracker – graham crackers that are already perforated may be a good choice.) After this attention-getting smash, the teacher could launch into a series of brainstorming questions to get students to think about how to protect matter. A sample of a teacher-led discussion can be found in the **bold** text below, with possible student responses in *italics*.

Today we will be reading about NASA's Genesis mission, in which a robotic spacecraft was sent over 1,600,000 kilometers or one million miles away from Earth toward the Sun in order to collect pure samples of solar wind. Scientists believe these solar samples hold the key to unlocking the mystery of how our Solar System formed. You can imagine how eager they are to get these samples back on Earth to study. So after 2½ years of collecting solar wind, the samples will travel great distances to return to Earth. Imagine the problems the samples could encounter during their return trip. How could they be protected during the million-mile journey homeward? *(Students may suggest some type of sealed, insulated, or padded container that is safely secured within a spacecraft).* **What about when the solar samples travel through Earth's atmosphere at a speed of nearly 40,000 kilometers per hour (25,000 miles per hour)? (Students may suggest that somehow the particles would need to be secured in place so that they don't move around, like a seatbelt secures passengers in a plane.) Once the Sample Return Capsule enters Earth's atmosphere, it will be influenced by the force of gravity, which causes objects to accelerate at a rate of 9.8 meters per second for each second of its free-fall (MASH egg/cracker on the floor). And this (pointing to smashed egg/cracker) is what will happen if the mission team members don't figure out a way to control the accelerating Sample Return Capsule.**

- **How can we counter the effects of gravity to slow the Sample Return Capsule***? (Possible student responses: Put wings or a parachute on the capsule)*
- **How will it work?** *(Possible student responses: Remote control)*
- **Will that be enough?** *(Possible student responses: Something to cushion the landing)*
- **Something you will want to consider is that the Genesis scientists are very worried about contaminants from Earth mixing with these pure solar wind samples. How can the capsule come back to Earth without being exposed to contaminants?** *(Possible student responses: air-tight seal, avoid any impacts that could break the seal)*
- **How will the mission team know when and where the samples arrived?** *(Possible student responses: Carefully planning in advance, computer programming, radar)*
- **How can these particles be recovered safely and without damaging the pure samples inside?** *(Possible student responses: Use a net or an inflatable landing pad to catch the container of samples; use contamination-control techniques like a surgeon)*

TEACHER TIP
THINK-PAIR-SHARE

Set a clear time frame for each stage of this strategy. Using a kitchen timer may be helpful.

1. Students are presented with an open-ended question.
2. **Think -** Allow time for students to tackle the question individually. Ask them to write their reflections.
3. **Pair** – Students share their individual thoughts with a partner. They then combine their insights into one common response in writing.
4. **Share** – Each pair reports their insights, solutions, etc. to the rest of the class.

Lymna, F. (1981). "The responsive classroom discussion." In Anderson, A. S. (Ed.), Mainstreaming Digest, College Park, MD: University of Maryland College of Education.

Explain to students that mission team members have to brainstorm all potential problems and weigh the risks and benefits of potential solutions before making decisions about how to proceed in the mission. Then, after making a decision, the technology design and testing processes begin, which could, in turn, lead them back to the solution-planning phase to search for a better alternative.

2. Distribute a copy of the student text "About NASA's Genesis Mission." Explain to students that they will learn about some of the challenges the Genesis team members faced in designing and planning the mission. Then, students will brainstorm possible solutions to solve mission-related problems. Finally, students will learn what the Genesis team decided to do to recover particles of solar wind on Earth.

3. The text is intended to be read in sections followed by a few reflection questions. Students should complete questions either individually, with a partner, or as a group. To increase the level of student participation and quality of reflections, teachers may want to consider using a strategy like "Think-Pair-Share" (refer to "Teacher Tip" box) for the open-ended reflection questions. Younger students may benefit from a teacher-guided reading and discussion. An "Answer Key" with possible student responses can be found in the Appendices section of this teacher guide.

4. Encourage students to be creative in coming up with solutions for recovering the Genesis Sample Return Capsule. Although the spacecraft is robotic, people are involved in the recovery process in order to operate the technical equipment. If students seem to need help brainstorming, get them to think about stunts they've seen in movies in which a moving target is captured.

ALTERNATIVE STRATEGY

If faced with time constraints, an alternative to having students read the two texts, "About Genesis" and "Genesis' Dramatic Recovery," could be to download the Mission Fact Sheet and assign it as reading homework.

5. Once students have completed their final problem-solution graphic, have them share their final recommendations with the rest of the class.

6. After students share their recommendations, pass out the "Genesis' Dramatic Recovery" student text and have students read about the recovery process NASA has planned for the Sample Return Capsule.

7. As with the first student text, "Genesis' Dramatic Recovery" is intended to be read in sections followed by a few reflection questions. Students should complete questions either individually, as a group, or using a strategy like "Think-Pair-Share" before moving on to the next section of text. Teachers of younger students may determine the best approach would be to read the text aloud and discuss the reflection questions together as a class. An "Answer Key" with possible student responses can be found in the Appendices section of this teacher guide.

TEACHER GUIDE—APPENDICES FOR INTRODUCTION SECTION

APPENDIX A: STANDARDS

NATIONAL SCIENCE EDUCATION STANDARDS ADDRESSED

(Source: *National Science Education Standards*)

(View a full text of the National Science Education Standards)

Science and Technology **— Grades 5-8**

Abilities of Technological Design

- Identify appropriate problems for technological design.
- Design a solution or product.

Understandings about Science and Technology

- Scientific inquiry and technological design have similarities and differences.
- Science and technology are reciprocal.
- Perfectly designed solutions do not exist.

Science in Personal and Social Perspectives **— Grades 5-8**

Risks and Benefits

- Individuals can use a systematic approach to thinking critically about risks and benefits.

APPENDIX B: TEACHER RESOURCES

http://genesismission.jpl.nasa.gov/educate/Field_Trip/genesis/cd_index.html
Take a look inside a Class 10 clean room at NASA's Johnson Space Center with the *Cleanroom Interactive Field Trip.*

http://genesismission.jpl.nasa.gov/educate/kitchen/resource/factsheets/index.html
Access a series of Genesis mission fact sheets.

http://genesismission.jpl.nasa.gov/educate/scimodule/CollProcess/index.html
The Genesis module *Dynamic Design: A Collection Process* contains texts and activities that explore the relationship between basic design concepts and the process of collecting solar wind. Also includes a student text as well as scripted PowerPoint presentation about earlier solar wind collection during the Apollo missions.

http://genesismission.jpl.nasa.gov/educate/scimodule/Destination_L1.html
Extend the excitement of Genesis across the curriculum with the *Destination L1: A Thematic Travel Unit*. The million-mile journey that the Genesis spacecraft took to Lagrange point 1 (L1) provides the context for this interdisciplinary module.

http://genesismission.jpl.nasa.gov/product/lanl_video_product.html
Testing to Assure Mission Success: A Look Inside Los Alamos National Laboratory, a 10-minute video available online, highlights the various instrumentation testing conducted by Genesis mission planners. Includes a teacher guide and student activity.

APPENDIX C: ANSWER KEYS

Possible Responses to Reflection Questions in "About Genesis"

1. **Genesis mission engineers designed special equipment to deal with the challenges of collecting solar wind. Using the graphic below, describe or draw the solution they designed and used during the collection process. Then list what you think are drawbacks and benefits of this solution.**

Solution

- *The spacecraft is run by robots.*
- *Solar wind will be gathered in special collectors made of small tiles of diamond, gold, sapphire, and silicon.*
- *These collectors were made under nearly contamination-free conditions.*

Drawbacks or Risks

- *Seems like very expensive materials.*
- *If something as small as solar wind can get inside the tiles, then wouldn't they shatter if they collide with something larger like a meteor?*

Benefits

- *No risks to humans.*
- *Since materials allow solar wind particles to embed, there are less worries about losing these small samples.*
- *"Ultra-clean" technology will allow more accurate data to be collected.*

2. **What additional protection did the Genesis engineers design for the spacecraft launch and re-entry?**
   - *A sealed container to protect the science payload.*
   - *Instrumentation tests at Los Alamos National Laboratory:*
     - *Vibration tests*
     - *Temperature variations*
     - *Impact tests from potential micrometeoroids*

3. **Lagrange point L1, where the gravitational forces of the Sun and Earth are balanced, is only 1.6 million kilometers (one million miles) away. Since Earth and the Sun are approximately 150 million kilometers (93 million miles) apart, why isn't this balance point halfway between them?**
   The Sun is more massive than Earth and therefore has a stronger gravitational force.

4. **Clearly, the Genesis team had to consider the problems they'd encounter in trying to retrieve the solar samples. Use the graphic below to analyze the problems, pose possible solutions, and weigh the risks and benefits associated with the solutions. Then write a statement recommending to NASA's Genesis mission how best to recover the Sample Return Capsule.**

Possible Responses to Reflection Questions in "About Genesis"–Continued

Problems

- *People or structures could be hurt if the Sample Return Capsule (SRC) landed on them.*
- *The solar wind particles could be lost or destroyed.*
- *Contaminants from Earth could get into the sample.*

Solutions

- *Use a big net to catch SRC.*
- *SRC lands in the ocean.*
- *Target return to an uninhabited location.*
- *Use parachutes to slow the SRC.*
- *Catch it before it hits the ground.*

Risks / Costs

- *The force of landing on a net could still damage samples inside the capsule.*
- *Water could damage, contaminate, or cause the loss of the samples.*
- *Coordinating a targeted return location or mid-air capture would be a challenge, involving a lot of resources.*
- *Traveling at such a high velocity, the parachute could rip off.*

Benefits

- *Net or water landing would be a low-cost solution, but samples could still be damaged or contaminated.*
- *Returning to a specific uninhabited location would minimize risks to people or structures.*
- *Parachute technology already exists to get design ideas.*
- *A mid-air catch would protect solar wind and people and/or buildings on the ground.*

Final Recommendation

Put parachutes on the SRC to slow it down. Coordinate the return to a large uninhabited area. Use a large crane-type of equipment to catch the SRC. A speed boat with a net/hook device in mid-air over the ocean. A plane with a net/hook device.

Possible Responses to Reflection Questions in "Genesis' Dramatic Recovery"

1. **Why do you think the Genesis mission planners felt it necessary to deploy a series of parachutes – the small round drogue chute and then the larger rectangular parafoil? Why didn't they just use one main parafoil?**
   - *As a back-up, in case one didn't work.*
   - *Needed several to slow it down.*
   - *Large rectangle may not work if it's decelerating too quickly.*
   - *Parafoil moves down and side-to-side in a spiraling fashion. If it is deployed too early, it might soar sideways too much and go off course.*

2. **Having a back-up helicopter was one way that the Genesis mission team reduced the risks involved in the recovery.**
   a) **What other risks or uncontrollable variables can you think of that may pose a problem for a successful retrieval?**
      - *Bad weather (e.g., wind, rain, etc.). The spacecraft and Sample Return Capsule do not separate properly, throwing the return off course.*

   b) **What back-up plan could you propose to deal with the potential risk you identified in "a" above?**
      - *Consult weather experts. Do not have return occur during high winds and precipitation. Put some sort of tracking device on the capsule, so that ground control technicians can monitor the return.*

3. **Once the science canister is removed from the Sample Return Capsule, both will be taken separately to the laboratories at NASA's Johnson Space Center. Why would scientists and engineers want to study the empty Sample Return Capsule? What could they learn?**
   - *Scientists and engineers want to see how the SRC materials and equipment held up during a multi-year mission in space. For example, they could study the outer shell materials to see how well they endured the intense heat from re-entering the atmosphere, look for evidence of micrometeoroid impacts, and test the functioning of the batteries and equipment. All of the information could then be applied in developing materials and equipment for future space missions.*

4. **After Genesis scientists study and analyze the solar wind samples, why is it important to carefully preserve these samples for future generations of scientists?**
   - *Future scientists will not have to rely on another mission to collect solar wind for future studies.*
   - *Technologies change/advance over time, and perhaps applying new technology to the same data (solar wind samples) will yield new insights and results in the future.*

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Genesis Sample Return: Catching a Piece of the Sun

About NASA's Genesis Mission

STUDENT TEXT

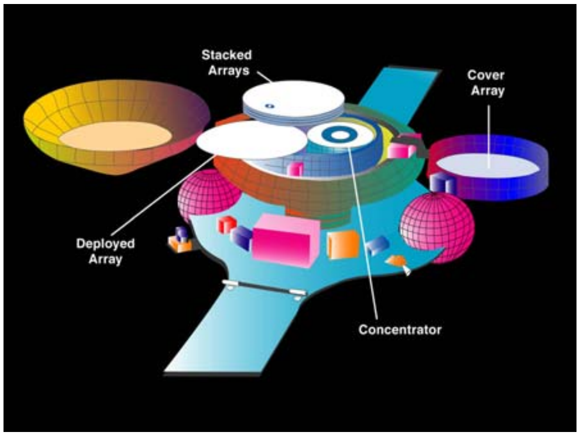
NASA is about to shed some light on several unsolved mysteries: How did we get here? How was the Solar System formed? How can life exist on Earth but not on planets like Venus? The Genesis spacecraft, launched on August 8, 2001, set out to gather clues in pieces of solar wind.

The Sun contains over 99% of the matter that makes up our Solar System. Scientists believe that pieces of the Sun that are flung into outer space (elemental abundances of the ***solar wind***) resemble the dust, gas, and ice from which all planets, moons, comets, asteroids and the Sun itself evolved over the past 4.6 billion years. To better understand the connection between solar wind and how our Solar System changed after it was formed, NASA's Genesis spacecraft traveled nearly 1.6 million kilometers (one million miles) toward the Sun to capture particles of the solar wind and bring them back to Earth for study. Scientists estimate the total amount of solar wind returned will have a mass that is similar to a few grains of sand.

What Is Solar Wind?

While the Sun is mostly made up of hydrogen and helium, studies of solar wind collected during NASA's Apollo missions (1969-1972) suggest there are trace amounts of more than 60 other elements identified in the periodic table. The exact composition of the Sun is yet to be determined, as is an understanding of how that chemical makeup resulted in the diverse Solar System we now know. The Genesis mission hopes to build on this science by determining the exact abundances of the Sun's various chemical components; all of which are known elements, as the mission does not expect to discover any new elements. The scientific theory behind the Genesis mission is that retrieving solar wind particles—pieces of the Sun's outer layer—and analyzing those samples will give us greater insight into planetary formation and diversity. "The Genesis mission is a crucial step in the future of planetary exploration," Principal Investigator Don Burnett explains. "By bringing back solar matter that we can analyze in laboratories on Earth, we will be providing the fundamental data to understand how planets formed in the early history of our Solar System."

Equipped with both an appreciation for the wealth of scientific information encoded in the solar particles and an understanding about where these clues reside, the Genesis team of scientists and engineers tackled the challenge of figuring out just how to "catch a piece of the Sun."



Capturing Solar Wind

For this entirely robotic mission, the Genesis team constructed the specially designed spacecraft and science instruments (***payload***) needed to collect and safely return the solar wind samples. The science instruments aboard the spacecraft include collector arrays, solar wind monitors, and the concentrator. The five **collector arrays** are essential equipment used during the mission. Similar in size and shape to a bicycle wheel, each collector array contains 55 small hexagonal tiles made up of materials such as silicon, gold, diamond, and sapphire. During the collection phase of the mission, these arrays rotated outward from their protective canister. Miniscule solar wind particles collided with the arrays with such tremendous force that the matter actually became embedded in the collector tiles or wafers. While exposed, the arrays faced the risk of damage from possible micrometeoroid impacts. By using small tiles to construct each array, mission scientists hoped to contain the damage, thus reducing the risks to the remaining tiles.

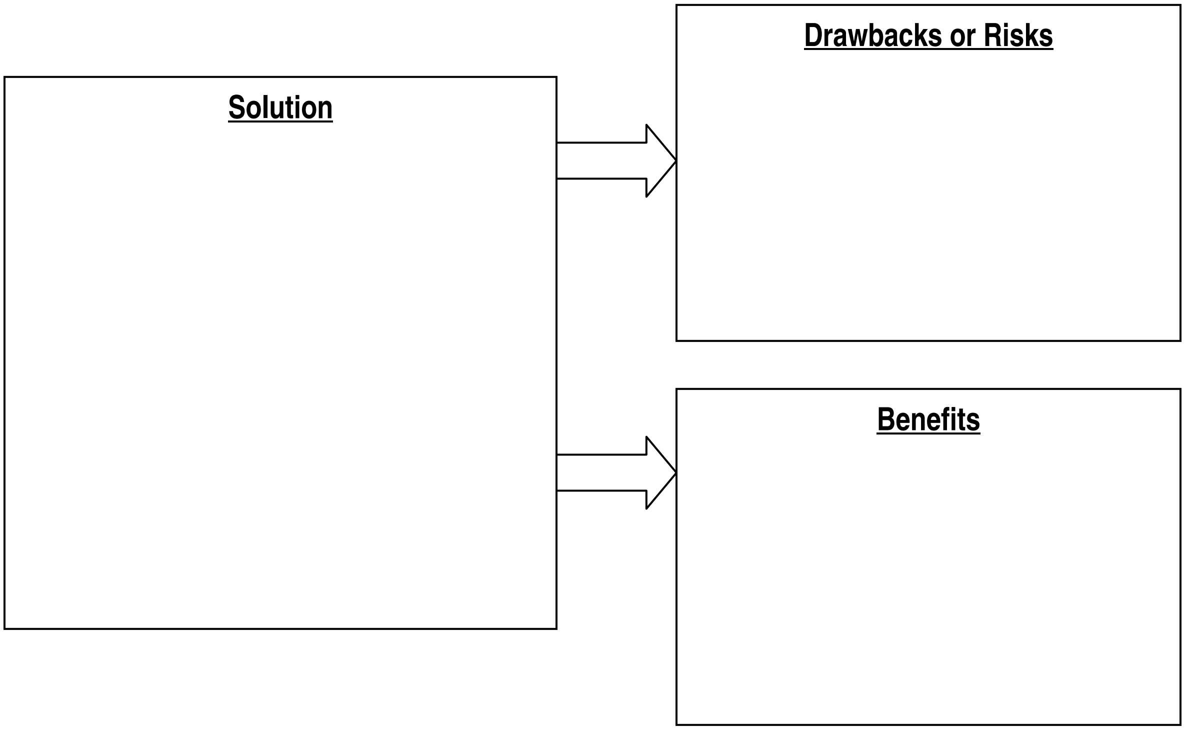
Among the five collector arrays, two bulk solar wind collectors were always exposed: one inside the capsule lid and the other rotated outward from the pancake stack of arrays. The remaining three arrays were controlled by the **solar wind monitors** and only exposed at particular times, depending on the kind of solar wind encountered. The solar wind monitors detected the ions and electrons of the solar wind coming toward the spacecraft, then sent signals to expose the correct collector array. The concentrator, an electrostatic mirror, attracted light elements so that more particles could be collected.

Because of the important role these instruments perform in the mission, extensive instrumentation testing was conducted at Los Alamos National Laboratory, which served to inform both mission and spacecraft design, as well as ensure the success of the Genesis spacecraft and mission. Through a series of tests, mission team members were able to troubleshoot how to protect the instrumentation from vibrations during launch, extreme changes in temperatures, and potential micrometeoroid impacts. Furthermore, great care was taken in guarding the equipment from any potential damage that could contaminate the solar wind samples and skew the scientific data. These precautions included: assembling the collectors under ultra-clean conditions at NASA’s Johnson Space Center and storing the arrays in a sealed protective container during both the spacecraft launch and re-entry into Earth’s atmosphere.

Three months after launching and journeying nearly a million miles toward the Sun, the Genesis spacecraft reached its orbital destination, known as Lagrange point L1, the point at which the gravitational forces of the Sun and Earth are balanced. Mission scientists determined L1 to be economical and well-suited for data collection in that the spacecraft could reside there for several years using a minimal amount of fuel. On December 3, 2001, the collectors were exposed to begin the 2½ years of orbiting while the Genesis spacecraft sunbathed in solar wind and collected pure samples for scientific study.

Reflection Questions

1. Genesis mission engineers designed special equipment to deal with the challenges of collecting solar wind. Using the graphic below, describe or draw the solution they designed and used during the collection process. Then, list what you think are drawbacks and benefits of this solution.



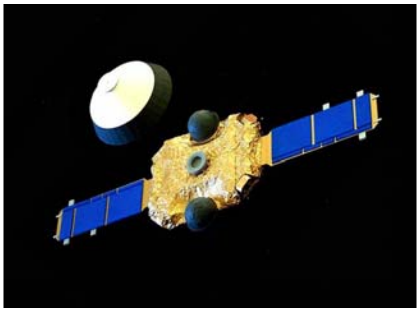
2. What additional protection did the Genesis engineers design for the spacecraft launch and re-entry?

3. Lagrange point L1, where the gravitational forces of the Sun and Earth are balanced, is only one 1.6 million kilometers (one million miles) away. Since Earth and the Sun are approximately 150 million kilometers (93 million miles) apart, why isn't this balance point halfway between them?

Genesis Returns


The MegaSIMS is a powerful instrument that will analyze the returned solar wind particles.

Some may wonder why it's necessary to return the solar wind samples to Earth for study. Why not analyze the particles' composition in space? Since the analysis instruments are too large to be transported in a spacecraft, mission scientists needed to develop a plan for recovering the collected samples. The recovery process began in April 2004 when the microscopic ions and mission payload were carefully stowed in the cylindrical-shaped Science Canister within the Sample Return Capsule (SRC). The SRC provides protective storage for the payload in transit during the five-month journey back to Earth. Then the plan calls for the SRC to split from the rest of the spacecraft on the morning of September 8, 2004, several hours before entering Earth's atmosphere. The remaining portion of the spacecraft will be rerouted to a long-term orbit around the Sun, while the SRC enters into Earth's atmosphere over central Oregon. After much brainstorming, the Genesis team determined a suitable retrieval plan.

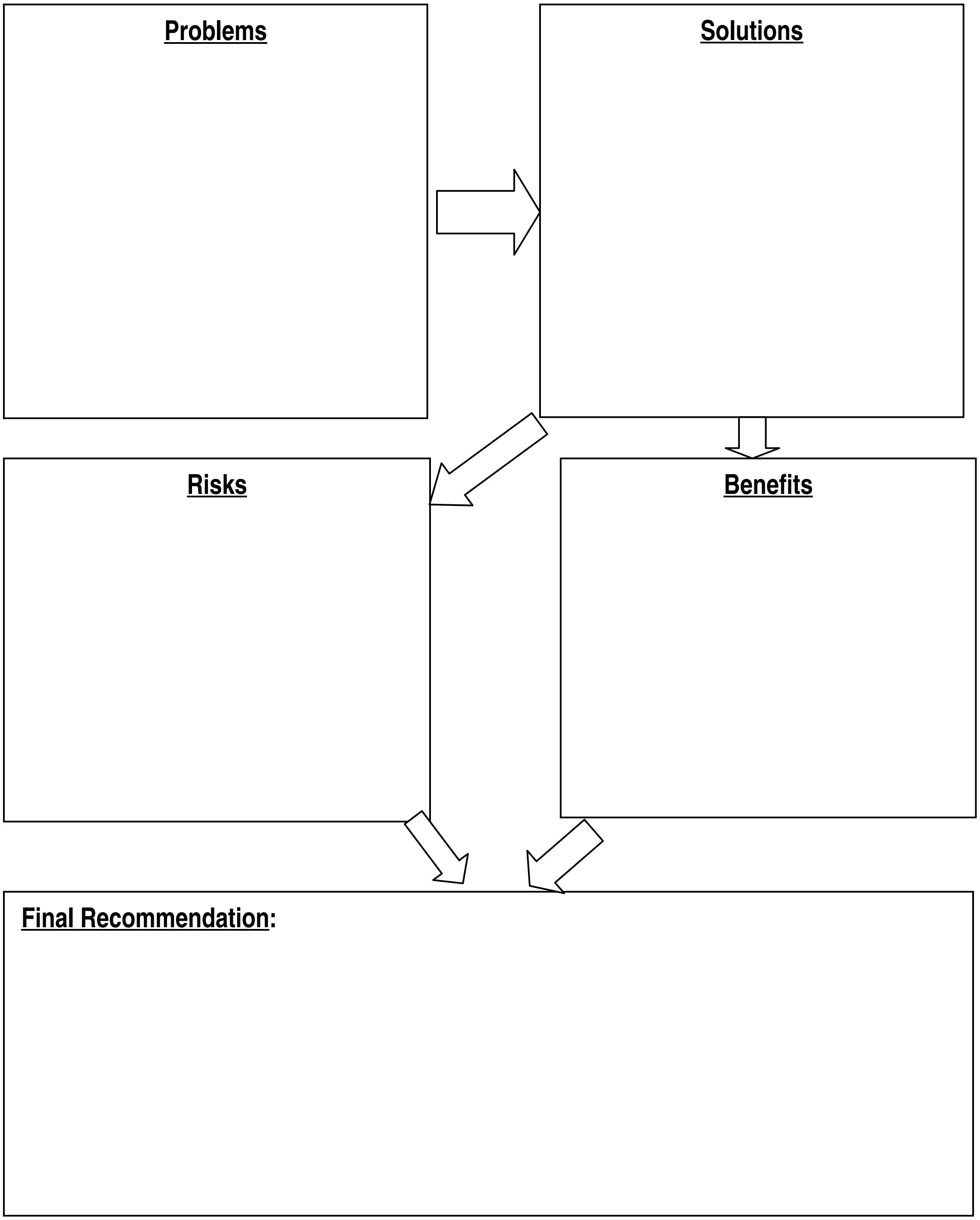

Early in the morning of September 8, 2004, the Genesis Sample Return Capsule separates from the spacecraft.


Similar to this image of the aeroshell approaching Mars, the Sample Return Capsule will enter Earth's atmosphere traveling at a speed of nearly 11.3 kilometers (7 miles) per second.

In planning the sample return, Genesis scientists and engineers faced an enormous challenge: how to recover these solar specks safely as they plummet from the atmosphere? How can the 205-kilogram (452-pound) SRC be slowed down? And, what can be done to ensure that the miniscule contents─with a collective mass similar to several precious grains of sand—won't be damaged or contaminated upon return to Earth?

Reflection Questions

4. Clearly, the Genesis team had to consider the problems they'd encounter in trying to retrieve the solar samples. Use the graphic below to analyze the problems, pose possible solutions, and weigh the risks and benefits associated with the solutions. Then write a statement recommending to NASA's Genesis mission how best to recover the Sample Return Capsule.



Genesis Sample Return: Catching a Piece of the Sun

Genesis' Dramatic Recovery

STUDENT TEXT

Making a dramatic entrance on September 8, 2004, the Genesis Sample Return Capsule (SRC) returns to Earth in an astonishing mid-air capture. Like an action-packed scene from a James Bond movie, the SRC recovery inspires the same edge-of-your-seat suspense. Professional stunt pilots flying helicopters with special retrieval equipment will swoop in and snag the solar wind samples that Genesis has collected during its 2½-year solar bath. To ensure the cargo returns to Earth undisturbed, NASA has coordinated a flying trapeze-inspired, mid-air recovery of the SRC over an expansive stretch of desert in Utah.

The Genesis Project Manager, Don Sweetnam, describes the capture as one of the riskiest parts of the mission: "At the end we must get the Sample Return Capsule to return to a tiny spot in the Utah desert and then snag it with a helicopter before it hits the ground." While action films rely on special effects, stunt experts, and rehearsals to achieve success, the Genesis team carefully designed, coordinated, and tested the recovery process in order to minimize the risk involved in retrieving the solar wind samples undamaged and uncontaminated.

On the morning of September 8, 2004, the spacecraft aligns the SRC to its target course and separates from the Sample Return Capsule. Then the SRC enters Earth's atmosphere heading toward its mid-air retrieval site above the Utah Testing and Training Range, a US Air Force and Army facility. Nearly 30 kilometers (19 miles) above the ground, the SRC begins to decelerate when the lid of the re-entry capsule ejects and releases the first parachute. This small drogue chute helps to break the speed and stabilize the 205-kilogram (452-pound) capsule.

Moments later, when the SRC is just about 6 kilometers (20,000 feet) above ground, a larger rectangular-shaped parafoil—much like a hang glider—allows the capsule to spiral gently downward at an approximate speed of 4.5 meters per second (10 miles per hour). Meanwhile, two chase helicopters—one lead and one backup— outfitted with specially designed retrieval equipment, move in for the mid-air capture. The mid-air retrieval system consists of a pole fastened to the landing skid on the pilot's side of the helicopter. At the end of this pole is a hook attached to a cable which is used to snag the parachute and reel in the SRC. The lead helicopter flies into the parafoil's glide path from behind, hooks and collapses the chute, and gently lowers the SRC in a cradle that then can be rolled into the special tent; all in an effort to avoid disturbing the solar samples inside.

Genesis' Dramatic Mid-air Capture!
Utah Test and Training Range
September 8, 2004

Reflection Questions

1. Why do you think the Genesis mission felt it necessary to deploy a series of parachutes─the small drogue chute and then the larger rectangular parafoil? Why didn't they just use one main parafoil?

2. Having a back-up helicopter was one way that the Genesis mission team reduced the risks involved in the recovery.
    a. What other risks or uncontrollable variables can you think of that may pose a problem for a successful retrieval?

    b. What back-up plan could you propose to deal with the potential risk you identified in "a" above?

Mission Troubleshooting
How does the robotic Sample Return Capsule know when to deploy the drogue chute and main parafoil? The SRC is equipped with a special acceleration sensor switch that is activated as soon as the SRC makes contact with the upper atmosphere. From that point, the chutes are deployed according to a built-in timer. If this acceleration sensor switch were to fail, a barometric pressure switch would become the back-up system.

What if the lead helicopter should miss? The back-up helicopter then swoops in for the capture. Taking into consideration the distance above ground, the speed of the helicopter, and the SRC's descent, Genesis engineers have determined there is enough time for the lead and back-up helicopters to have several chances at capturing the chute in mid-air. Test runs with this new mid-air retrieval technology have been 100% successful on the first attempt.

What if it should be an especially windy or stormy day? The Genesis team has a back-up solution for uncooperative weather as well. If bad weather presents a risk to the successful retrieval, the spacecraft may resort to a holding pattern, a six-month parking orbit.

What Happens to the Solar Wind Samples Next?
Once successfully captured, the SRC is safely transported to a contamination-controlled tent at the Utah Test and Training Range, where the sample canister will be carefully extracted. Using a small hose, ultra-pure nitrogen gas will be injected into the canister to control the environment. Later, the science canister

and the Sample Return Capsule travel separately to their final destination at NASA's Johnson Space Center in Houston, Texas.

After the innovative design work, careful construction of the payload, years of sunbathing to gather solar wind particles, and a deliberately orchestrated, spectacular mid-air capture of the Sample Return Capsule, many feel that the real excitement of the Genesis mission is just about to begin. Mission scientists can finally embark on their long-awaited study, unlocking the mysteries contained in these treasured solar wind samples.

Once the science container returns to the ultra-clean laboratory at the Johnson Space Center, the samples will be cautiously extracted, safely preserved, and carefully studied for many years to come. Because great care has been taken to protect the solar wind particles from any contamination throughout this multiple-year journey and to ensure their purity for future scientists' analysis, the Genesis team hopes that this will be the only solar wind sample return mission ever needed.

Reflection Questions

3. Once the science canister is removed from the Sample Return Capsule, both will be taken separately to the laboratories at NASA's Johnson Space Center. Why would scientists and engineers want to study the empty Sample Return Capsule? What could they learn?

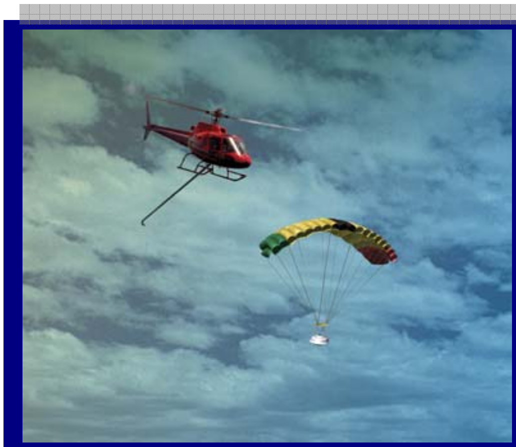
4. After Genesis scientists study and analyze the solar wind samples, why is it important to carefully preserve these samples for future generations of scientists?

Genesis Sample Return: Catching a Piece of the Sun

Investigation: Capture a Moving Target

TEACHER GUIDE

SUMMARY OF ACTIVITIES



Genesis' Dramatic Mid-air Capture!
Utah Test and Training Range
September 8, 2004

In the introductory activities of this mini-module, *Why Sample Return?*, students learn about the recovery process planned for Genesis as well as how the mission team faced challenges and tried to minimize the risks associated with a solar wind sample return mission. During this section, *Capture a Moving Target,* Genesis' sample recovery process provides the context for students to explore the relationships between science and technology as well as motions and forces. By facing the challenge of creating a suitable parachute and implementing it in a simulation of Genesis mid-air capture, students develop their abilities of technological design. Furthermore, the activities provide an exciting, real-world context for learning physical science concepts of motions and forces.

The student activities in *Capture a Moving Target* are divided into three parts as described in the chart below. Each activity could be completed within one or two class periods, with the exception of the PowerPoint presentation option in Part 3.

Parachute Physics: A Lesson that Drags – Part 1	**Model of Genesis' Mid-air Capture – Part 2**	**The Physics of Genesis' Sample Recovery – Part 3**
Students gain an understanding of the physics concepts related to parachutes, such as mass, air resistance, friction, drag, acceleration, speed, velocity, and terminal velocity.	Students use common household items to construct a model of the Genesis' sample recovery process. Then they have an opportunity to reflect on the benefits and limitations of their physical models.	Students apply their understanding of physics concepts to the Genesis' sample return and recovery process by creating a PowerPoint presentation.

GENESIS
SEARCH FOR ORIGINS
Education

Genesis Sample Return: Catching a Piece of the Sun

Parachute Physics: A Lesson that Drags

TEACHER GUIDE—PART 1

OBJECTIVES: Learn about Genesis' recovery process, experiment with parachute designs, and make recommendations for a mid-air capture.

MATERIALS (for each group of four students)

- Student activity sheet, "Parachute Physics: A Lesson that Drags—Part 1" (one copy per student)
- Stopwatch (ideally one per group, or groups can share)
- Tape measure or meter stick (to measure height of drop; one tape and one measurement is sufficient for the entire class)
- Butcher paper, streamers, adding machine tape (enough to stretch the height of the parachute drop)
- Triple beam balance or double pan balance scales for measurement in grams (have a couple for the class to share)
- Roll of transparent tape
- Glue stick
- Paper hole puncher
- Ruler measuring in centimeters
- Various sizes of round objects – coffee cans, embroidery ring, lampshade, etc. (to be used as a template for drawing/cutting circles for parachutes)
- An assortment of materials that can be used to make parachutes: plastic trash bag liners, plastic sandwich bags, plastic grocery bags, newspaper, tissue paper, cellophane, scraps of fabric, etc. (Students could be asked to bring in parachute materials from home.)
- Lightweight string such as fishing line, dental floss, or embroidery thread (approximately 5 meters per group)
- Pipe cleaners (five or more per group)
- Plastic film canisters with lids (Ideally one per person; however, students can share since they will be deploying chutes one at a time)
- A combination of pennies and nickels (students can bring their own—5 to 10 coins). Can substitute washers if these are available.

Teacher Tip

If more guidance in parachute design would be beneficial to students, various parachute patterns are available at the following Internet sites:

http://www.sci.mus.mn.us/sln/tf/p/paperclip/paperclip.html

http://media.nasaexplores.com/lessons/01-026/9-12_2.pdf

http://www.pbs.org/wgbh/nova/teachers/activities/pdf/3101_mars.pdf

http://www.swe.org/iac/LP/para_02.html

PROCEDURE

1. To find out students' prior knowledge and experiences regarding parachutes, facilitate a class discussion or small group brainstorming session. A "K-W-L Chart" may work well.

2. Explain to students that NASA's Genesis mission will be using parachutes to help recover a container of solar wind samples. If students did not read the student texts in the *Introduction* section of this mini-module, provide them with some background information about the mid-air capture. The mission fact sheet, containing a brief storyboard sequence of informative graphics, is available at: http://www.genesismission.org/educate/kitchen/resource/factsheets/index.html

3. Pass out a copy of the student activity sheet "Parachute Physics: A Lesson that Drags─Part 1" to each student. The initial texts and SRC Recovery Profile graphic with questions may be challenging for younger students. The teacher should consider reading the texts aloud, providing additional explanations, and guiding students through a collective interpretation of the profile graphic. A larger SRC Recovery Profile graphic, which can be used to create an overhead transparency, is attached as one of the Appendices to this teacher guide. Also, if students are seeing these physics terms for the first time, the teacher may want to read the section about "How Parachutes Work" together as a class. Older or more advanced students could work either individually or with one additional partner to complete the section with the SRC Recovery Profile graphic. An "Answer Key" with possible student responses can be found in the Appendices section of this teacher guide.

4. For the "Design a Chute Activity," divide the class into small groups of four students. Distribute the materials listed above to each group.

5. Explain to students that during this activity the film canister will represent the Genesis Sample Return Capsule and the coins/washers will be the collector arrays. Their job will be to determine the best size, style, and design of parachute to slow the model of the descending SRC during the recovery process. If your students have already read the student texts, "About NASA's Genesis Mission" and "Genesis' Dramatic Recovery," they may comment that the best design is the one the mission is using. You may want to point out that the mission uses two different types of chutes─the small round drogue chute and the larger, rectangular parafoil. Each student has the task of designing one parachute—unique from all group members' creations—and then developing a model of his/her parachute. After each group has created their four different chutes, students will drop them from a particular place (e.g.,top of a stairwell, bleachers) with a set height. Using a measuring tape, the teacher should determine the set height for the class to use.

6. Take precautions when determining the location for deploying the parachutes. It may be best to have only adults (other teachers and adult volunteers) fulfill the parachute drop roles, while students remain on the ground in their roles as Timer, Velocity Verifier, and Recorder.

7. It may be necessary to review with students the difference between speed and velocity. While velocity and speed are calculated in the same way **(distance ÷ time)**, velocity includes direction. Show examples of velocity calculations and discuss how you would like for students to describe direction during this activity. See "Teacher Tip" box above for one possibility.

Teacher Tip

Below the parachute drop point, use masking tape to make a compass rose indicating the four directions: north, south, east, and west. This could help the "Velocity Verifier" describe the direction of the chutes' descents.

8. After students have completed "Parachute Physics," have each group share their recommendations and reflections about which of their four chutes would be best suited for the Sample Return Capsule mid-air capture. This could lead in to a follow-up discussion about such physics concepts as how surface area affects the amount of air resistance, or how mass affects acceleration and terminal velocity. Some suggested discussion prompts are below (in **bold**) along with possible student responses (in *italics*).

a. **Based on your experiment, what can you determine about how the parachute's size affects its rate of descent?**
The larger sized parachutes descended slower. The larger the surface area of the parachute, the more air resistance builds up to counter the force of gravity more effectively.

b. **The Genesis mission will use two different parachute shapes: a round drogue chute and a rectangular parafoil. Did you find that the shape of the parachute affected its descent? If so, how?**
Answers will vary and depend on the shapes created. In general, rectangular-shaped chutes will fall at an angle, while round ones may fall straight. Adding vents in the chute can minimize wobbling.
TEACHER NOTE: *It may be interesting for students to know that the rectangular parafoil naturally takes a downward-spiral trajectory, which Genesis planners determined to be most suitable for a mid-air snag.*

c. **How did the number of coins/washers affect the parachutes' rate of descent?**
More coins caused the parachute to fall faster. Because of the larger mass, it took longer to generate enough air resistance to counter the force of gravity and reach terminal velocity.

d. **What material characteristics do you feel are best suited for parachutes?**
Material should be lightweight, durable, and tightly woven in order to trap air underneath to build up air resistance.
TEACHER NOTE: *The parachutes used in the Genesis mission are made of nylon; this fabric was selected for its strength, low mass, and its ability to be packed densely into a small volume. The risers and load lines are made of Kevlar, a high-strength fiber that is used to make bullet-proof vests. The Kevlar is tightly woven into flat straps, which can be packed into a small area more efficiently.*

9. *StudyWorks Online! The Physics Classroom* offers helpful examples, animations, and interactive exercises to help students understand such physics concepts as air resistance, the acceleration of gravity, and terminal velocity. As a follow-up to this hands-on activity, teachers could guide students through this Web site.

TEACHER GUIDE—APPENDICES FOR INVESTIGATION SECTION PART 1

APPENDIX A: STANDARDS

NATIONAL SCIENCE EDUCATION STANDARDS ADDRESSED

(Source: *National Science Education Standards*)

(View a full text of the National Science Education Standards)

Science and Technology — Grades 5-8

Abilities of Technological Design

- *Identify appropriate problems for technological design.*
- *Design a solution or product.*
- *Implement a proposed design.*
- *Evaluate completed technological designs or products.*

Understandings about Science and Technology

- *Scientific inquiry and technological design have similarities and differences.*
- *Science and technology are reciprocal.*
- *Perfectly designed solutions do not exist.*

Physical Science — Grades 5-8

Motions and Forces

- *The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.*
- *An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.*
- *If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.*

NATIONAL MATHEMATICS STANDARDS ADDRESSED

(Source: *Principles and Standards for School Mathematics*)

(View a full text of the Principles and Standards for School Mathematics)

Number and Operations — Grades 6-8

Understand numbers, ways of representing numbers, relationships among numbers, and number systems.

- *Develop meaning for integers and represent and compare quantities with them.*

Measurement — Grades 6-8

Understand measurable attributes of objects and the units, systems, and processes of measurement.

- *Understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, and volume.*

Apply appropriate techniques, tools, and formulas to determine measurements.

- *Solve simple problems involving rates and derived measurements for such attributes as velocity and density.*

APPENDIX B: TEACHER RESOURCES

http://media.nasaexplores.com/lessons/01-026/9-12_2.pdf
In this NASA lesson entitled *The First-Ever Space Rescue Vehicle*, students compare and contrast the aerodynamic design of parachutes and parafoils.

http://www.aero.hq.nasa.gov/edu/but/helicopters/helicptr.html
NASA offers a kid-friendly multimedia explanation showing how helicopters fly.

http://www.cc.gatech.edu/projects/DITC/designTasks/parachute/keyConcepts/howParWork.html
Georgia Tech's *Design in the Classroom: How Parachutes Work and Fail*, provides informative texts, activities, and an online video that discusses how the design and shape of parachutes affect their descents.

http://www.pbs.org/teachersource/mathline/lessonplans/msmp/awchute/awchute_procedure.shtm
Aw Chute! is a middle school math lesson, offered by PBS Mathline, in which students construct parachutes and use algebra to determine the rate of descent.

http://www.pbs.org/wgbh/nova/teachers/activities/pdf/3101_mars.pdf
To accompany the television program *MARS Dead or Alive, NOVA* features classroom activities for students to investigate the variables affecting a parachute's descent and to design a chute of their own.

http://www.physicsclassroom.com/Class/newtlaws/newtltoc.html
The Physics Classroom, developed for high school students, provides helpful explanations and animations to illustrate physics concepts and Newton's laws of motion.

http://www.swe.org/iac/LP/para_02.html
Parachutes and Parafoils, a lesson offered by the Society of Women Engineers, provides background information as well as directions and patterns for making different chutes.

APPENDIX C - ANSWER KEY: Answers to SRC Recovery Profile Questions

1. **On the profile, the dashed line indicates the atmosphere. Earth's atmosphere is expansive and doesn't have a clear "starting line." Why do you think Genesis mission planners used a specific starting point, 125 kilometers above the ground, to identify the atmosphere?**
   They needed to have some type of reference point in order to plan when events will happen.

2. **At each point, notice the letter "E." Above the dashed line, the letter E is followed by a negative number of "hrs." Below the dashed line, the number following "E" is positive and expressed in "min" units.**
   a. **What do you think "E" represents?**
      The SRC's Earth entry.

   b. **What does "E–4 hrs" refer to in point #1?**
      Four hours prior to the SRC's entry into Earth's atmosphere.

   c. **How long after Earth Entry does the main chute deploy?**
      Six and one-half minutes.

   d. **What does "E + 19 min" refer to in point #5?**
      Nineteen minutes after the SRC's Earth entry.

3. **What do the numbers (expressed in km) indicate?**
   The number of kilometers above ground at which each event will occur.

4. **Refer to all points either on or below the dashed line.**
   a. **What do the "V's" represent?**
      Velocity.

   b. **Why do you think the values indicated by the "V's" change from point #2 to point #3?**
      At point #2, the Earth's gravitational force causes the SRC to accelerate. However, the SRC causes air resistance or friction to build up and oppose the gravitational force, which is why it slows down by point #3.

   c. **At point #3, the SRC will descend at a rate of 425 meters per second (m/s); at point #4 the vertical descent is 44 m/s, and at point #5 it's 4.5 m/s. What causes the SRC to slow down?**
      Increased air resistance, drag, or friction from the two chutes.

      ***TEACHER NOTE**: Explain to students that the shape of the parafoil causes a spiral motion, so in addition to a downward or vertical velocity, there is also a forward velocity. The numbers indicated on the profile only reflect the downward velocity or vertical descent. Also, the SRC recovery profile used nominal numbers for velocity, but in actuality, there are ranges. You may want to ask students to consider why mission planners would choose to use nominal numbers instead of the actual range.*

   d. **What is the purpose of the drogue chute?**
      To help break the speed of the descending SRC.

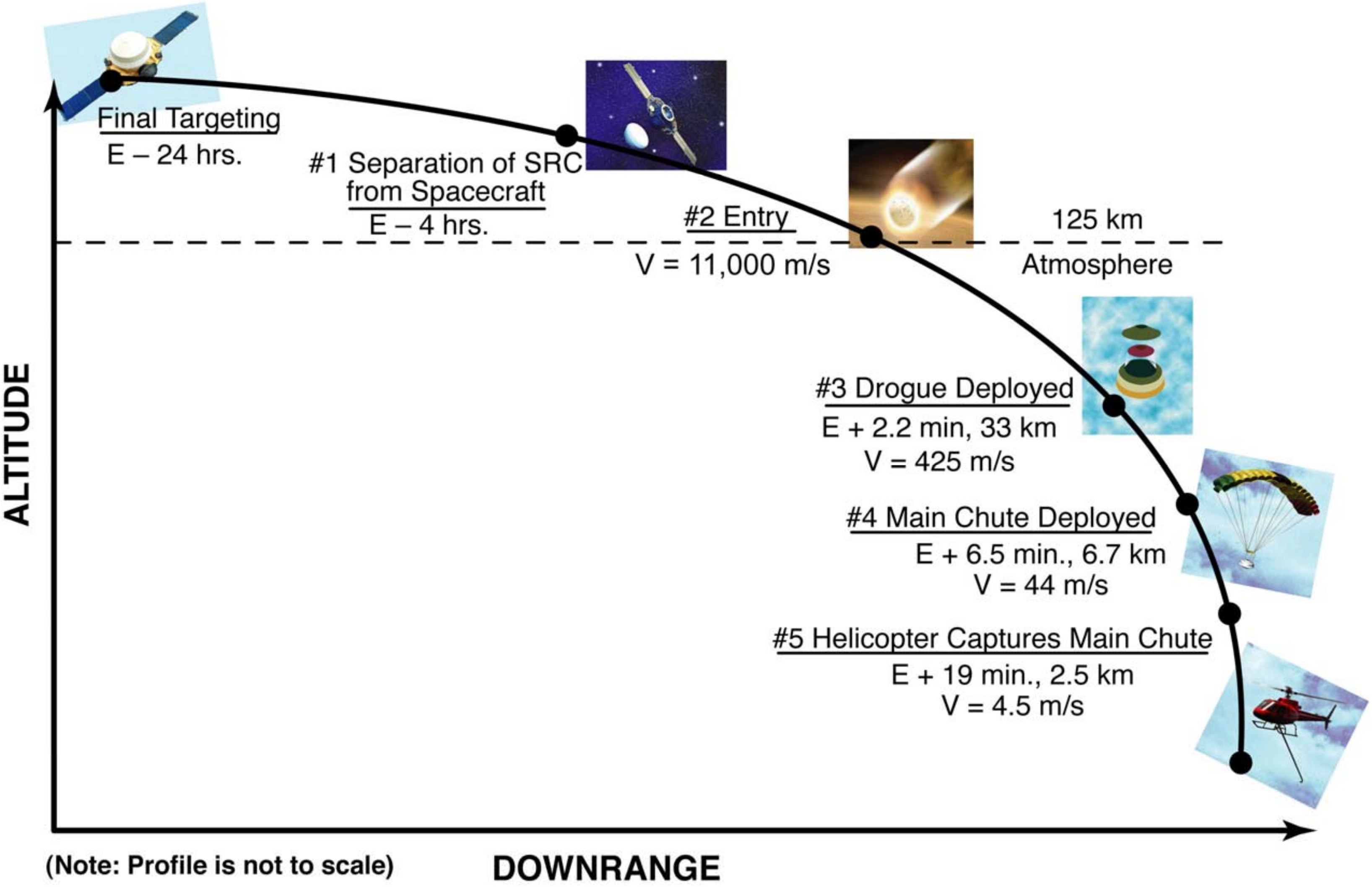
      ***TEACHER NOTE:** It might be interesting to share with students that early in the mission planning there was no drogue chute. Because there is a period during re-entry where the SRC could tumble, the drogue was added to help keep the capsule stable.*

5. **Where on the graph do you think terminal velocity is reached?**
   Terminal velocity is reached just after each chute is deployed.

   ***TEACHER NOTE:** This question would be useful to discuss with the class. After each chute is deployed, it actually only takes a few seconds to reach terminal velocity. As the SRC descends, the atmosphere gets denser, which helps make the parachutes more efficient.*

6. **What questions do you still have about the SRC recovery profile?**
   Refer to the list of URLs at the end of this guide to assist students in finding answers to their questions.

SRC Recovery Profile



Final Targeting
E – 24 hrs.

#1 Separation of SRC from Spacecraft
E – 4 hrs.

#2 Entry
V = 11,000 m/s

125 km
Atmosphere

#3 Drogue Deployed
E + 2.2 min, 33 km
V = 425 m/s

#4 Main Chute Deployed
E + 6.5 min., 6.7 km
V = 44 m/s

#5 Helicopter Captures Main Chute
E + 19 min., 2.5 km
V = 4.5 m/s

(Note: Profile is not to scale)

Genesis Sample Return: Catching a Piece of the Sun

Parachute Physics: A Lesson that Drags

STUDENT ACTIVITY—PART 1

How Do Parachutes Work?

An object falls to the ground, accelerating as it falls because it is being pulled downward by an **unbalanced force**— *a force that is not being countered or balanced by an opposing force of equal power in the opposite direction.* In a free-falling situation, this unbalanced force is **gravity**—the force that attracts objects to Earth. The velocity (*speed and direction*) of a free-falling object changes and accelerates because of gravity. Physicists have determined a numerical value to indicate the acceleration of free-falling objects that are only being subjected to the force of gravity. The **acceleration of gravity (symbolized by "g")** is 9.8 meters per second per second (9.8 m/s/s). This means that for each second that an object is free-falling; it will accelerate (increase in velocity – both speed or direction) at a rate of 9.8 meters. This assumes there are no other forces, such as air resistance, influencing the object's motion.

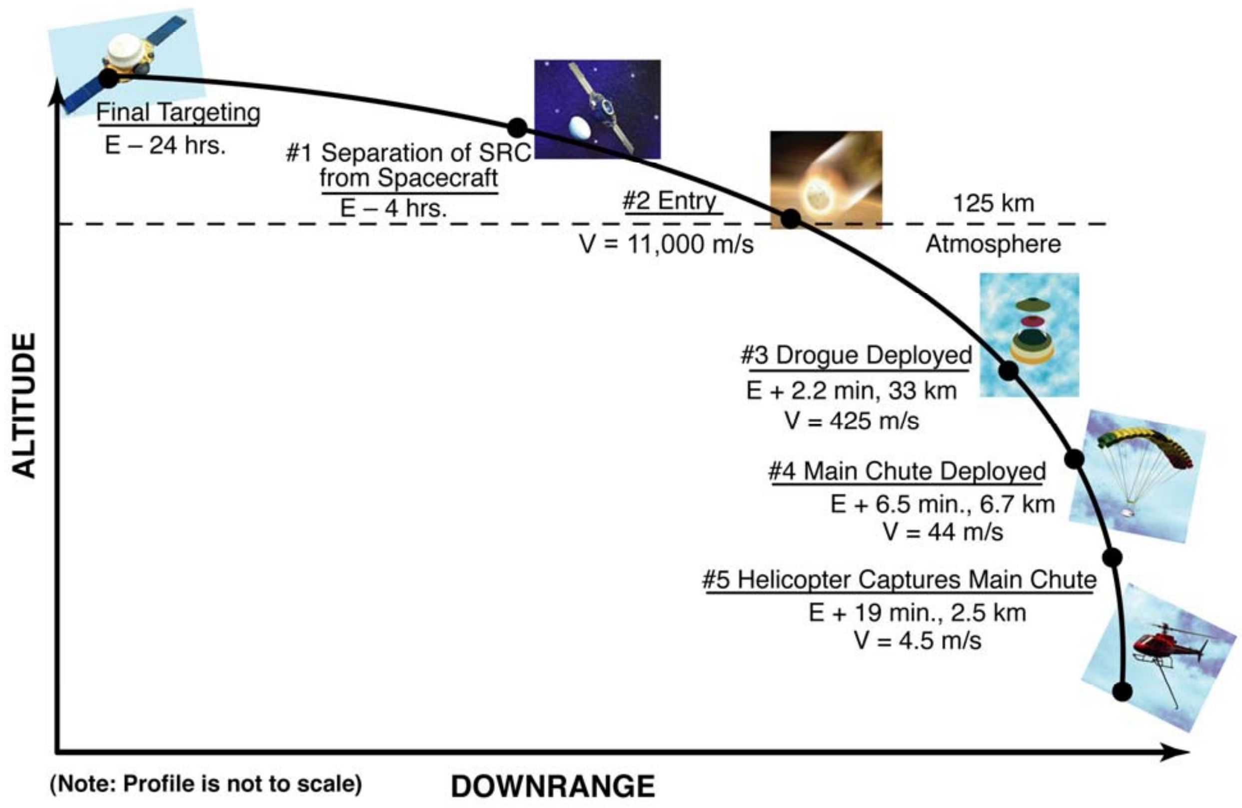
Parachutes can create an opposing force to counter the force of gravity. This force is known as **air resistance, friction, or drag**. When a parachute is deployed and opens, it encounters resistance or pressure from air molecules. While gravity is pulling the falling object downward, air resistance is pushing up on the parachute. Eventually, the two forces balance each other, and the object no longer accelerates; it has reached a point of **terminal velocity**. Now, within Earth's atmosphere, all free-falling objects encounter air resistance; however, the design and shape of parachutes can help to maximize the amount of air resistance.

Genesis' Mid-air Capture

The Genesis mission team had to perform calculations to determine how fast the Sample Return Capsule (SRC) could descend, and then they carefully considered and experimented with parachute designs to slow the descending SRC.

The graph below is a profile of events that represents the Genesis Sample Return Capsule's descent to Earth as it travels over the Pacific Ocean, Oregon, Nevada, and Utah. Scientists and engineers use graphs like this to illustrate and plan for critical periods of time. To better understand each of the recovery stages plotted along the graph below, refer to the student texts "About NASA's Genesis Mission" and "Genesis' Dramatic Recovery." "Altitude" on the y-axis refers to the SRC's distance above ground, and "Downrange" on the x-axis indicates the SRC's direction of travel. Respond to the following questions to help you interpret the graph.

SRC Recovery Profile



1. On the profile, the dashed line indicates the atmosphere. Earth's atmosphere is expansive and doesn't have a clear "starting line." Why do you think Genesis mission planners used a specific starting point, 125 kilometers above the ground, to identify the atmosphere?

2. At each point, notice the letter "E." Above the dashed line, notice the letter E followed by a negative number of "hrs." Below the dashed line, the number following "E" is positive and expressed in "min" units.

- **a.** What do you think "E" represents?

- **b.** What does "E–4 hrs" refer to in point #1?

- **c.** How long after Earth Entry does the main chute deploy?

- **d.** What does “E + 19 min” refer to in point #5?

3. What do the numbers (expressed in km) indicate?

4. Refer to all points either on or below the dashed line.
  - **a.** What do the “V’s” represent?

  - **b.** Why do you think the values indicated by the “V’s” change from point #2 to point #3?

  - **c.** At point #3, the SRC will descend at a rate of 425 meters per second (m/s); at point #4 the vertical descent is 44 m/s, and at point #5 it’s 4.5 m/s. What causes the SRC to slow down?

  - **d.** What is the purpose of the drogue chute?

5. Where on the graph do you think terminal velocity is reached?

6. What questions do you still have about the SRC recovery profile?

Design a Chute Activity

Purpose: In this activity, your group will experiment with different sizes and designs of parachutes to see which will be the most effective in activating the force of air resistance or friction to slow the downward pull of the Sample Return Capsule (represented by a film canister).

Procedure:

1. You will have a selection of materials to work with in designing your own parachute. What qualities would you look for in parachute materials?

2. Discuss parachute design ideas with your group to be sure everyone creates a different parachute─unique from each other's. In the space below, design a sketch of your parachute with the attached SRC (film canister). Be sure to include the following:
    - The materials used in constructing the chute
    - The dimensions of the chute in centimeters
    - The length of the chute strings
    - Show how the SRC (canister) will be attached to the chute

3. Using the provided materials, make your parachute. As a group, agree to a specific number of coins you will each place inside your film canister (SRC).

    Each film canister will hold _______ (#) of coins during this first parachute drop.

4. Share the four parachutes created in your small group. In the table below, identify each parachute (could be student's name or create another memorable name for your parachute). Include the dimensions of each parachute in centimeters. Also find the mass of each parachute with the SRC canister containing the coins attached and record the mass in grams. *Note: Put a piece of tape over the lid of your canister so that coins do not fall out after deployment.* Next to each parachute, predict which will descend the fastest and slowest. Rank each parachute using a 1-to-4 scale (1 being the fastest and least effective in combating the force of gravity; 4 being the slowest and most effective parachute in increasing the force of air resistance).

Parachute	**Dimensions, centimeters**	**Mass, grams (with canister)**	**Predicted Rank 1st, 2nd, 3rd or 4th place**

5. During the parachute drops, each person in your group will take turns fulfilling each role below:
   - Parachute Launcher (an adult may take this role)
   - Timer (using stop watch)
   - Velocity Verifier (determines the parachute deployed and in which direction it soared and then fell relative to the point from where it was dropped)
   - Recorder (uses chart below for reporting and shares information with all group members so that everyone may perform the velocity calculations and have a completed chart).

6. Before deploying parachutes, drop the SRC without a chute and record the time of its free-fall in the **Trial 1** column. In the **Velocity** column, write the direction “downward.” Then for each parachute, record the official **Time of Fall** in seconds as well as a brief description of the direction it traveled under **Velocity**. The direction of all falling objects will be downward; however, the Velocity Verifier may notice that the parachute moved to the right or left of the initial starting point. Be sure to include these directions as well. (If using a compass rose, include specific directions—north, south, east or west—in the **Velocity** column.)

Parachute	**Time of Fall Trial 1** (in seconds)	**Velocity Trial 1** *(speed and direction)*	**Time of Fall Trial 2** (in seconds)	**Velocity Trial 2** *(speed and direction)*
SRC alone		Speed: Direction:		Speed: Direction:
		Speed: Direction:		Speed: Direction:
		Speed: Direction:		Speed: Direction:
		Speed: Direction:		Speed: Direction:
		Speed: Direction:		Speed: Direction:

7. After each parachute has been dropped and timed, perform calculations to determine how fast each chute fell by dividing the distance (d) by the time (t) in seconds. For instance, if the distance (d) from the parachute drop point to the ground is 9 meters, and the time (t) it took for the parachute to reach the ground was 3 seconds, you would calculate:

d ÷ t or 9 ÷ 3
V = 3 meters per second (m/s), downward

Use the space below for your calculations. Then, record the calculated speeds in the **Velocity** column of your table.

8. Review the tables above to see how close your predicted outcomes and actual recorded times were.

9. Now you will increase the mass of the SRC and test the parachutes again. Students will add an agreed-upon number of coins to their film canisters and launch their parachutes again.

Each film canister will hold _______ (#) of coins during this second parachute drop.

10. Write an if/then statement that predicts how the increase in coins (mass) will affect the time of fall and velocity.

11. Repeat the parachute drop process again and report the results in the Trial 2 columns. Perform the velocity calculations in the space below and include both speed and direction in the **Velocity** columns.

12. Discuss the following questions as a group and record your reflections. Answers should be based on information found in the data tables.
    a. Between all of the parachutes, which was most effective (slowest to fall)? Explain why you think it was more effective.
    b. What can you conclude about the size of the chute and how it affects air resistance?
    c. Do you think the shape of the parachute affects drag? Explain your response.
    d. How did the increased mass of the film canister/SRC affect the fall?
    e. Among all of the tested parachutes, which would you recommend to be used for the SRC mid-air capture? Explain your selection.
    f. What do you feel could done to modify the design of the recommended chute to make it even more effective?

GENESIS
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Education

Genesis Sample Return: Catching a Piece of the Sun

Model of Genesis' Mid-air Capture

TEACHER GUIDE—PART 2

OBJECTIVE: Create a parachute and device to capture a model Sample Return Capsule in mid-air.

MATERIALS

- Copies of student activity "Model of Genesis' Mid-air Capture—Part 2"
- Cotton string or yarn (about 2 meters per group)
- Pipe cleaners (5 per group)
- Masking tape
- Markers (for labeling stages of recovery)
- Butcher paper (cut into strips with a width between 15 and 25 centimeters), rolls of decorative streamers, or adding machine tape—the length must stretch from parachute release location to the ground. Each group will need one strip of paper.
- Scissors
- Measuring tape or metric ruler
- Safety goggles for each student

From "Parachute Physics: A Lesson that Drags—Part 1" *(Students may reuse their parachutes or, if necessary, re-create them with modifications).*

- Completed "Parachute Physics" student activity
- Various sizes of round objects for tracing circular parachute designs—coffee cans, frisbee, embroidery ring, lampshade, etc.
- An assortment of materials that can be used to make parachutes: plastic trash bag liners, plastic sandwich bags, plastic grocery bags, newspaper, tissue paper, cellophane, scraps of fabric, etc. (Students could be asked to bring in parachute materials from home.)
- Lightweight string such as fishing line, dental floss, or embroidery thread (approximately 2 meters per group)
- Plastic film canisters with lids (ideally one per person; however, students can share since they will be deploying chutes one at a time).
- A combination of pennies and nickels—3 to 5 coins per group. (Can substitute washers if these are available.)

PROCEDURE

1. Explain to students that this activity will involve working together in small groups to create a model of the Genesis mid-air capture. It may be helpful to facilitate a discussion about the use of models in science. Refer to "Scientific Modeling." Ask students to think about the benefits and limitations of their models while they simulate the mid-air capture. Clarify to students that while the Genesis' recovery involves two chute deployments, students will simulate only one main chute deployment.

2. During this simulation, students will work in the same small groups as they did during Part 1, "Parachute Physics." This time, however, they will only need to create one parachute as a group.

3. Students will need to refer to their completed "Parachute Physics" activity to determine which parachute they will use and if their parachute needs modifications to be more effective.

4. The parachute will be attached to a film canister representing the Sample Return Capsule (SRC), while the coins or washers inside provide weight and could be a representation of the collector arrays. Suggest to students that they place a piece of tape over the lid of their film containers to keep contents from scattering.

5. Give students the pipe cleaners and cotton string/yarn to make their "retrieval equipment." Encourage them to find a way to make a sturdy and supportive hook device using only the pipe cleaners and strings provided.

6. Students will simulate the mid-air capture to scale from drogue chute deployment to the capture. It may be necessary to help students determine the scale by either providing it for them (e.g., 1 mm measured = 10 meters in actual elevation), or assisting them in developing an appropriate scale. **Note:** *It will not be possible to include the Earth Entry point in the scale; however, ask students to label the section above the Drogue Chute Deployment as the Earth Entry region on their strips of paper. They should include the SRC's velocity and altitude of the Earth Entry point in their label.*

7. Instruct students to label the stages of Genesis' sample recovery along their strips of paper: ***Earth Entry, Drogue Chute Deployment, Main Chute Deployment, Helicopter Capture Range (upper and lower limits).*** Students should include the actual altitude (in meters or kilometers above ground) at each stage and the anticipated velocity of the descending Sample Return Capsule. Provide students with markers so that labels stand out. It may help for students to refer to the table below, which is also included on their activity handout.

SRC Recovery Phase	**Time** *(begins when the SRC enters Earth's atmosphere)*	**Velocity** *(vertical descent of SRC in meters per second)*	**Altitude** *(meters above ground)*
Earth Entry	0 begins	11,000 m/s	125,000 meters
Drogue Chute Deployment	2.2 minutes after Earth entry	425 m/s	33,000 meters
Main Chute Deployment	6.5 minutes after Earth entry	44 m/s	6,700 meters
Helicopter Capture	19 minutes ─ first attempt begins	4.5 m/s	Capture range: First pass 2500 meters ─ final pass 1500 meters above ground

8. Students may need assistance securing their labeled paper strips from the parachute release spot to the "ground." Note: *Depending on scale, it may be necessary to establish a height of "knee level" as the "ground," making it possible for students to actually capture the descending parachute.* It may be best for an adult to be in charge of taping the paper scale to the highest point, while students secure the paper to the ground.

9. Emphasize the importance of safety during this simulation and require students to wear goggles for eye protection.

10. Based on the amount of class time, determine how much time each group will have to practice and make modifications before the official mid-air capture trials─at least 10 minutes recommended. Then, when the official trial runs begin, emphasize to students that they will have three chances to capture the parachute and canister.

11. After students have conducted their three official trial runs and discussed the reflection questions, facilitate a discussion about how the model relates to the actual mid-air capture, as well as the benefits and limitations of physical models. Some suggested discussion prompts are provided below.

a. **Mention to students that the Genesis mid-air capture trials have been 100% successful to date.**
   i. **How much practice should happen before the event?**
   ii. **If you only had one or two chances to catch the Sample Return Capsule, how confident would you be?**

b. **If you had an opportunity to repeat this simulation…**
   i. **What could be done to improve your success rate?**
   ii. **What if this simulation was done outside/inside, what additional variables would there be?**

c. **Reflect on the uses of models in science and technology.**
   i. **What makes for a good model?**
   ii. **Why do all models have limitations?**
   iii. **How are models useful in designing solutions to problems?**

d. **How can computers be used to make more accurate models?**

Extension Opportunity

Present students with a **DESIGN CHALLENGE** to be completed at home. Can students design and construct a more effective, successful model of Genesis' mid-air capture?

TEACHER GUIDE—APPENDICES FOR INVESTIGATION SECTION PART 2

APPENDIX A: STANDARDS

NATIONAL SCIENCE EDUCATION STANDARDS ADDRESSED

(Source: *National Science Education Standards*)

(View a full text of the National Science Education Standards)

Science and Technology — Grades 5-8

Abilities of Technological Design

- *Identify appropriate problems for technological design.*
- *Design a solution or product.*
- *Implement a proposed design.*
- *Evaluate completed technological designs or products.*

Understandings about Science and Technology

- *Scientific inquiry and technological design have similarities and differences.*
- *Science and technology are reciprocal.*
- *Perfectly designed solutions do not exist.*

Physical Science — Grades 5-8

Motions and Forces

- *The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.*

Science in Personal and Social Perspectives **— Grades 5-8**

Risks and Benefits

- *Individuals can use a systematic approach to thinking critically about risks and benefits.*

NATIONAL MATHEMATICS STANDARDS ADDRESSED

(Source: *Principles and Standards for School Mathematics*)

(View a full text of the Principles and Standards for School Mathematics)

Measurement — Grades 6-8

Apply appropriate techniques, tools, and formulas to determine measurements.

- *Solve problems involving scale factors, using ratio and proportion.*

APPENDIX B: TEACHER RESOURCES

http://media.nasaexplores.com/lessons/01-026/9-12_2.pdf
In this NASA lesson entitled *The First-Ever Space Rescue Vehicle*, students compare and contrast the aerodynamic design of parachutes and parafoils.

http://www.aero.hq.nasa.gov/edu/but/helicopters/helicptr.html
NASA offers a kid-friendly multimedia explanation showing how helicopters fly.

http://www.airplane-and-helicopter-charters.com/astar-helicopter.html
This site provides information about helicopter models, including the AStar, the model that will be used for Genesis' mid-air capture.

http://www.cc.gatech.edu/projects/DITC/designTasks/parachute/keyConcepts/howParWork.html
Georgia Tech's *Design in the Classroom: How Parachutes Work and Fail* provides informative texts, activities, and an online video that discusses how the design and shape of parachutes affect their descents.

http://www.mcrel.org/epo/resources/sci_modeling.asp
Scientific Modeling, an informative text, highlights the benefits of using various types of models in science.

http://www.pbs.org/teachersource/mathline/lessonplans/msmp/awchute/awchute_procedure.shtm
Aw Chute! is a middle school math lesson, offered by PBS Mathline, in which students construct parachutes and use algebra to determine the rate of descent.

http://www.pbs.org/wgbh/nova/teachers/activities/pdf/3101_mars.pdf
To accompany the television program *MARS Dead or Alive, NOVA* features classroom activities for students to investigate the variables affecting a parachute's descent and to design a chute of their own.

http://www.physicsclassroom.com/Class/newtlaws/newtltoc.html
The Physics Classroom, developed for high school students, provides helpful explanations and animations to illustrate physics concepts and Newton's laws of motion.

http://www.swe.org/iac/LP/para_02.html
Parachutes and Parafoils, a lesson offered by the Society of Women Engineers, provides background information as well as directions and patterns for making different chutes.

Genesis Sample Return: Catching a Piece of the Sun

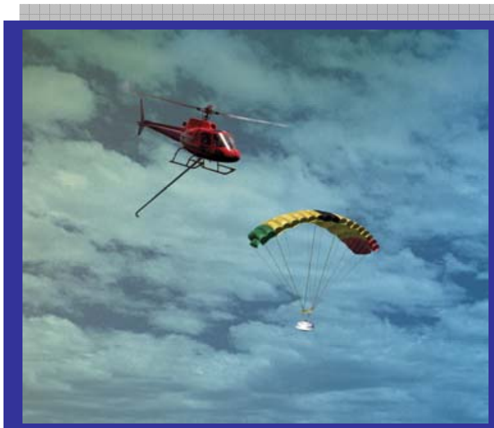
Model of Genesis' Mid-air Capture

STUDENT ACTIVITY—PART 2

BACKGROUND INFORMATION

In "Parachute Physics: A Lesson that Drags—Part 1," your group learned about and experimented with such physics concepts as:

- Balanced and unbalanced forces
- The acceleration of gravity
- The opposing force of air resistance, friction or drag
- How to affect the force of air resistance with the size and shape of parachutes
- How the unbalanced forces of gravity and air resistance counter each other, eventually leading to terminal velocity



Genesis' Dramatic Mid-air Capture!
Utah Test and Training Range
September 8, 2004

Now, in Part 2, your group will have a chance to model the Genesis mission's exciting mid-air capture using your best parachute design. The table below indicates the anticipated time, velocity, and altitude (in meters above ground) for each stage of the Sample Return Capsule (SRC) recovery process.

SRC Recovery Phase	**Time** *(begins when the SRC enters Earth's atmosphere)*	**Velocity** *(vertical descent of SRC in meters per second)*	**Altitude** *(meters above ground)*
Earth Entry	0 begins	11,000 m/s or 11 km/s	125,000 meters
Drogue Chute Deployment	2.2 minutes after Earth entry	425 m/s	33,000 meters
Main Chute Deployment	6.5 minutes after Earth entry	44 m/s	6,700 meters
Helicopter Capture	19 minutes — first attempt begins	4.5 m/s	Capture range: First pass 2500 meters — last pass 1500 meters above ground

PROCEDURE:

1. Refer to the parachute recommendations you made at the end of “Parachute Physics” in Part 1. Your group only needs one parachute for the simulation. You may rebuild your Part 1 chute or build a better one. If you decide to build a new parachute or did not do the previous activity, then using the space below, design a sketch of your parachute with the attached Sample Return Capsule (film canister). Be sure to include the following:

- The materials used in constructing the chute
- The dimensions of the chute in centimeters
- The length of the chute strings
- Show how the SRC (canister) will be attached to the chute

2. Using the provided materials, make your parachute. As a group, agree to a specific number of coins or washers you will place inside your film canister (SRC).

The film canister will hold _______ (#) of coins during this mid-air capture simulation.

3. Your group will be given a piece of cotton string and pipe cleaners to use as a hook and retrieval equipment for the mid-air capture. In the space below, sketch a design for your retrieval equipment. Include the dimensions for both the string and hooking device.

4. Create your retrieval equipment using the design in #3.

5. After making your retrieval equipment, test it to be sure that it can adequately snag and hold your parachute.

a) Does it work? Is it strong enough to hold the parachute? ☐ **Yes** ☐ **No**

b) If "no," what can you do to change the equipment and correct the problem? Explain below and then correct the problem.

6. Your group will simulate the mid-air recovery process to scale.

a. Determine the scale you will use and fill in the blanks below.

The Genesis mission planners used 125 km above ground as a reference point to designate where the SRC enters Earth's atmosphere. In our simulation, the parachute will be dropped from a height of ____________ meters above the ground.

One meter/millimeter in our simulation equals ___________ meters/kilometers in the actual Genesis sample return. (Circle the unit of measurement used in your scale.)

b. Complete the chart below to indicate the scale you'll be working with for your simulated capture.

Stages of Sample Recovery	**Altitude in the Genesis Mission** *(kilometers above ground)*	**Altitude or Height in Our Simulation's Scale** *(meters or millimeters above ground)*
SRC Enters Earth (or parachute drop)	125 km	
Drogue Chute Deployed	33 km	
Main Parafoil Deployed	6.7 km	
Mid-Air Capture	Occurs between 2.5 and 1.5 km	Enter range
Ground	0	"Ground" is represented by the end of the paper strip. In the simulation, the "ground" will need to be slightly above ground; for example, "knee level."

7. You will use either a roll of streamers, adding machine tape, or butcher paper to stretch the entire distance/height, from the location where your parachute will be dropped all the way to the ground. If using butcher paper, cut the strip so that the width is no more than 25 centimeters. The length of your strip depends on the height of your parachute drop location. At the top of the strip of paper, label the **Earth Entry** stage; include the reference point for altitude above the ground, and the velocity of the descending SRC. Then carefully measure and label the remaining stages of the sample recovery according to your simulation's scale: ***Drogue Chute Deployment, Main Chute Deployment, Helicopter Capture Range (upper and lower limits).*** Along with each stage, indicate the velocity and altitude of the actual SRC recovery process (refer to the chart on the first page of this activity).

8. Secure your labeled strip of paper to the place where you will release your model parachute. The end of the strip of paper represents the ground. It may be necessary to tape the end at a "knee level" height to allow some room for your group's simulated mid-air capture.

9. Your teacher will give each group a set amount of time to practice your recovery process using your retrieval system (string with pipe cleaner hook) and make any changes before the official trial runs. Then your group will have three official trials to capture the SRC by the parachute string within the helicopter capture range indicated on your paper scale. Record your results and any comments in the data table below.

Trial	Capture	No Capture	Comments
First			
Second			
Third			

10. After the three official trials, discuss the reflection questions below as a group and record your responses.

a) Explain why you think you were successful/unsuccessful.

b) Based on what you have learned, how could you improve your design?

c) Do you feel this simulation is a helpful model of the mid-air capture the Genesis team will encounter? Justify your response with explanations based on your experience.

d) How could this model be improved so that it more accurately reflects the variables the Genesis mission will encounter in the mid-air recovery process?

Genesis Sample Return: Catching a Piece of the Sun

The Physics of Genesis' Sample Recovery

TEACHER GUIDE—PART 3

OBJECTIVE: Students share the physical science applications of Genesis' mid-air capture.

In this activity, students develop a PowerPoint presentation in which they demonstrate their understanding of the physics concepts introduced in the previous activities by relating them to the Genesis' sample recovery.

MATERIALS

- Copies of "The Physics of Genesis' Sample Recovery—Group PowerPoint Presentation" with accompanying "Scoring Rubric."
- Paper to create a storyboard rough draft of each slide in the presentation.
- Computers equipped with PowerPoint software
- Genesis presentation graphics

PROCEDURE

1. In this activity, students have an opportunity to demonstrate their understanding of some of the physics concepts they learned in "Parachute Physics" and "Model of Genesis' Mid-air Capture." The PowerPoint presentation can be a collaborative small group activity; perhaps students could remain in the same parachute groups from Part 1.

2. Distribute the requirements and accompanying rubric for "The Physics of Genesis' Sample Recovery."

3. Before students begin developing their PowerPoint slide show of the sample recovery, it may be helpful to get them thinking about the parachute falling process and to determine at which point it would be best to initiate the mid-air capture. The Physics Classroom Web site contains an animation of a skydiver with the changing net forces of air resistance and gravity and their effects on acceleration. Watching the animation can help students identify at which points the forces are unbalanced and balanced.

4. Allow time for students to plan and draft their project. It may be necessary to show students how to resize, copy and paste, and animate the Genesis images.

5. Review tips for creating effective PowerPoint presentations. Some helpful tips are listed on a California State University Media Services flyer at: http://www.csus.edu/ums/pres-flr.pdf. More beneficial presentation guidelines are available at: http://www.powerpointers.com/cliotools.htm.

6. In preparation for the PowerPoint presentations, spend some time discussing public speaking conventions with students. A helpful student text, *Decision Making: Communicating, Questioning, and Listening,* is available online. Allow time for students to practice before making their final presentations to the class.

APPENDIX A: STANDARDS

NATIONAL SCIENCE EDUCATION STANDARDS ADDRESSED

(Source: *National Science Education Standards*)

(View a full text of the National Science Education Standards)

Science and Technology — Grades 5-8

Abilities of Technological Design

- *Identify appropriate problems for technological design.*
- *Evaluate completed technological designs or products.*

Understandings about Science and Technology

- *Scientific inquiry and technological design have similarities and differences.*
- *Science and technology are reciprocal.*
- *Perfectly designed solutions do not exist.*

Physical Science — Grades 5-8

Motions and Forces

- *The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.*
- *An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.*
- *If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.*

***Science in Personal and Social Perspectives* — Grades 5-8**

Risks and Benefits

- *Individuals can use a systematic approach to thinking critically about risks and benefits.*

NATIONAL LANGUAGE ARTS STANDARDS ADDRESSED

(Source—*Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education–3rd Edition*)

(View a full text of Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education)

Language Arts - Grades 6-8

Uses listening and speaking strategies for different purposes.

- *Makes oral presentations to the class (e.g., uses notes and outlines; uses organizational pattern that includes preview, introduction, body, transitions, conclusion; and point of view; uses evidence and arguments to support opinion; uses visual media).*
- *Uses appropriate verbal and non-verbal techniques for oral presentations (e.g., modulation of voice, inflection, tempo, word choice, grammar, feeling, expression, tone, volume, enunciation, physical gestures, body movement, eye contact, posture).*

APPENDIX B: TEACHER RESOURCES

http://deepimpact.jpl.nasa.gov/high_power/pdf/STCommQuesListen.pdf
Decision Making: Communicating, Questioning, and Listening, a student text available through NASA's Deep Impact mission, offers some helpful guidelines for public speaking.

http://www.jpl.nasa.gov/genesis/educate/kitchen/resource/factsheets/index.html
All of the Genesis mission fact sheets are available online.

http://www.jpl.nasa.gov/genesis/mission/return.html
Spotlight: Genesis Spacecraft Returns to Earth Sept. 2004, a feature story on the Genesis mission Web site, contains useful background information to assist students in developing their presentations.

http://www.physicsclassroom.com/Class/newtlaws/newtltoc.html
The Physics Classroom, developed for high school students, provides helpful explanations and animations to illustrate physics concepts and Newton's laws of motion.

http://www.powerpointers.com/cliotools.htm
A useful resource for developing effective presentations.

Genesis Sample Return: Catching a Piece of the Sun

The Physics of Genesis' Sample Recovery

STUDENT ACTIVITY—PART 3: GROUP POWERPOINT PRESENTATION

Purpose: In the previous activities, you've read about Genesis' action-packed sample return, had an opportunity to experiment with the physics of parachutes, and developed a model of the mid-air capture. Now it's your chance to show what you know by creating an animated PowerPoint slide show that explains the physics associated with each stage of this exciting solar wind sample recovery. A selection of graphics have been provided for you. These images can be resized, copied and pasted within your presentation. Working in a small group, your job is to put together animation, sound effects, and written explanations to develop an informative and captivating presentation about Genesis' sample return. Your teacher will identify the specific audience for your presentation.

Requirements for PowerPoint Presentation:

- A total of **six slides**
- **Slide 1** should include a catchy title, the name of the mission and all group members' names
- **Slides 2 - 6** should present the sample recovery process in order – beginning with the spacecraft separation—and show your understanding of the physics associated with each stage.
- Each slide must have images, animation, sound effects, and explanations.
- Explanations must describe what is happening at each stage of the recovery. Be sure to address and show your knowledge of the following physics concepts and how they apply to Genesis' sample return:
  - ☐ ***acceleration of gravity***
  - ☐ ***air resistance***
  - ☐ ***velocity***
  - ☐ ***unbalanced force***
  - ☐ ***air friction***
  - ☐ ***terminal velocity***
  - ☐ ***balanced force***
  - ☐ ***drag***
  - ☐ ***mass***
- Explanations must be clearly written and edited.
- Students in each group must work together to design and plan the arrangement and information presented in the slide show.
- Each student is responsible for writing and presenting at least one of the recovery stage slides.
- As a group, practice your presentation and provide feedback to each other regarding the content (Is it interesting? Clearly explained?) as well as delivery (voice, pacing, eye contact, use of visual aids).

The Physics of Genesis' Sample Recovery

SCORING RUBRIC: GROUP POWERPOINT PRESENTATION

The rubric below can be used to evaluate each group's presentation on The Physics of Genesis' Sample Recovery. Some boxes were left blank so that teachers may add evaluation criteria of their own.

	0	1	2	3	4
Understanding of Content ***The following concepts must be identified and thoroughly explained:*** *- Acceleration of gravity* *- Unbalanced force* *- Balanced force* *- Air resistance* *- Air friction* *- Drag* *- Velocity* *- Terminal velocity* *- Mass*	Not enough information presented to evaluate your groups' understanding.	One or more of the required pieces of information is missing.	Demonstrates a basic understanding of the physics related to Genesis' sample return. However, one or more of the listed requirements is incomplete or based on incomplete information.	Demonstrates a complete understanding of the physics concepts related to Genesis' sample return, but not in great detail. More information is needed for one of the required concepts and/or how it relates to Genesis.	Demonstrates a complete and detailed understanding of the required physics concepts and how they apply to Genesis' return.
Communicates Effectively with Presentation Software	Your group's presentation is confusing and hard to follow because of several communication problems in two or more of the following areas: - Written explanations - Visuals, animations, sound effects - Public speaking skills	A part of the presentation is confusing or hard to follow because of a communication problem in one of the following areas: - Written explanations - Visuals, animations, sound effects - Public speaking skills	Your group communicates the required information; however, one of the following features of the presentation needs improvement: - Written explanations - Visuals, animations, sound effects - Public speaking skills	Your group clearly communicates the required information using: - Error-free written explanations - Appropriate visuals, animation and sound effects - Appropriate oral presentation skills that do not distract the audience.	Information about Genesis' return is communicated clearly and effectively using: - Well-written explanations - Engaging and appropriate visuals, animation and sound effects - Strong oral presentation skills that keep the audience attentive.

	0	**1**	**2**	**3**	**4**
Participation	The presentation reveals that your group did not work well together or use class time wisely to prepare and practice.	Your presentation reveals that your group needs to collaborate better. It appears that one or two people did the majority of the presentation. Time spent preparing and practicing as a group is inadequate.	Your presentation shows that your group may have worked well together at times, but not always. One or more participants did not contribute equally to the actual presentation. The group may have practiced in preparation for the presentation, but not as much time spent as needed.	Your presentation reveals that your group worked well together. Each person contributed equally to the presentation. A bit more time spent preparing and practicing would have been helpful.	Your presentation reveals that your group worked well together. Each person contributed to a strong presentation that reflects a significant amount of time spent preparing and practicing.

Adapted from Marzano, Robert J. (2000). *Transforming classroom grading*. Alexandria, VA: Association for Supervision and Curriculum Development.