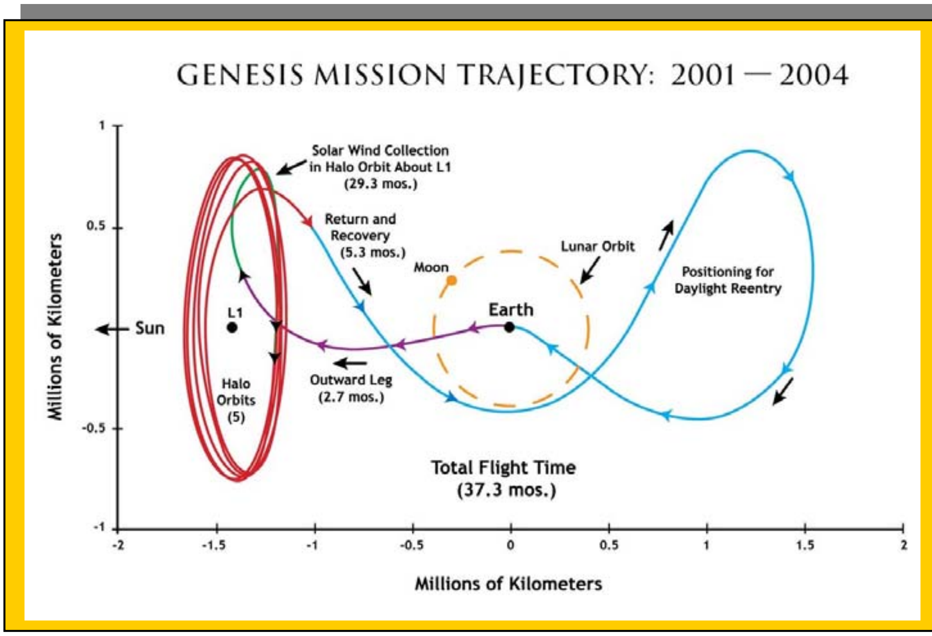
GENESIS SEARCH FOR ORIGINS Education

Sample Analysis

What Are We Made Of? The Sun, the Earth, and You

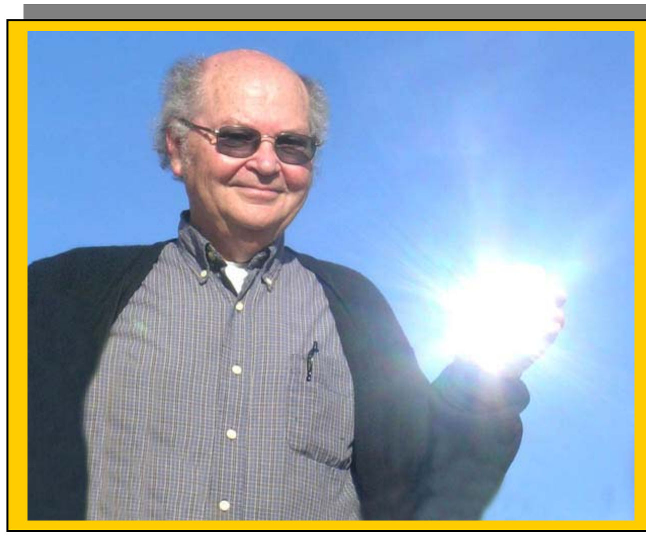
TEACHER GUIDE

BACKGROUND INFORMATION



Genesis is one of NASA's Discovery missions, and its purpose is to observe the solar wind, collect its ions, and return them to Earth. Launched on August 8, 2001, the spacecraft traveled to a point about 1.5 million kilometers (just under 1 million miles) from Earth where the gravitational attraction of Earth and the sun are balanced: the Lagrange 1 point, or "L1." At this location Genesis was well outside of Earth's atmosphere and magnetic environment, allowing it to collect a pristine sample of solar wind. Genesis' overall flight path resembles a series of loops: first curving towards the sun and away from Earth to the L1 point, circling five times around it, and then falling back for a brief loop around the opposite Lagrange point, called "L2," in order to position the spacecraft for a daylight return to Earth.

The spacecraft's science instruments worked together to categorize and sample the solar wind. The collection period concluded on April 1, 2004. Three weeks later, Genesis executed the first of five thruster firings, sending it on a trajectory that eventually placed its sample return capsule in Earth's upper atmosphere on September 8. As if the return of NASA's first space sample mission since Apollo 17 were not dramatic enough, the technique in which the sample return capsule was to capture adds to the mission's distinctiveness. As the capsule parachuted toward the ground at the U.S. Air Force's Utah Test and Training Range (UTTR), two three-person crews flying specially outfitted helicopters were on stand-by to capture the capsule in mid-air to prevent the delicate samples from being disturbed by even the slight impact of a parachute landing.



Don Burnett, Genesis Principal Investigator and Lead Scientist of California Institute of Technology, holds a collector wafer.

On September 8, 2004, the Genesis sample return capsule drogue parachute did not deploy during entry, descent, and landing operations over the UTTR. The drogue parachute was intended to slow the capsule and provide stability during transonic flight. After the point of expected drogue deployment, the sample return capsule began to tumble and impacted the Test Range at 9:58:52 MDT, at which point vehicle safing and recovery operations began.

Despite the hard landing, due to the extraordinary efforts by the recovery team, samples were collected and preserved. Those samples have been taken to NASA's Johnson Space Center, Houston, Texas, where the collector materials are stored and maintained under extremely clean conditions to preserve their purity for scientific study throughout the century. Currently, samples have been distributed world wide to scientists who will continue analyses and begin building a new solar wind periodic table.

ACTIVITY OVERVIEW

Students will understand that elements are the basic building blocks of all things found on Earth and in space including water, the human body, and the Earth, the sun, and the planets. By counting elements extracted from a simulated sample, students will learn how the extraction of atoms from the Genesis samples help scientists have a better understanding of the abundances of elements from the solar wind. The hands-on experience helps students to discover that the elemental abundances from the sun can be used as a baseline to compare with the diverse bodies of our solar system.

ESTIMATED LESSON TIME

Two 45 minute periods

> The bead amounts below do not reflect actual elemental abundances; these are for illustrative purposes only.

MATERIALS

- Computer, projector and speakers to view animation.
- Animation “The Journey” located online at: http://genesismission.jpl.nasa.gov/science/gen_anim.html
- One clear plastic shoe box-shaped container (6”x6”x5”h).
- Pony Beads (with a hole in the middle): A total of range of between 1000-4000 beads is best depending on your class size. The following are suggested numbers for a total of 3,549 beads. Percentages are also provided.
    - 2160 yellow representing the gold collector wafer materials (three large bags of 720) or 60.9 percent of total
    - 720 orange representing hydrogen one large bag of 720) or 20.3% of total
    - 360 blue representing helium (one half large bag of 720) or 10.1% of total
    - 245 green representing calcium (one small bag of 245) or 6.9% of total
    - 64 red representing oxygen or 1.8% of total

For each lab group:

- One 8 oz. clear plastic cup for analyzing one sample
- Colored pencils or markers
- Periodic Table of the Elements
- Cardboard box lid (During classroom trials, we found that it was helpful to have a box lid for each group so that the pony beads are contained.)

- Student Activity Sheet
- Excel Spreadsheet Template (Optional)

PREPARATION:

- Pre-research: visit mission Website: http://genesismission.jpl.nasa.gov
- Prepare beads and containers before the start of the lesson

HELPFUL PRIOR LEARNING EXPERIENCES

Some familiarity with the Periodic Table of Elements and the element symbols used can assist student learning in this activity. Genesis offers an interactive Periodic Table that can provide some initial exposure to the content: http://genesismission.jpl.nasa.gov/educate/scimodule/cosmic/ptable.html

PROCEDURE

Part 1: What Are Elements?

1. Distribute the student handout to each student. Much of the ensuing discussion coincides with the handout questions. Depending on your students' level of understanding and background knowledge, you may choose to have students complete the handout during the class discussion or afterward.
2. Ask students to identify the composition of water (hydrogen and oxygen) or the atmosphere (nitrogen, oxygen, argon, carbon dioxide).
3. Ask students to classify these components as elements or compounds and place this information on the board:
    a. Hydrogen-element (only Hydrogen atoms)
    b. Oxygen-element (only Oxygen atoms)
    c. Nitrogen-element (only Nitrogen atoms)
    d. Argon-element (Only Argon atoms)
    e. Carbon dioxide-compound (each molecule has one carbon and two oxygen atoms)
4. Ask students to identify what makes carbon dioxide different than the other components. (Students might suggest that carbon dioxide is made of two different types of atoms, where the others are made of only one type of atom.)
5. Explain that they just defined an **element as a substance made up of a singe type of atom**. An element cannot be broken into simpler components by chemical processes. Explain that there are 92 naturally occurring elements that can be solids, liquids, or gases. Prompt students to write their own definition on the handout.

Part 2: What Are We Made Of?

> **Helpful Starter Questions**
> 1. Do you have all of the elements in your body?
> (Answer: No)
> 2. How many elements are in your body?
> (Answer: about 13 main elements with some trace elements)

1. Ask students to list the thirteen elements that they think make up the human body. List these on the board.
2. Explain that an easy way to remember the thirteen elements is with the fun phrase and a Periodic Table of the Elements: See Hopkins Cafe More Salt or C HOPKINS Ca Fe More Na Cl. Use this phrase to list these thirteen elements: C for Carbon, H for Hydrogen, O for Oxygen, P for Phosphorus, K for Potassium, I for Iodine, N for Nitrogen, S for Sulfur, Ca for Calcium, Fe for Iron, M for Magnesium, Salt= Na for Sodium, Cl for Chlorine. Note that there are other trace elements not found in this fun phrase: (Cobalt, Copper, Zinc, and Fluorine).
3. Prompt students to complete the matching activity on page 2 of their handout.

Part 3: What Is the Earth Made Of?

1. Next, direct students to page 3 of their handout, "Elements on Earth." Explain that the table highlights the top ten most abundant elements on Earth and the relative percent of Earth's mass. The elements are distributed unevenly, with some much more common than others. The ten most

abundant elements on Earth make up more than 99% of our planet as shown in the following table:

Element	Symbol	Relative % of Earth's Crust
Oxygen	O	46.6
Silicon	Si	27.7
Aluminum	Al	8.1
Iron	Fe	5.0
Calcium	Ca	3.6
Sodium	Na	2.8
Potassium	K	2.6
Magnesium	Mg	2.1
Titanium	Ti	0.4
Hydrogen	H	0.1

Table 1: The Ten Most Abundant Elements on Earth

2. After students study table 1, ask them questions similar to the following:
   a. Describe the three columns of information in this table. (element, element symbol, relative percent of Earth mass which compares the abundances of this element)
   b. Which is the most abundant element found on Earth? (oxygen)
   c. How does the amount of iron compare with the amount of aluminum? (There is less iron.)
   d. Compare the amounts of sodium and potassium found on Earth. (There is roughly the same amount of each of these elements. There is slightly more sodium than potassium—0.2 percent more.)

Part 4: What Is the Sun Made Of?

1. Explain to students that because we live on Earth, it is easier to determine the relative amounts of Earth's elements than we can from objects in space. Direct students to consider question 7 on their handout: How do you think we could determine the relative abundances of elements from an object in space, such as the sun? (Accept all responses. This question helps students to see the purpose for scientific space missions, like Genesis.)
2. Introduce the video animation, "The Journey," http://genesismission.jpl.nasa.gov/science/gen_anim.html to students by explaining that Genesis, one of NASA's Discovery missions, devised a plan for determining the relative abundances of elements from the sun. As they watch the video, ask students to consider: Why would it be beneficial to study the chemistry of the sun?
3. After showing the video animation, facilitate a class discussion by asking the following:
   - Why study the chemistry of the sun? What clues will it provide? (As the video revealed, 99% of the

Helpful Starter Questions

1. How big is an atom? (Answer: Between 0.1 and 0.5 nanometers)
2. How do we get atoms from the collector wafer? (See Going Further)
3. How many atoms were actually collected on Genesis? (Answer: 100,000,000,000,000,000,000 Or: One Hundred Quintillion)

materials in our solar system are preserved in the sun. Therefore, studying the sun provides clues to the formation of our solar system. The video mentions that the solar system formed 4.6 billion years ago. Spend a moment explaining to students about the **solar nebula**: the cloud of dust and gas from which our solar system formed 4.6 billion years ago).

- What is the greatest challenge of studying the chemistry of the sun? How did the Genesis mission overcome this challenge? (The video mentions the intense heat of the sun as 10,000°F. Genesis determined that they could collect solar wind that came from the sun from a safe distance.)
- What is the significance of solar wind? (The solar wind contains ions of every element. By collecting particles of solar wind, Genesis is able to analyze the elemental abundances of the sun, and therefore, the entire solar system as well.)
- What did Genesis use to collect solar wind? (Collection wafers were exposed to the solar wind and particles became embedded in the wafers.)

To assist you in answering students' questions, refer to the additional Genesis mission background information provided as an appendix in this teacher guide.

Activity: (Observation Stage)

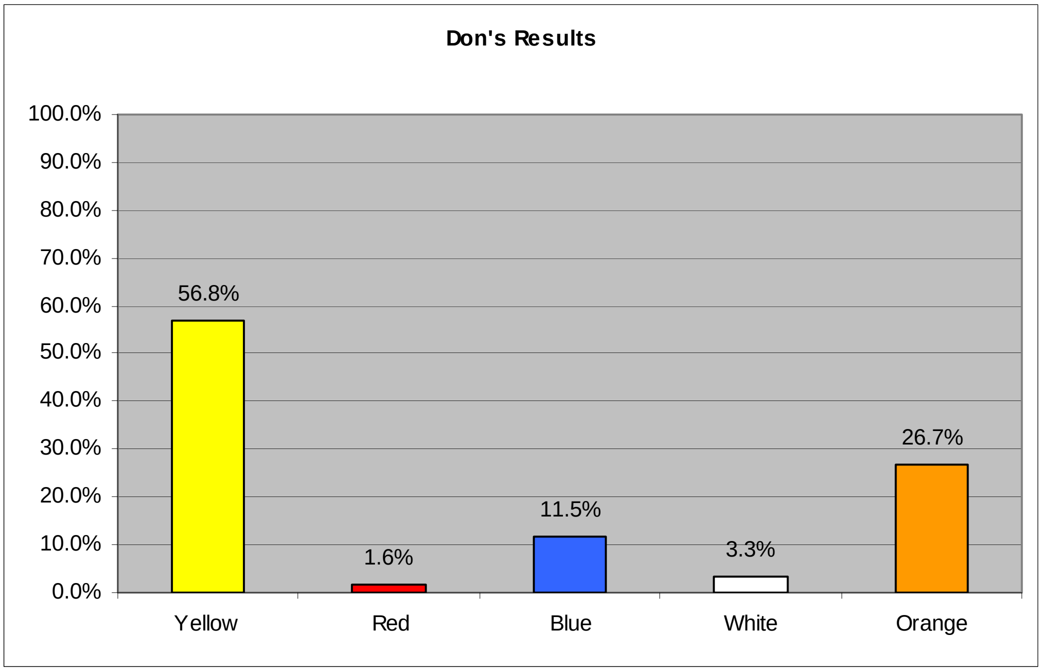
1. Show the large clear plastic container to the class. Explain that this container represents one Genesis collection wafer and that the yellow beads inside the container represent the atoms that make up the wafer. Explain that the other colors represent solar wind particles that have embedded into the wafer during the collection process.
2. Students should work in lab groups of three to four students per group. Once in the group, students should decide which color of bead each person will count.
3. Display the plastic container in the middle of the classroom so that students can see at least one side. The side view offers students a vantage point to analyze the wafer material and solar wind that has embedded into the wafer. Students should view each side of the container.

Activity: (Extraction Stage)

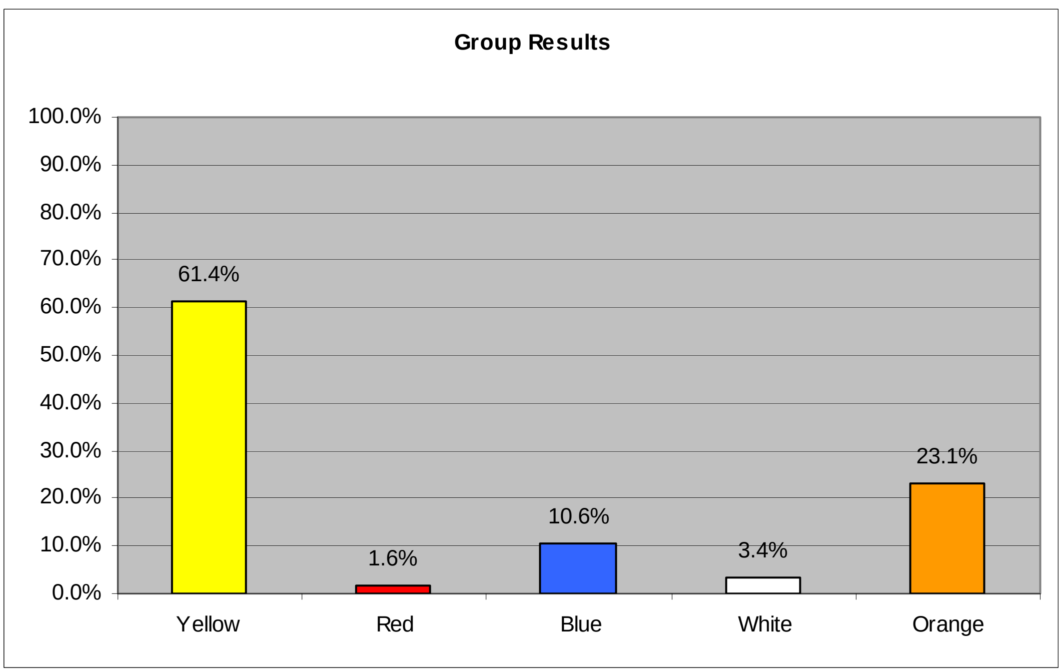
1. Working in these same lab groups, each group member should extract one handful of the beads and place them in a clear plastic cup.
2. Students should count their number of beads of each color in their cup and complete the data table.
3. Based on this sample, each group should now make a bar graph that depicts the percentage of different elements located in their sample.

Technology Application
Students may use the Excel spreadsheet to enter their data and create their own graphs for comparison.

Example Graph:



4. Students should compare their graphs with others in the class. Once each group has compared their elemental percentage, one student from each group can come to the board to contribute to a combined graph that represents the elemental abundances from the entire wafer (box). This student would share the total number of each element (color bead) from their group. The class can then make a graph showing the percentage of each element.



5. Ask students questions similar to the following:
    a. How did each of your elemental abundances compare with other groups'? (Students should state that while the exact amounts are different, the percentages are similar)
    b. Which graph do you think is a better representative sample of the solar wind in the wafer? Why? (Students should indicate that the reference graph is a better representation because it contains a larger sample than their individual, smaller samples.)
    c. What will the results from the Genesis mission science analysis tell us about our solar system? Hint: What did you do in the activity? (Students should indicate that Genesis is counting the different amounts of elements found in the sun, just like they counted the different colored beads in their sample. Genesis will help us learn more about the amounts of different elements from the sun.)

Activity (Analysis Stage)

1. Refer students to the "Comparing Earth to Sun" section of their handout. Students are provided with a table and graph containing a comparison of the composition of the Earth's crust and the sun's photosphere. After studying the table and graph, students should answer the questions provided on page 7 and 8 of the student activity sheet. Below are possible answers:

11. On the graph on the student activity sheet, lighter elements are on the left and heavier elements are on the right. Compare the percentage of elements in the sun's photosphere with the percentage of elements in the Earth's crust. Why do you think this is so?

Possible answer: The sun has a larger percentage of lighter elements compared with the Earth. This is because the sun's photosphere is made up of gaseous elements whereas the Earth's crust is made up of solid material.

12. The table and graph above shows percentages of each element in the sun's photosphere and the Earth's crust. Which body has a larger variety of elements?

Possible answer: When looking at the table, there appears to be a larger variety of elements found in the sun's photosphere. When looking at the graph the opposite appears to be true because the sun has a larger number of elements with small percentages that do not appear on the graph.

13. If Earth originated from the same solar gas and dust as the sun, why is learning the amounts of each element in the sun important to understanding the solar system?

Possible answer: The sun provides a baseline of the amounts of elements that scientists can then use to compare with the current composition of the planets. Genesis will prove a better understanding of this baseline.

2. Conclude by reinforcing that Genesis provides a better understanding of the composition of the early solar system, a baseline of the amounts of elements that scientists can then use to compare with the current composition of the planets.
3. Ask students, "If you could collect samples from space, what type of samples would you collect? Why?"

Going Further

Show the animation "Processing the Atom." http://genesismission.jpl.nasa.gov/science/gen_anim.html

Provide students with a second container filled with three shades of blue (light blue, medium blue, dark blue) beads or marbles in a collection matrix of yellow with the percentages similar to what was used before. Students extract as in procedure #3. This time, students should make the connection that these represent different isotopes of the same element. This would represent the isotopic abundances of one element on their periodic table. For more information on isotopes, advanced students can read the text, "The Periodic Table: Atoms, Elements, and Isotopes" located at: http://genesismission.jpl.nasa.gov/educate/scimodule/UnderElem/UnderElem_pdf/TeachText.pdf

Some advanced students might be interested in using the Secondary Ion Mass Spectrometer (SIMS) interactive simulation located at: http://genesismission.jpl.nasa.gov/multimedia/sims.html

The teacher guide that accompanies this interactive is located at: http://genesismission.jpl.nasa.gov/educate/scimodule/sims_mini-mod.pdf

National Science Education Standards Addressed[1]

Physical Science Grades 5-8

Properties and Changes of Properties in Matter

- There are more than 100 known elements that combine in a multitude of ways to produce compounds which account for the living and nonliving substances that we encounter

Principles and Standards for School Mathematics Addressed[2]

Data Analysis and Probability Grades 6-8

Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

- Select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatterplots

National Educational Technology Standards for Teachers[3]

Technology Productivity Tools

Students use technology tools to enhance learning, increase productivity, and promote creativity.

- Grades 6-8: Use content-specific tools, software, and simulations to support learning and research.

Technology Research Tools

Students use technology tools to process data and report results

- Grades 6-8: Select and use appropriate tools and technology resources to accomplish a variety of tasks and solve problems

[1] National Research Council. (1996). *National science education standards*. Washington DC: National Academy Press.

[2] National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. United States: Key Curriculum Press.

[3] International Society for Technology in Education. (2000). *Technology standards for teachers*. Eugene, OR: International Society for Technology in Education.

Sample Analysis

Additional Mission Information

APPENDIX

Overview
The Genesis spacecraft was launched on August 8, 2001, on a mission to "catch a piece of the sun." The spacecraft traveled more than one million miles toward the sun to a place called Lagrange Point 1 (L1) collected solar wind particles for 26 months. The sun is 93 million miles from the Earth, so the spacecraft was still at a safe distance.

The Genesis capsule returned to Earth on September 8, 2004 and the recovered solar wind collectors were delivered to a permanent curation facility at the Johnson Space Center. The collected solar wind atoms are being extracted from the collectors and are being analyzed to determine the abundances of isotopic materials in the solar wind which make up the ancient origins of the solar nebula. This crucial information may allow us to understand the very origins of our solar system.

The Collection Process
The Genesis spacecraft collected solar wind through a system of passive collector wafers and a new instrument called the concentrator. The wafers were mounted on five collector arrays that were 73 centimeters in diameter on the Genesis payload. Each array consisted of 54 complete hexagon wafers and six partial hexagon wafers. Each wafer is 85 millimeters across and 0.4 to 0.6 millimeters thick. There were four arrays stacked together in the container and one found on the lid. The lower stacked arrays were shaded from the solar wind when not in use. The top array and the array in the lid were used to collect bulk solar wind (they were always exposed). The bottom three arrays are used to collect samples from specific regimes of solar wind. The solar wind collectors are constructed from wafers made of very pure, very clean materials attached to an array frame. Most of the wafers were made from silicon, and others were diamond, platinum, and germanium. Some wafers were layered with aluminum and gold. The science team chose these materials as collectors because each has advantages during analysis. The wafers captured and held the solar wind samples. Throughout the two year solar wind collection period, every element from hydrogen to uranium was collected on the wafers for analysis upon the spacecraft's return to Earth.

For more information, download additional mission fact sheets at:
http://genesismission.jpl.nasa.gov/educate/kitchen/resource/factsheets/index.html