DOCUMENT RESUME

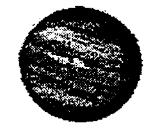
ED 430 786		SE 062 562

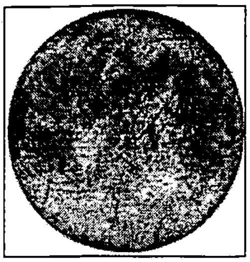
TITLE	"Galileo Calling Earth..."
INSTITUTION	National Aeronautics and Space Administration, Washington, DC.
PUB DATE	1999-00-00
NOTE	8p.
PUB TYPE	Guides - Classroom - Teacher (052)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Astronomy; *Integrated Activities; Middle Schools; Science Education; Scientific and Technical Information; *Space Exploration; Space Sciences; *Technology; Technology Education
IDENTIFIERS	*Galileo Orbiter; Jupiter (Planet)

ABSTRACT

This guide presents an activity for helping students understand how data from the Galileo spacecraft is sent to scientists on earth. Students are asked to learn about the concepts of bit-rate and resolution and apply them to the interpretation of images from the Galileo Orbiter. (WRM)

“Galileo Calling Earth...”





Grade Level: Middle school
Description: How is the data from the Galileo spacecraft sent to scientists on Earth?
Objective: Students will learn about bit-rate and resolution, and then apply these concepts to the interpretation of images from the Galileo Orbiter.

Materials: Pencils for shading
Vocabulary: Digital signals, charge-coupled device (CCD), pixel, resolution

Introduction

Except for some journey's to the Moon, all spacecraft sent to explore the solar system have been one-way trips. This means that the information collected, including pictures, has to be sent back to Earth electronically. At first, this would seem to be very easy; after all, television stations beam billions of pictures into homes every day. However, the energy required for TV broadcast is very high and the signal gets very weak after a few tens of kilometers. Not only is the distance in space much greater, but the energy available on the spacecraft is tiny -- the total is less than the light bulb in your reading lamp. To solve this problem, cameras on the spacecraft convert pictures into **digital signals** that can be sent as a series of ones and zeros using very little electrical power. This exercise will show you how these digital images (“pictures by the numbers”) work.

Because film is not returned from the spacecraft, we must use some other means to record a picture. Most spacecraft today use cameras somewhat similar to home-use video cameras, based on **charge-coupled devices**, or **CCDs**. CCDs are electronic “chips” divided into a grid (see Figure 1). Each cell in the grid is called a picture element, or **pixel**. To keep track of the pixels, the grid is divided into lines and samples. The area to be “pictured” is focused by a lens onto the CCD, which is sensitive to light -- the more light, the higher the electrical charge. The electrical charge of each pixel (identified by line and sample) is measured and recorded in computer memory, then sent back to Earth.

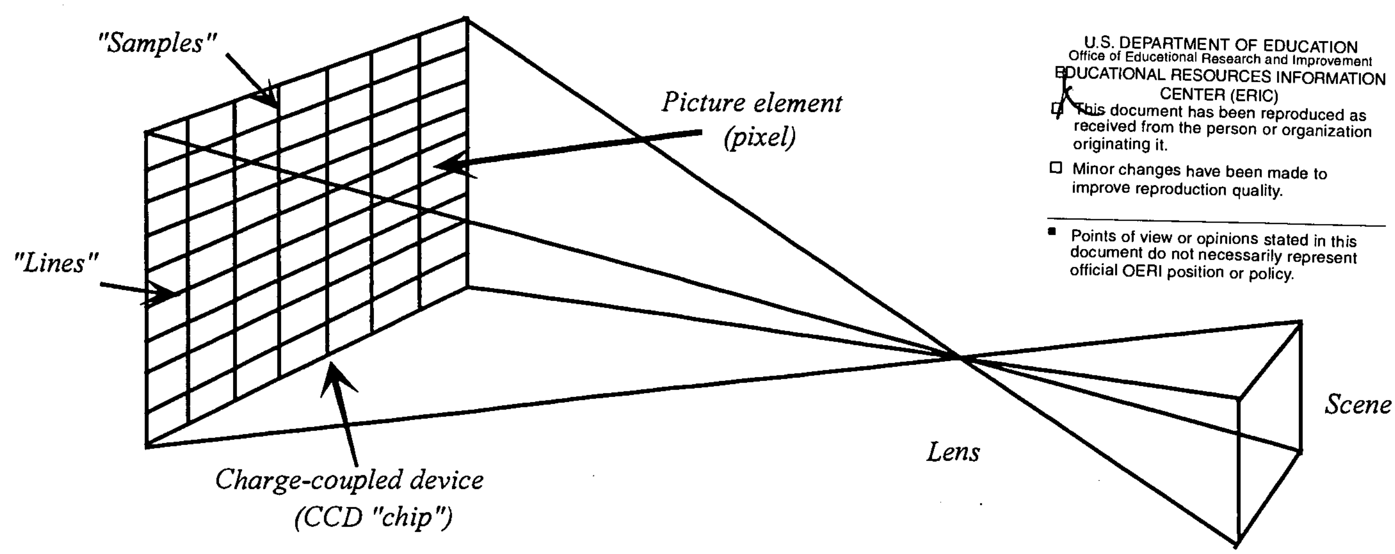


Figure 1. Charge-coupled device (CCD) cameras receive the "scene" from a lens, much like a conventional camera. Each "pixel" measures the brightness level electronically.

Graphics

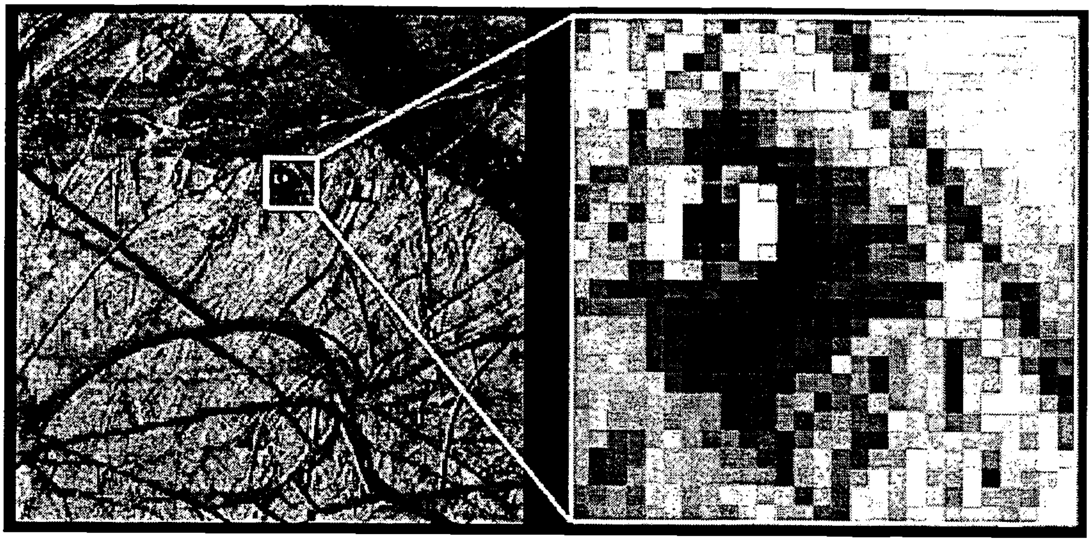


Figure 2. The picture on the left shows part of the moon of Jupiter, named Europa, taken by the CCD camera on board the Galileo spacecraft. It covers an area about 97 km (60 miles) wide. The enlargement on the right shows the actual pixels and levels of grey that make up the image.

						b							
					b	b	b						
				b	b	b	b	b					
			b	b	b	b	b	b	b				
		b	b	b	b	b	b	b	b	b			
b	b	b	b	b	b	b	b	b	b	b	b	b	b
b	b	b	b	b	b	b	b	b	b	b	b	b	b
b	b	b	b	b	b	b	b	b	b	b	b	b	b
b	b	b	b	b	b	b	b	b	b	b	b	b	b
b	b	b	b	b	b	b	b	b	b	b	b	b	b

b = black

Figure 3

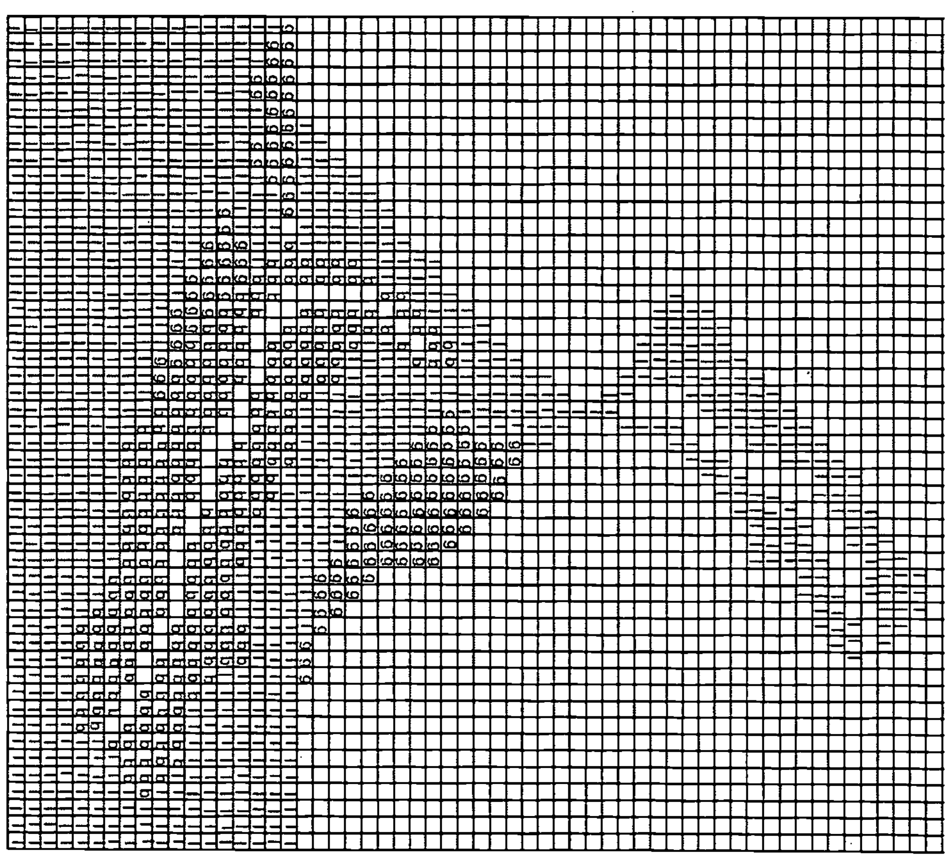
"Galileo Calling Earth..."

Graphics

										l			
									l	l	l		
								l	l	l			
						l	l	l	l				
						l	l	l					
					l	l	l						
					l	l							
						l							
						l							
					l	l	g						
				l	b	g	g	g					
			l	b	l	l	l	g	g				
		l	l	b	b	l	l	l	g	g			
g	g	g	g	b	b	b	b	l	l	l	l	l	l
l	l	l	g	g	b	b	b	b	b	b	l	l	l
l	l	l	l	l	l	l	b	b	b	b	b	b	l
l	l	l	l	l	l	l	l	l	l	b	b	l	l
l	l	l	l	l	l	l	l	l	l	l	l	l	l

l = light gray
g = dark gray
b = black

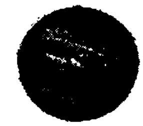
Figure 4



l = light gray
g = dark gray
b = black

Figure 5

"Galileo Calling Earth..."



Student Worksheet

Name: ______________________________ Date: ______________

Procedure

Figure 2 shows an image returned from the Galileo spacecraft's CCD camera. The image is of Europa, one of Jupiter's moons. The area in the box is enlarged to show the pixels of different brightness levels (shades of gray). For simplicity, let us say that only two possible brightness values for each pixel can be returned to Earth, one value for bright pixels and the other value for dark pixels. In computer language, this would be called **1-bit** data, meaning 2^1 (2 raised to the first power), which equals 2 possible values (bright or dark). The computer attached to the camera keeps track of the value for each pixel by line and sample. Figure 3 shows a line and sample grid and the value for each pixel (blank square = white, or bright; *b* = black, or dark). Take a pencil and fill in each pixel labeled with a *b*. What do you see as the result? What type of landform might this be?

Although this is a crude picture, you should get the idea!

Now, how could we improve the result shown in Figure 3? Instead of having only black or white pixels, how about having some shades of gray? Remember that we still have to send the information on each pixel back to Earth electronically in computer form. Instead of 1-bit coding ($2^1 = 2$ values), we will use **2-bit** coding, or 2^2 ($2 \times 2 = 4$ values). Now we can have white, black, and two shades of gray. Figure 4 shows a grid "map" on which b = black, g= dark gray, 1 = light gray, and blank = white. Use a pencil and shade in these tones. Now what do you see? Do you see anything that you were unable to detect in the first picture?

We could continue improving the picture by increasing the number of gray levels with 3-bit data (2^3, or $2 \times 2 \times 2 = 8$ values), 4-bit data (2^4, or $2 \times 2 \times 2 \times 2 = 16$ values), etc. Most of the pictures you have seen for Jupiter and its moons used 8-bit encoding (2^8).

How many shades of gray does this represent? ______________

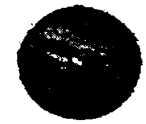
In fact, the human eye can separate less than two dozen shades of gray. This means that 8-bit pictures contain much more information than you could detect if you were looking directly at the area. Computer processing of the pictures enables all of the data to be used for analysis.

Can you think of some other ways of improving the picture shown in Figure 4? The grid is rather coarse, meaning there are not many pixels. Figure 5 shows the same scene but with more lines and samples of pixels. The encodement is still the same ($2^2 = 4$ levels of brightness). Shade the pixels using the same method as in Figure 4. Now what are you able to see in the picture?

This improvement refers to **resolution**, meaning the size of the area shown by one pixel. Resolution depends on the size and number of pixels on the CCD chip, the camera lens (telephoto, normal, or wide-angle lens), and the distance to the scene.

Now when you look at a picture from space, see if you can recognize the pixels and remember how the image was returned to Earth!

"Galileo Calling Earth..."



Teacher Notes

Answers to Questions

1. Figure 3. A cone-shaped mountain.
Ask your students what kind of mountain might be represented. The cone shape is typical of some types of volcanoes.

2. Figure 4. A cone-shaped mountain with a gray cloud above it. Shadows on the mountain and the cloud which appears to be oriented toward the right from the summit.
Now ask your students to consider the possible origin for the mountain and the cloud. This feature could be an actively erupting volcano, with the wind blowing from the left to the right.

3. $2^8 = 2x2x2x2x2x2x2x2 = 256$ shades of gray.

4. Figure 5. More shading gives detail on the mountain and in the cloud. In particular, there is a dark zone with a central bright stripe down the flank of the mountain. This image suggests not only that the inferred volcano is 'smoking' (active), but that lava is erupting from the summit and flowing down its flank into the foreground.
Ask your students to think about this last image as being taken of some unknown planet or moon. What could be deduced from this picture about the planetary object?

a. The surface is made of some material strong enough to form a mountain; this could be rock or frozen water; thus it would be similar to the terrestrial ('Earthlike') planets such as Mars or Earth's Moon, or similar to the moons of the outer planets. Eliminated would be the gas giant planets, such as Jupiter, because they lack solid surfaces.

b. The object must have an internal heat source, such as radioactive elements or internal tides, producing enough heat to lend to volcanism. In addition, it is volcanically active today. Only Earth, Io (a moon of Jupiter), and Triton (a moon of Neptune) are known to have active volcanoes.

c. The object has an atmosphere and active winds. Venus, Earth, Mars, Triton, and Titan (a moon of Saturn) are the only known solid-surface object that have significant atmospheres and winds.

Extension

- What is meant by the term **bit rate**? How fast can Galileo send information back to Earth? Why is this figure *lower* than the anticipated value for the mission?

PRELIMINARY ROUND 1
TEACHER REPLY FORM
BRINGING JUPITER TO EARTH:
An Educator Guide with Activities in Science, Mathematics and Technology

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

Please take a moment to respond to the statements and questions below. You can submit your response by mail or fax to: Richard Shope, Jet Propulsion Laboratory, 4800 Oak Grove Drive, MS 301-160, Pasadena, Ca. 91109, FAX (818) 393-9815.

1. With what grades did you use the educator guide and activities?

Number of **Teachers/Faculty**

____ K-4 _____5-8 _____9-12 ____Community College College/University
____Graduate
____Undergraduate

Number of **Students**

____ K-4 _____5-8 _____9-12 ____Community College College/University
____Graduate
____Undergraduate

Number of **Others:**

____Administrators/Staff ____Parents ____Professional Groups ____Civic Groups

____General Public Other ______________________________

2. What is your 9-digit zip code? __ __ __ __ __ – __ __ __ __

ACTIVITY TITLE: ____

3. How was the quality of this activity?

☐ Excellent ☐ Good ☐ Average ☐ Poor ☐ Very Poor

4. How did you use this activity?

☐ Background Information
☐ Demonstrate NASA Materials
☐ Integration Into Existing Curricula
☐ Lecture
☐ Team Activities
☐ Multiple Intelligences Activities
☐ Critical Thinking Tasks
☐ Group Discussions
☐ Hands-On Activities
☐ Kinesthetic Activities
☐ Collaborative Group Activities
☐ Science and Math Standards Integration

☐ Other: Please Specify: ________________________________

5. What features of this activity did you find particularly helpful?
(Please be as specific as possible, citing examples from activity you used)

6. How can we make this activity more effective for you?
(Please be as specific as possible, citing examples from activity you used)

7. Additional comments:
(Please address specific issues of concern to you, and ideas that you feel will help us improve this activity prior to its final publication.)

8. Please take a moment to consider how the activity you used fits within the matrices of the National Science Education Standards, the Mathematics Standards, and the Science Process Skills, by marking the appropriate boxes on the following pages.

   What role does these types of matrices play in your decision to use a particular lesson?

NOTICE

REPRODUCTION BASIS

☐ This document is covered by a signed "Reproduction Release (Blanket) form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☑ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").