Education Programs
Inspiring Tomorrow's Explorers
SPACE FOUNDATION

Get the Picture

Adapted from NASA Goddard Space Flight Center

Objectives

Students will:

- Simulate data transfer from a gamma-ray satellite to a computer and create an image from the data.
- Use matrix addition or subtraction to operate on data collected by a gamma-ray detector.
- Locate discrete gamma-ray sources in the universe by using the scientific method.

Suggested Grade Level

6th – 12th grades

Subject Areas

Science, Math, Technology

Timeline

Two, 50-minute periods

Standards

NGSS Standards

- **HS-PS4-5.** Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- **HS-PS4-2.** Evaluate questions about the advantages of using a digital transmission [and storage] of information.

21st Century Essential Skills

- Learning Skills (critical thinking, analysis, creativity, collaboration, communication)
- Literacy Skills (information, media, technology, environmental)
- Life Skills (flexibility, leadership, initiative, productivity, global awareness, listening)

Background

The activities found in this lesson provide students with a hands-on experience which will simulate the process of downloading actual data from a High-Energy Satellite and allow students to translate these data into colored or shaded pixels. Gamma-rays are the most energetic form of electromagnetic radiation, with over 10,000 times more energy than visible light photons. If you could see gamma-rays, the night sky would look strange and unfamiliar. The familiar sights of constantly shining stars and galaxies would be replaced by something ever-changing.

Your gamma-ray vision would peer into the hearts of solar flares, supernovae, neutron stars, black holes, and active galaxies. Gamma-ray astronomy presents unique opportunities to explore these exotic objects. By exploring the Universe at these high energies, scientists can search for new physics, testing theories and performing experiments which are not possible in Earth-bound laboratories.

Most gamma-rays are absorbed by the Earth's atmosphere. Thus, cosmic gamma-rays are typically observed from high-altitude balloons and satellites. As scientists seek to maximize the amount of useful data per observation dollar spent, they often will sum many smaller exposures to make a longer exposure which can reveal the source in greater detail. Exposure is a measure of how much useful data is obtained from any given observation.

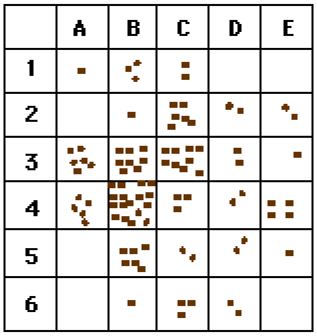
In gamma-ray astronomy, exposure is even more crucial than usual. Typically, as you go up in energy, any individual source emits fewer photons. Since gamma-rays are the highest energy photons, they are the most precious. Many gamma-ray observations of even the strongest sources can be weeks in duration.

In order to simplify these concepts, the first activity will demonstrate how the number of counts are assigned to a pixel or a predetermined location on the detector. The second activity demonstrates how the data are converted into colors or shades which allow us to view an image of a cosmic source.

In the first exercise, the pennies will represent the photons, and the egg crate separators represent the receiving instrument on the satellite. Let students take turns tossing a few pennies at a time into the egg crate separator. Continue until all 100 pennies have been tossed. If some do not land in the crate, do not worry, not all photons hit the high-energy satellite.

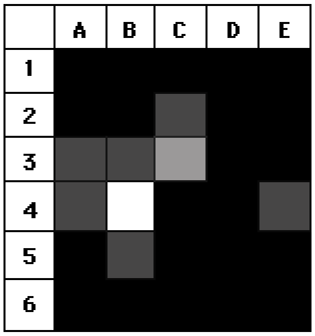
Count the number of pennies (photons) in each cup and fill in the corresponding 6X5 grid. Note: There are six vertical and five horizontal cups.

Samples of Penny Toss and Corresponding Matrix



	A	B	C	D	E
1	1	3	2	0	0
2	0	1	6	2	2
3	6	8	9	2	1
4	5	17	3	2	4
5	0	6	2	2	1
6	0	1	3	2	0

The second activity simulates the concept of binning. This is very similar to what you do with a histogram when you use a range of numbers for each category. You may assign the following colors to the data in the penny toss 0-3 = black; 4-8 = dark gray; 9-13 = light gray; numbers >14 = white. If your numbers do not correspond to the ranges we suggest, modify the ranges. Use the values you put into your 6X5 grid in the first activity to color in a new 6x5 grid. The picture below shows our data once colors have been filled in. In our experiment, 91 pennies landed in the egg crate and 9 on the floor.



Students should have a basic understanding of matrix addition and subtraction. Students should also have a basic understanding of the electromagnetic spectrum and concepts in astronomy/space science. See Imagine the Universe! (High-Energy Astrophysics Learning Center) CD or Website: http://imagine.gsfc.nasa.gov for more information.

Vocabulary

high-energy, gamma-rays, X-rays, matrix addition, matrix subtraction, actual data, satellite, Compton Gamma-Ray Observatory (CGRO), detector, photon, binned data, cell, statistical significance, statistical analysis, sigma, standard deviation, normal distribution

Materials

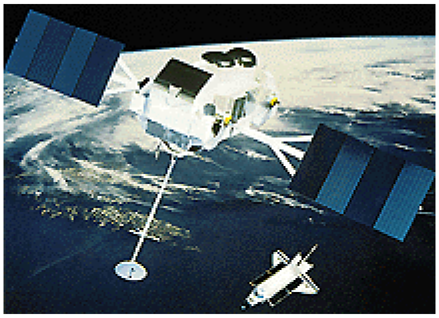
- 100 pennies
- 5 egg crate separators (holds 30 eggs)
- One transparency per group
- Tape
- Two 6 x 5 grids for each group
- Labels for egg crates
- One TI-82 graphics calculator per group
- 4 hours CGRO data
- 1 day of CGRO data
- 4 days of CGRO data
- 14 days of CGRO data

Lesson

Activity 1: Simulation of Data Collection

1. You will need to mark each egg crate separator in such a manner that you can identify each cell. Labels are available at the end of this lesson which can be printed and taped to the top and side of each egg crate separator. Prepare each egg crate by taping the labels A-E along the top and 1-6 along the side so that each egg cup can be uniquely identified.
2. Tell students that since we understand how numbers are assigned to different shades or colors, we can examine how scientists use high-energy data to

determine the location of a source emitting gamma-rays. The activity we are about to do simulates a high-energy satellite (such as the Compton Gamma-Ray Observatory) collecting data over time. Each group will be given one day's collection of high-energy photons, which they will enter into a 6 X 5 matrix.



3. Divide students into five groups (A-E). There is one egg crate separator needed per group. Stack the five egg crate separators on top of each other and place them on the floor at the edge of a table. Have a student or the teacher drop 20 pennies into the top layer of the egg crate separators, making sure the pennies are dropped from roughly the same location each time. This simulates a discrete source in the sky. The pennies should fall into several of the cups. Remove the top layer and hand it to Group A. Repeat the process of dropping 20 pennies from roughly the same location into each layer of egg crate separators and giving one layer to each group.
4. Once each group has an egg crate separator with pennies in the cells, you will use matrix addition to sum the data. Students can enter their 6X5 matrix in the TI-82 graphing calculator , making sure the letter of the matrix matches the letter of each group. Remind the students that if a cell is empty, they will enter 0 in that location. Students can then link and copy the data from the other calculators so that they have five matrices (A-E) to add, or they can copy their matrix on an overhead transparency and sum the data in the matrices by hand.
5. Tell the students that the location of a high-energy source cannot be determined unless the source's data shows statistical significance. In order to determine statistical significance, follow the procedure and explanations in "Finding a Source" (found at the end of the lesson).

ACTIVITY 2: Using Real Data

Now the students will be taking on the role of a high-energy astronomer in order to determine the minimum number of days of data needed to find the source. The importance of this real-life activity becomes obvious when one learns of the cost associated with collecting this data. Hundreds of thousands of dollars are spent each day collecting data, so finding a source in the least amount of time is imperative to astronomers.

1. Hand students the CGRO Data Collected Over 4 Hours and have them predict where any source(s) is(are) located. This allows for a good discussion of how to label the matrix so that all the students will know which cell is being discussed. Then have them look at CGRO Data Collected Over 1 Day to see if their predictions may still be correct or if they change their minds about where any source may be located. Using the CGRO Data Collected Over 1 Day, have students block off the eight cells surrounding the highest number (in this case, any pixels with >7) and check for statistical significance. See directions in "Finding a Source". Repeat this calculation for the CGRO Data Collected Over 4 Days, and 14 Days. Ask: during what time interval does statistical significance occur? Answer: it happens between 4 days and 14 days of data gathering.
2. The students should then determine the minimum number of days needed to determine the location of a source. They can do this by starting with 4 days and adding multiples of either 4 hours, 1 day, or 4 days until they achieve statistical significance. Remind them that they are looking for the MINIMUM amount of time required for the observation.
3. Ask students these follow up questions:
    a. How many separate sources showed up in the final data set?
    b. Was the 4 hour set of data useful in any way? (Compare what you get if you take 6 times 4 hours versus 1 day.)

NOTES TO TEACHER:

From the Data Collected Over 4 Hours, students will not be able to make accurate predictions even though there are two 3's evident in the data. There are two sources. The first will appear in the lower right quadrant after 4 days of data. The second source in the upper left quadrant will not appear until after 9 days of data. If students round to one decimal place, eight days of data will demonstrate statistical significance of the source but for an astronomer, that rounding will alter the significance of the source. To an astronomer it is very important to be absolutely sure that a source is located.

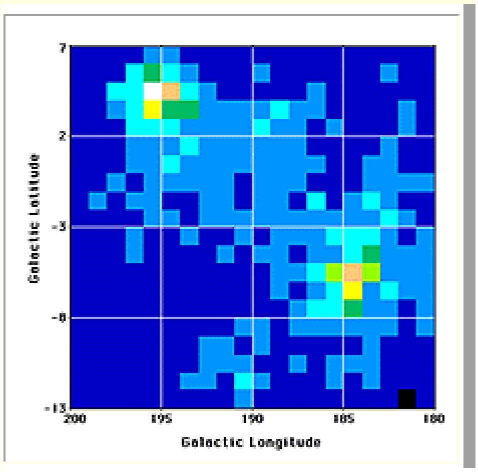
ACTIVITY 3: Get the Final Picture

1. Now we will have the students create an image from the CGRO data collected over the nine days determined in Activity 2. Images can be created by using several methods. Have one group use data from Day 1 and multiply it by 9. The next group should take data from Day 4 and double it then add data from Day 1. Another group could subtract Day 1 and Day 4 data from Day 14 or students could subtract 5x(Day 1) from Day 14. Students will then create color images from the binned data and compare pictures. Use the following color scale to color a 20x20 grid.

Black	0 - 1.3
Navy Blue	1.4 - 10.9
Medium Blue	11.0 - 20.0

Turquoise	20.1 - 29.6
Green	29.7 - 38.1
Lime Green	38.2 - 48.3
Yellow	48.4 - 57.9
Tan	58.0 - 67.0
Orange	67.1 - 78.6
Purple	78.7 - 85.5
Red	85.6 - 94.9
White	95.0 - 114.0

Below you will find actual CGRO image created by digital pixels using 9 days of data.



Data After Nine Days

Extensions

- Students could create a timeline for astronomical discoveries and superimpose it over a time line of historical events. In art class, students could create an artist's impression of a nebula, neutron star, black hole or other high-energy source.
- Students could create a short science fiction story in language arts class.
- Visit http://www.discoverspace.org/ for more innovative ideas and resources.

Evaluation/Assessment

- Final CGRO color image.

Resources

http://imagine.gsfc.nasa.gov/docs/teachers/lessons/picture/picture_main.html

CGRO Data Collected Over 4 Hours

0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	1	0	0	1	0	1	0	0	0	1	0	1	0
0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	1	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
1	1	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0
0	1	0	1	0	2	0	0	1	0	0	0	0	1	0	0	0	1	0	0
0	0	0	2	1	1	0	0	0	0	0	1	0	0	0	2	0	0	0	0
0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
0	1	0	1	1	0	3	0	0	0	0	0	0	0	0	0	1	0	0	1
0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	1	2	0	0	1	0	0	0	0	1	0	0	0
0	1	1	1	0	0	0	1	2	1	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	1	0	1	1	3	1	0	2	0	0
0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	2	0	0	0	0
0	0	0	0	0	0	1	0	1	0	0	1	0	1	2	1	1	0	1	0
0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0

CGRO Data Collected Over 1 Day

0	0	1	0	1	0	0	0	2	1	1	0	0	1	0	0	1	1	1	0
0	1	1	1	0	2	0	1	0	2	2	0	3	2	2	0	0	1	0	0
2	1	1	2	3	2	0	3	1	1	7	2	4	0	0	2	1	0	4	0
0	0	3	1	0	0	1	1	2	3	1	4	2	1	2	1	1	1	0	3
1	0	0	0	2	4	4	2	0	0	3	0	2	1	0	1	2	0	1	1
1	3	1	2	3	4	3	1	1	0	0	1	0	2	1	2	0	0	0	1
1	3	7	0	3	3	0	3	3	0	1	2	1	2	2	1	0	1	0	0
1	1	4	3	6	7	3	1	2	0	0	0	0	1	1	0	2	1	0	0
2	2	2	8	6	4	0	0	0	2	0	1	1	0	1	2	0	1	0	2
2	1	2	4	3	4	2	2	1	0	2	1	1	0	0	0	1	0	1	0
1	2	6	1	0	1	2	3	2	1	1	3	1	0	1	2	0	1	0	3
0	2	0	3	2	1	4	0	1	1	1	1	4	0	0	1	2	0	1	1
1	2	2	2	0	4	3	1	1	1	1	3	1	0	3	3	0	1	0	0
3	1	1	1	0	0	0	0	1	1	1	1	0	1	2	1	2	1	2	1
2	2	3	0	0	0	1	2	3	2	1	2	1	2	2	2	4	0	2	1
1	3	1	1	1	3	2	1	3	2	0	3	4	2	3	4	2	1	0	1
0	1	0	0	1	0	4	0	2	4	4	1	4	9	7	4	1	2	0	0
0	1	0	0	1	1	5	1	0	0	1	2	1	5	5	15	4	1	0	1
0	0	1	0	3	0	3	0	1	2	0	2	0	2	6	4	1	1	2	0
0	2	2	2	1	0	2	1	0	2	2	1	0	1	3	0	2	2	0	0

CGRO Data Collected Over 4 Days

00	00	03	01	03	02	01	02	06	04	06	07	05	02	02	04	01	04	02	00
01	01	04	09	03	10	00	03	01	05	12	02	08	11	04	00	01	04	03	02
05	05	04	08	04	05	03	06	06	07	12	07	08	02	00	02	01	02	06	00
02	02	04	10	01	05	02	06	04	07	02	07	04	03	07	03	02	05	00	04
06	03	04	06	06	12	07	06	05	03	08	04	04	02	04	03	05	01	03	02
08	04	07	09	14	11	09	06	06	04	03	07	03	03	02	05	01	05	01	02
05	09	11	06	21	08	05	06	08	02	05	03	03	04	05	03	03	02	02	02
07	05	09	14	27	19	11	09	07	04	03	01	04	04	04	02	02	03	02	01
05	04	09	21	16	09	05	04	08	06	01	07	06	02	04	04	04	04	01	02
06	05	07	09	16	10	09	07	04	06	05	04	06	04	02	04	05	03	04	03
04	08	14	03	05	06	08	09	07	08	05	07	07	02	06	05	04	02	04	05
01	05	06	09	06	03	10	02	06	09	05	07	10	04	03	05	04	00	05	05
06	07	04	08	04	06	04	03	04	09	06	07	06	04	08	12	04	05	03	01
04	01	08	06	01	03	05	03	04	07	06	07	09	09	13	07	06	07	05	05
03	03	07	04	03	00	04	09	07	06	05	08	10	12	09	06	08	03	05	03
03	08	02	03	08	08	04	04	07	11	07	06	08	04	11	15	11	05	03	06
04	03	04	02	04	01	08	02	06	07	13	08	09	21	21	25	12	05	06	02
00	02	02	04	07	01	09	02	05	02	04	02	04	11	24	50	13	09	03	01
02	02	05	00	03	02	03	03	03	08	02	04	02	07	12	17	09	05	03	03
00	04	04	03	01	02	03	04	04	04	06	04	01	04	09	03	05	04	01	02

CGRO Data Collected Over 14 Days

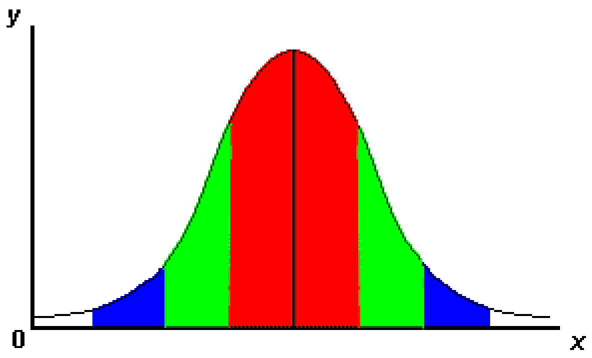
02	02	07	11	11	09	10	12	14	10	19	18	15	10	08	11	04	13	07	03
06	07	06	14	13	18	11	06	09	17	29	24	24	21	14	13	02	07	07	08
11	06	13	13	16	13	10	17	16	13	23	26	21	08	09	13	06	08	14	07
10	16	14	22	09	12	17	12	14	16	11	15	16	11	14	10	04	10	05	08
14	09	17	18	17	28	20	21	17	19	14	20	08	14	08	10	11	04	12	07
17	12	20	22	38	29	29	17	09	15	12	13	14	07	08	10	05	09	08	05
13	25	26	26	72	35	19	17	19	10	16	09	09	14	09	08	08	09	05	08
17	16	30	54	85	75	29	23	20	13	20	10	10	11	17	09	05	15	05	04
14	17	21	51	40	23	26	13	18	23	11	16	14	14	17	09	16	11	07	08
22	13	21	29	28	27	21	15	18	11	23	10	13	19	08	12	18	11	13	12
17	20	30	24	19	25	20	23	18	20	22	25	23	16	20	15	12	09	19	15
13	15	19	24	24	14	26	15	22	18	13	17	28	14	14	21	18	09	17	11
17	16	20	20	18	16	20	19	15	19	20	22	17	21	17	29	13	17	11	13
09	06	17	20	08	14	23	21	18	27	21	22	23	20	28	16	15	11	09	13
06	11	14	14	06	11	12	17	15	22	20	24	22	33	24	23	19	12	13	10
09	15	09	09	10	14	12	21	19	30	25	26	26	21	34	38	32	18	14	10
08	13	09	09	07	10	23	19	29	29	28	19	31	55	58	79	31	15	12	11
07	08	06	13	12	14	15	11	11	16	15	13	21	35	111	152	42	24	14	08
05	08	13	05	09	06	08	11	06	18	06	14	13	24	39	47	34	16	08	06
04	07	09	08	03	08	12	09	07	08	11	14	13	14	26	21	10	09	09	07

Finding a Source

How do scientists know when they have truly determined the location of a source emitting high-energy photons? They try to find out if the detection of the source has statistical significance, and in order to do this, they might use this "short cut" method related to standard deviation.

In order to understand what a standard deviation (also referred to as sigma) is and how it helps you to determine if you have detected a source or not in your data, we need to first learn about what statisticians call "normal distribution" of data.

A normal distribution of data means that most of the samples in a set of data are close to the "average," while relatively few samples tend to one extreme or the other. If you looked at normally distributed data on a graph, it would look something like this:

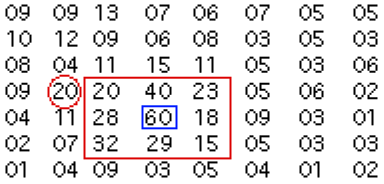


One standard deviation away from the mean in either direction on the horizontal axis (the red area on the above graph) accounts for about 68 percent of the data in this set. Two standard deviations away from the mean (the red and green areas) account for roughly 95 percent of the data. And three standard deviations (the red, green and blue areas) account for about 99 percent of the data. If the datum is greater than 3 sigmas away from the mean, it is truly an exceptional sample compared to all the rest of the data. This is what you would expect a source to look like compared to the background noise! In other words, if the difference between the two numbers you are testing is "greater than three times sigma", then you can be certain that you have located a source emitting high-energy photons.

In this activity, we can assume that one sigma is well approximated by the square root of the value of the pixel count that we are testing. You may ask your more advanced students to research why this would be the case, and when this approximation would break down.

Now consider the following:

Find the pixel with the highest number in it. Then exclude all of the pixels immediately surrounding this pixel and look for the highest number in any of the pixels directly outside the excluded area. In the example below, the maximum pixel count is 60 and the highest pixel count outside the excluded area is 20. Note that we exclude a box of pixels around the highest pixel because a real source will be imaged onto more than a single pixel; thus we exclude the nearest-neighbor pixels from consideration when looking for a statistical significance of a source (indicated by the maximum pixel count over the whole array) above the background, or noise.



09	09	13	07	06	07	05	05
10	12	09	06	08	03	05	03
08	04	11	15	11	05	03	06
09	20	20	40	23	05	06	02
04	11	28	60	18	09	03	01
02	07	32	29	15	05	03	03
01	04	09	03	05	04	01	02

So our source is 60, our sigma is sqrt(60)=7.8, and the highest pixel outside our excluded area is 20. We see that 60 - 3 x 7.8 > 20, so you can be 99% sure that you have located a source at the pixel position with 60 counts in it.

	A	B	C	D	E
1					
2					
3					
4					
5					
6					

Blank Grid, Activity 1

Egg Crate Labels

1 1 A A

2 2 B B

3 3 C C

4 4

5 5 D D

6 6 E E

"Better Living through Space"
June 2020

Space technology is all around us. Whether we rely on satellite imagery, GPS, novel materials or medical advances, space technology impacts our daily life. This month's field trip is focusing on how satellites "see." We use satellite data and images all the time. From forecasting weather to analyzing our changing climate to exploring distant places in space, satellites "see" things that we can't for ourselves.

Activity 1: "Pennies from Heaven"

Materials needed: empty egg cartons, tape, number and letters cut out, 100 small items like pennies, Skittles or beads, and a 6x6 graph print-out

Steps:

1. Cut the top off 3 egg cartons or 2 18-count egg cartons.
2. Tape the bases together so you create a grid of 6 cups by 6 cups.
3. Tape labels to the outside edge of the cups so that A-F is on the top of the grid and 1-6 is on the side of the grid.
4. Prepare 100 pennies, M&M's, buttons, or any other small object that can be dropped into the cups.
5. Place the egg carton grid on the floor. This is the satellite detector.
6. Drop your pennies or 100 other items from arm's length above the egg carton detector. These are light photons hitting the satellite detector.
7. After all items are dropped, count how many landed in each cup. Record the number on the graph below. Younger participants may need help recording numbers on the chart.

Follow up: Satellites do not see in color. Rather, they interpret an image based on how many of a certain wavelength of light hit their detector. The more times a detector is hit, the stronger that image source is. The strength of the image can be displayed in different shades of gray or different colors. Scientists add color to images ***after*** the data is received from the satellite. *You* can add color by designating numbers with colors. For example, if no objects landed in a cup, the cell stays white. If 1-3 pennies landed in a cup it is gray, 3-5 pennies equal dark gray, and black would be for anything over 5 pennies. You will not get a recognizable image, but you will understand how satellites "see" and why we can give any color we want to satellite images.

Satellites do not have just 36 detector cups. They have millions of detectors. Each cup could be called a pixel. In fact, 1 million "cups" per unit of measurement = 1 megapixel.

SPACE FOUNDATION
DISCOVERY CENTER

A B C D E F

1 2 3 4 5 6

	A	B	C	D	E	F
1						
2						
3						
4						
5						
6						

	A	B	C	D	E	F
1						
2						
3						
4						
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6						

	A	B	C	D	E	F
1						
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4						
5						
6						

Activity 2: “Pixel Pictures”

1. Print out several blank graphs (sheets below) — enough for each participant to do it at least once. Print enough picture graphs for at least half of the group.
2. Participants work in pairs to “send” and “receive” images. One will be the sender (the one with the pictured graph) and one the receiver (the one with the blank graph).
3. Line by line, the sender should tell the receiver which squares to color in. Just like a satellite, the sender should communicate a blank square or a black square using only the numbers “0” and “1”. Zero means the square is left white. One means the square is colored black.
4. The sender should NOT let the receiver see the picture. The receiver should say, for instance, “A1” and the sender should say zero if the box is empty, or 1 if the box should be colored in.
5. Continue until all the boxes are “read.” Compare pictures to see if the receiver got the correct information from the sender.
6. Now trade roles. Use a different image from another group. The Sender is now the Receiver and vice versa.

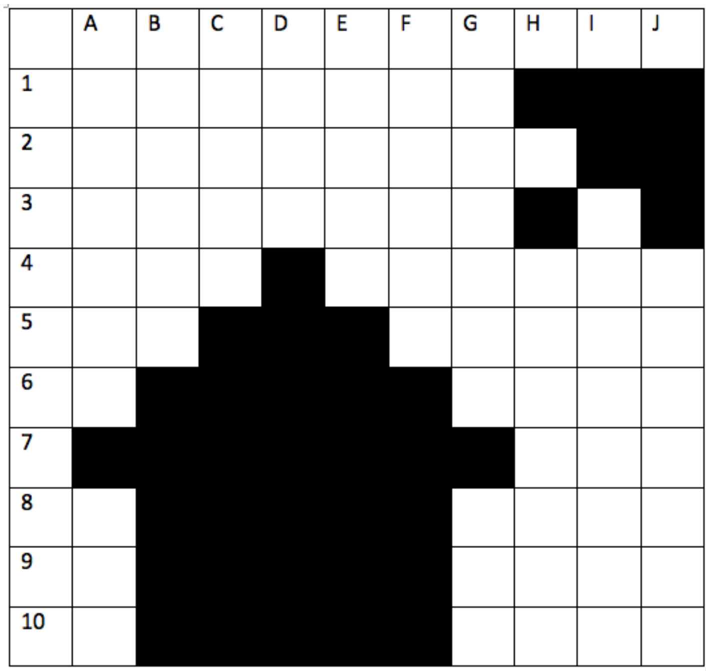
Follow up: It is difficult to see details of an image when there are only 100 squares “pixels”. The more squares we have in an image, the higher the resolution. Today’s satellites try to have as high of resolution as possible so you can zoom in on a location and still see a recognizable image.

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

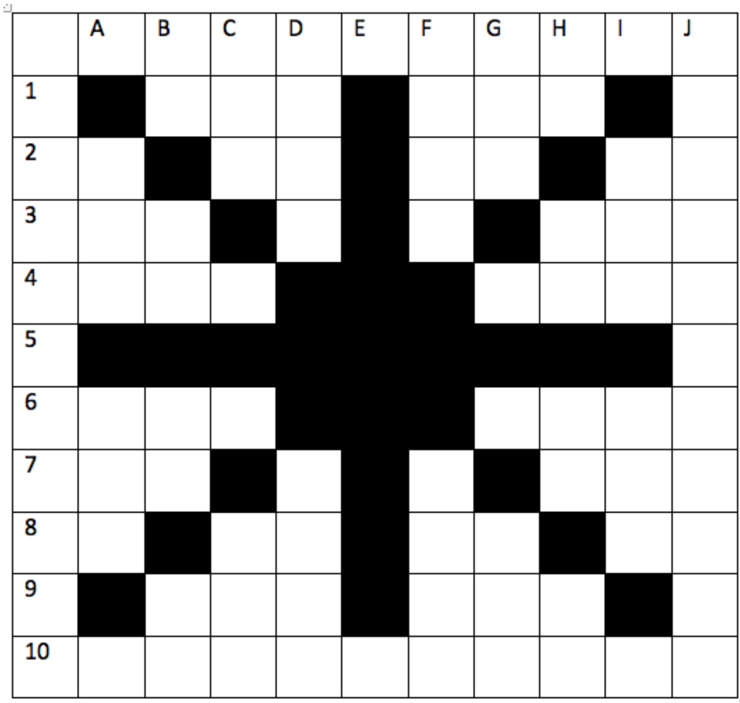
	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

	A	B	C	D	E	F	G	H	I	J
1										
2				■			■			
3				■			■			
4				■			■			
5										
6										
7		■							■	
8			■					■		
9				■	■	■	■			
10										

	A	B	C	D	E	F	G	H	I	J
1	■			■				■		
2		■			■		■			
3				■						
4	■	■	■	■	■	■	■			
5	■						■	■	■	
6	■						■		■	
7	■						■	■	■	
8	■						■			
9		■				■				
10			■	■	■					



	A	B	C	D	E	F	G	H	I	J
1								■	■	■
2									■	■
3								■		■
4				■						
5			■	■	■					
6		■	■	■	■	■				
7	■	■	■	■	■	■	■			
8		■	■	■	■	■				
9		■	■	■	■	■				
10		■	■	■	■	■				



	A	B	C	D	E	F	G	H	I	J
1	■				■				■	
2		■			■			■		
3			■		■		■			
4				■	■	■				
5	■	■	■	■	■	■	■	■	■	
6				■	■	■				
7			■		■		■			
8		■			■			■		
9	■				■				■	
10										

For the young ones that need a little more help:

	A	B	C	D	E	F
1		■			■	
2		■			■	
3						
4	■					■
5		■	■	■	■	
6						

	A	B	C	D	E	F
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2						
3						
4						
5						
6						

SPACE FOUNDATION
DISCOVERY CENTER

	A	B	C	D	E	F
1	■					■
2		■			■	
3			■	■		
4			■	■		
5		■			■	
6	■					■

	A	B	C	D	E	F
1						
2						
3						
4						
5						
6						