How Satellites See – The Martian

Adapted from the Lesson "How a Satellite Sees" Created by Vicky Gorman

Objectives

Students will:

- Use a simple binary system to relay information.
- Use a pixel method to put together and interpret images.
- Decide when images from the ground or sky are more helpful.
- Be able to describe differences between a photograph and an image.
- Understand that more pixels (higher resolution) equals a more defined image.

Suggested Grade Level

5th-12th grades

Subject Areas

Science, Math, Astronomy, Art

Timeline

45 minutes

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

Many satellites use rather basic technology, are decent resolution digital cameras in space, take individual pictures or continuous images along thin strips of land or sea, and relay their data by radio transmissions. Some Satellites are so powerful they can see objects that are just a few inches in size and, like the ones Google Maps and Google Earth use, can show objects that measure about 20 inches in size.

One misconception is that satellite images are photographs. Rather, satellites use

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remote sensing to collect information digitally. People use computers to convert this information to images. "Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." – Canadian Center for Remote Sensing.

Pixels are picture elements, where each pixel represents a square area on an image. Each square is a measure of the sensor's ability to resolve (see) objects of different sizes. By adding up the number of pixels in an image you can calculate the area of a scene. When scientists study the earth from space, they look at the amount of light reflected. The amount of light is characteristic of an object. For instance, the amount of light reflected from a rock, grass, or a pond, will be different. The satellite sensors give a different numeric value to each amount of light reflected. This data is then graphed. The graphs are called spectral signatures. By knowing the signature of a particular object, scientists can identify similar objects over a large geographical area. Because the amount of light reflected can be represented by numbers, if we just have the numbers, we can create an image. However, colors are often assigned.

Vocabulary

Pixels, resolution, binary, photographs, images, remote sensing

Materials

- Power Point "How Satellites See"
- Digital Art Blank Graph for half the class
- Digital Art Sample Pictures for half the class
- Black Crayons
- One set (envelope) of 3x3 squares and one numbered graph template per four students. Each envelope should contain:
  - Four 0's
  - One 1
  - Four 2's
  - Five 3's
  - Four 4's
  - Two 5's
  - One 6
  - Two 7's
  - Three 8's
  - One 9
  - One 10
  - Four 11's
  - One 12
  - One 13
  - One 14
  - Two 15's
  - One 16
  - Three 17's
  - One 18
  - Forty-six 19's
- One set of numbered strips per class

Lesson

1. Discuss the instance in the book when a satellite was most important (when they discovered Watney was alive because the solar panels had been cleaned off and the rover was moved).
2. Show Power Point, **slides 1-2.**

3. Do the following activity for how a satellite uses binary numbers. Place students into groups of two or three.
    a. Hand each pair of students a blank graph and a pictured graph. One will be the sender (the one with the pictured graph) and one the receiver (the one with the blank graph).
    b. Line by line, the sender should tell the receiver which squares to color in but using only the numbers 0 and 1. Zero means the square is left white. One means the square is colored black.
    c. 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.
    d. Continue until all the boxes are "read." Compare pictures to see if the receiver got the correct information from the sender.
    e. Try to make sure no picture is repeated at a large table (there are enough for four different patterns per table).
4. Show **SLIDES 3 – 6.** Discuss how the above activity relates to how satellites take images. Go over terminology.
5. Discuss if it is easier to monitor things from the ground or from space. **SLIDES 7 – 13.**
    a. Changes in landscape
    b. Where to build a new housing development or mall
    c. Where a farmer's dead crops are
6. Give each group a numbered graph template (the ones with large numbered squares) and display **SLIDE 14.** Students will work in groups of four. Also give each group an envelope with 3" squares. The students will work together to place them in the correct order on a grid. Once students are done, have them try to figure out what this could be. Tell them it is related to The Martian, but from the movie, not necessarily the book. (Also, this is not an image that would be seen from space. It was chosen because of the colors, as most things from The Martian are various shades of brown).
7. **Display slide 14 as they work.** The students probably will not be able to figure out what this is – they need more pixels! Have groups clean this activity up and **display Slide 15 – this is what they just put together.**
8. Give each group the laminated strips of pixel rows/columns (these are the ones that are colored and clipped together). The class now needs to work together to assemble this on one table. There are just too many squares to do this activity in the same way we did the first one, so the squares have been laminated in order in strips to make this easier/faster.
9. Once the strips are all placed, there may be enough pixels to figure out what this is if students are familiar with the movie: it is the Ares III mission patch! Display **SLIDE 16** – this is what they just put together (minus the border)!
10. **Show students Slide 17** and go over the extension activity.
    a. Tables will enter into a contest. Teacher will show **five slides, one at a time**, to the group. The slides start out with large pixel sizes. They need to guess what they are looking at. Teams will get the number of points corresponding to pixel size. Therefore, if they can guess what something is with a large pixel size, they'll

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get more points (the team with the most points at the end will receive your undying love and affection).
   b. Show the first set of slides (Slides 18-23). Wait a few seconds between each one. Team members must raise their hand to guess. Perhaps implement a penalty for teams that randomly guess without thinking they really know what it is.
   c. Repeat with slides 24 – 29, 30 – 35, 36 – 41, 42 – 47, and 48 – 53.
   d. The set with the comparison from the movie of the rover being moved is the whole point of this lesson – in the movie, the Earth-based NASA crew figured out Watney was alive because of satellite images of the Hab base.

Evaluation/Assessment

- Were the students able to figure out the pictures?
- Can they discuss how easy or difficult it was to figure out what they were looking at?
- Are they able to explain what they learned about pixels and how a satellite sees?

Extensions

1. Research different satellites. How do they transmit data? What are the different types of satellites? What happens to the old satellites once it is out of commission?
2. Design a new mission for surveying erosion. Have students research a place on Earth that is experiencing massive erosion. Then have students create/build a satellite that can take "pictures" of that specific area.
3. Visit http://www.discoverspace.org/ for more innovative ideas and resources.

Resources

Satellite Imaging Information:

- http://bgr.com/2014/02/13/google-maps-satellite-images/
- https://earthobservatory.nasa.gov/Features/RemoteSensing/remote_06.php
- http://www.tech-faq.com/how-satellite-images-are-made.html
- https://landsat.gsfc.nasa.gov/pdf_archive/How2make.pdf

Satellite Images:

- https://earthobservatory.nasa.gov/IOTD/view.php?id=88190
- http://www.dailymail.co.uk/sciencetech/article-2177202/The-changing-face-Earth-Dramatic-high-resolution-satellite-images-world-changed-decades.html
- https://www.cnet.com/pictures/see-before-and-after-of-earths-recent-big-changes-from-space/2/

Activities:

- https://batworld.org/wp-content/uploads/2011/03/EchotheBat1.pdf
- http://pinetools.com/pixelate-effect-image

"The Martian." Weir, Andy. New York: Crown Publishers, ©2011. (especially Sol 197 – 200).

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

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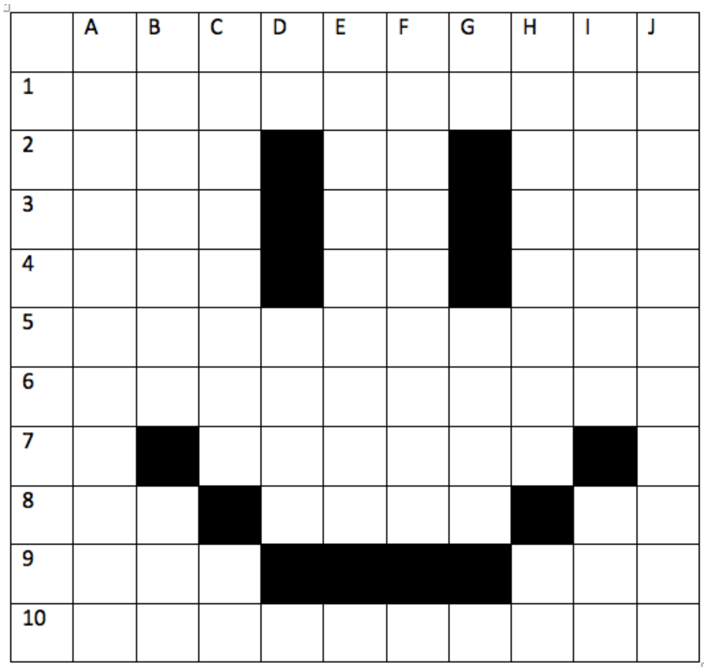

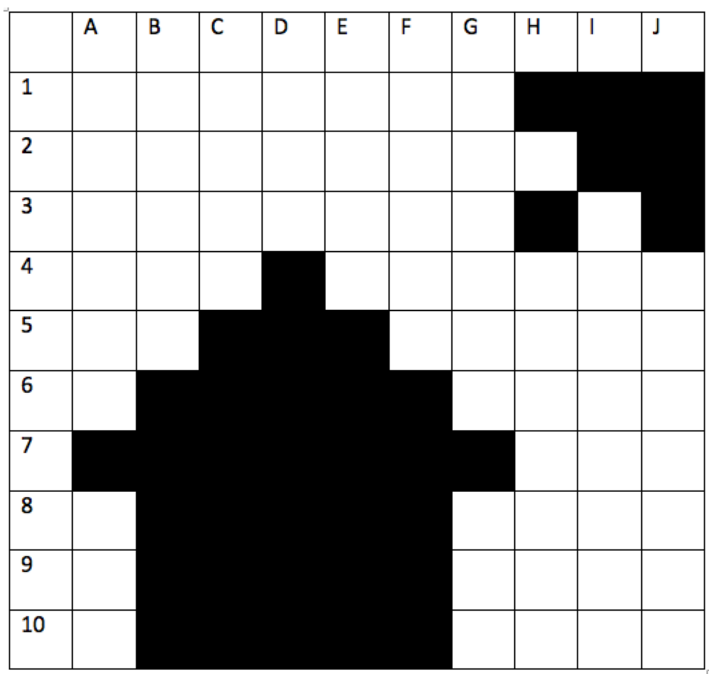

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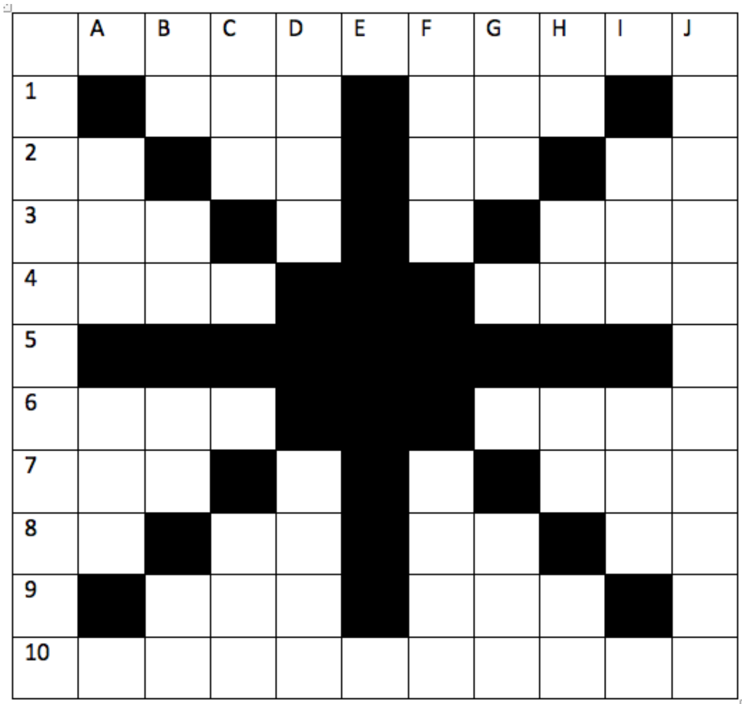
A B C D E F G H I J
1
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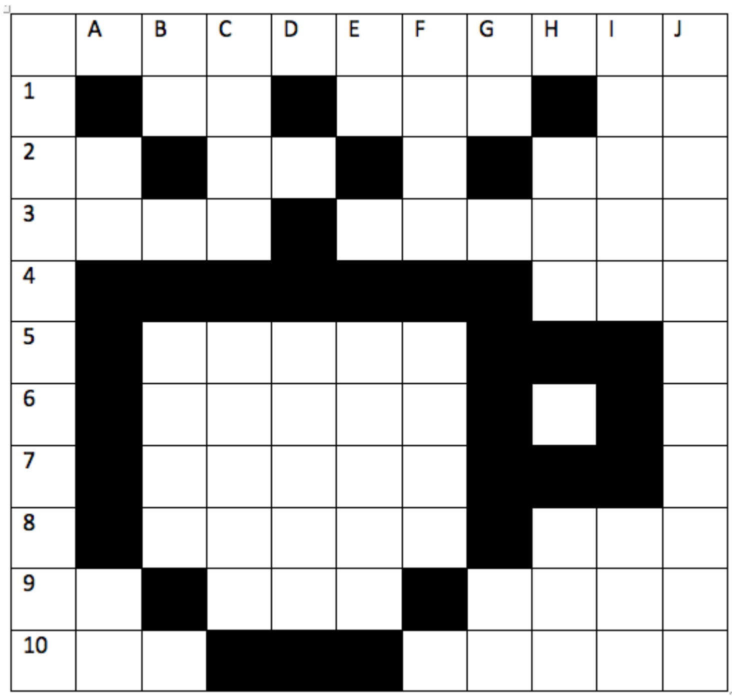
A B C D E F G H I J
1
2
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5
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Key for first mission patch pattern:

		0	1	3	4	19	8		
	8	19	19	19	19	19	11	4	
0	19	19	0	5	2	19	19	9	15
12	19	19	8	19	19	7	11	19	19
2	19	17	15	7	19	19	19	19	4
19	0	6	16	14	19	19	19	19	2
5	19	13	18	17	19	19	11	19	19
3	19	19	19	19	19	19	19	19	3
	3	4	19	19	19	19	19	2	
		17	19	19	3	10	11		

Color Key:

White = 0

Pink = 1

Gray1 = 2

Gray2 = 3

Gray3 = 4

Gray4 = 5

Yellow1 = 6

Yellow2 = 7

Brown1 = 8

Brown2 = 9

Brown3 = 10

Cream1 = 11

Cream2 = 12

Cream3 = 13

Orange1 = 14

Orange2 = 15

Orange3 = 16

Orange4 = 17

Orange5 = 18

Black = 19

Orange4 = 3

Orange5 = 1

Black = 46

Quantity of each color:

White = 4

Pink = 1

Gray1 = 4

Gray2 = 5

Gray3 = 4

Gray4 = 2

Yellow1 = 1

Yellow2 = 2

Brown1 = 3

Brown2 = 1

Brown3 = 1

Cream1 = 4

Cream2 = 1

Cream3 = 1

Orange1 = 1

Orange2 = 2

Orange3 = 1


ARES
LEWIS
WATNEY
VOGEL
JOHANSSON
BECK
MATRINEZ

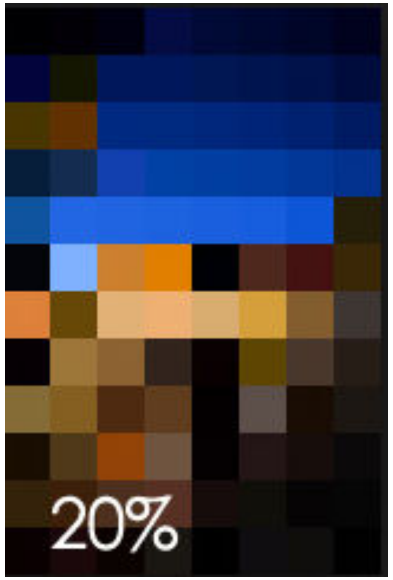
How Satellites See

- Zero = White Square
- Sender says, “Zero” every time a square should be left blank.

- One = Black Square
- Sender says, “One,” every time receiver should color in a square.

Pixels

- Pixels = picture elements
- Each pixel represents a square area on an image.
- Each square is a measure of the sensor's ability to resolve (see) objects of different sizes.
- Higher resolution (smaller pixel area) means the sensor is able to discern smaller objects.

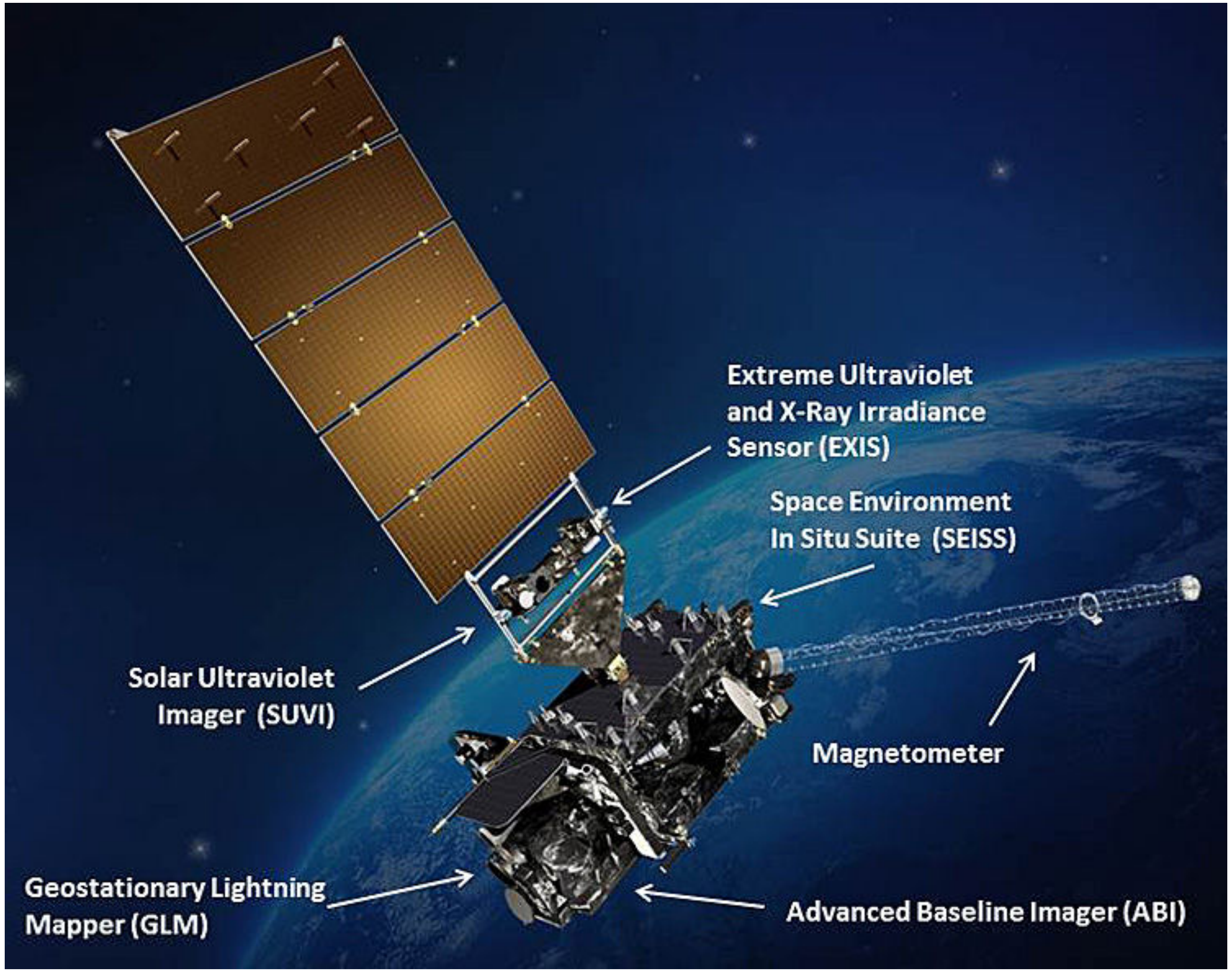


Misconception:

Satellite images are not photographs. Rather, satellites use remote sensing to collect information digitally. People use computers to convert this information to images.

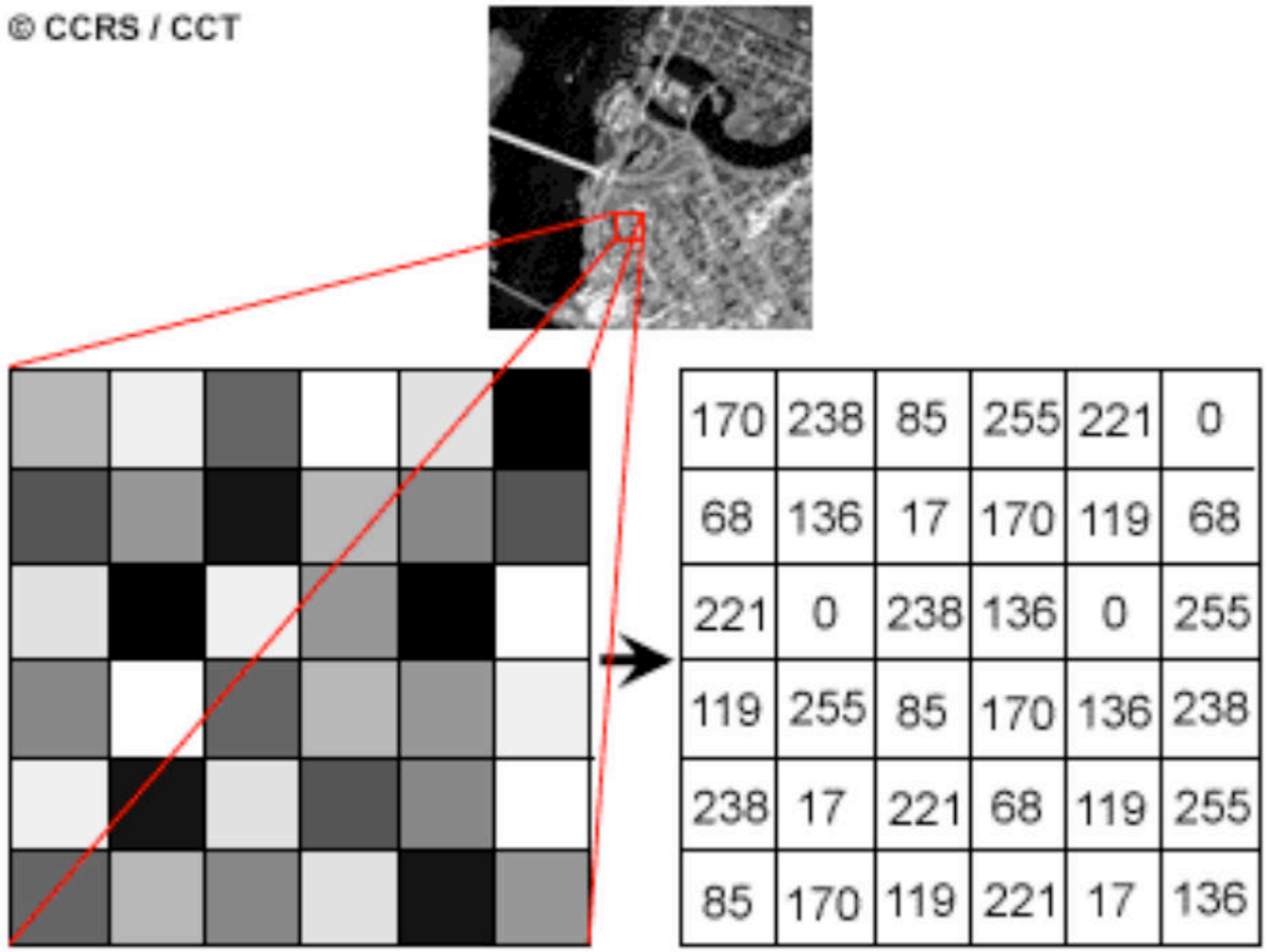
"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." – Canadian Center for Remote Sensing

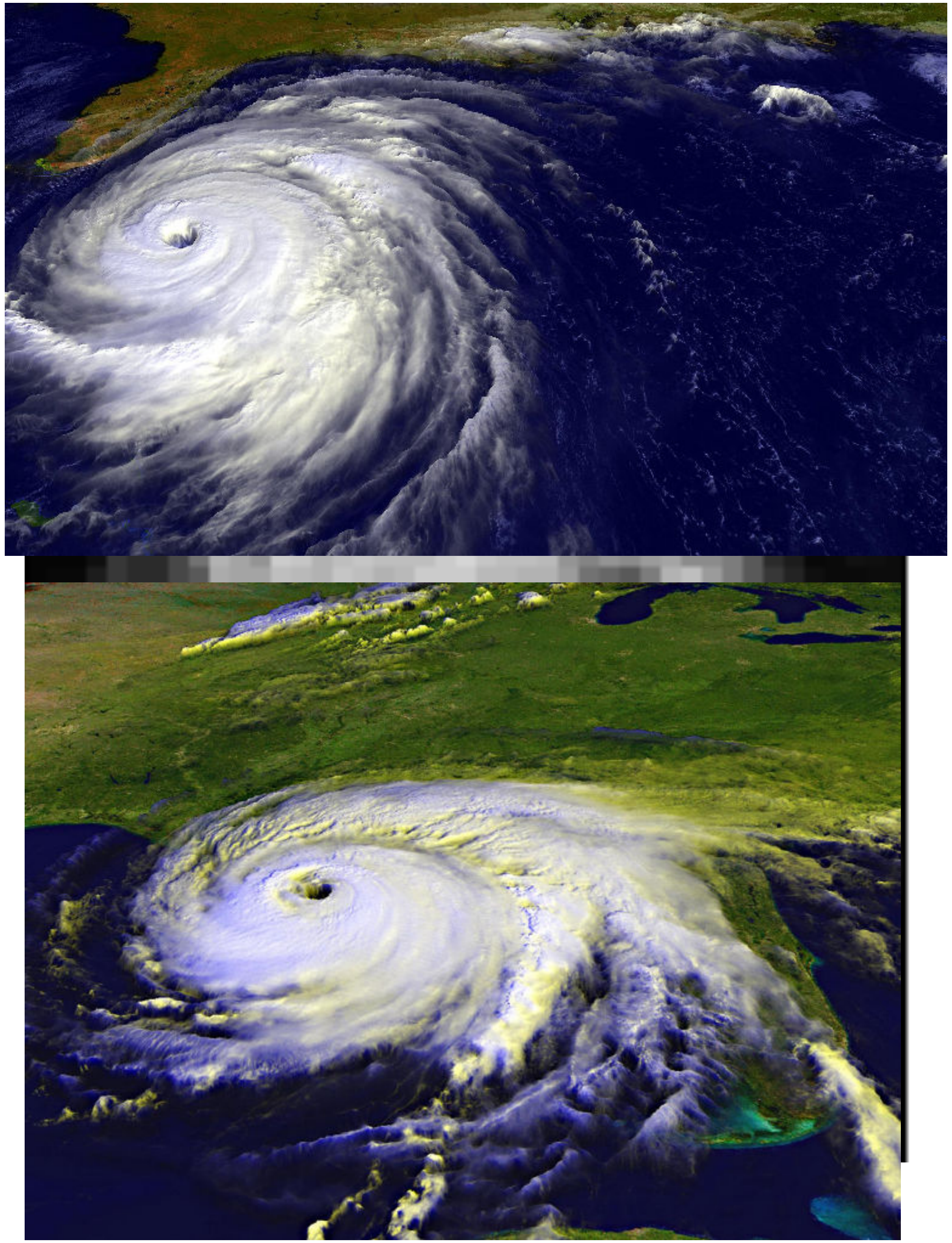
(Meanwhile, photographs are created using a camera, which uses a lens to focus the scene's visible wavelength of light into a reproduction of what the human eye would see).



Computers use binary numbers related to different shades of gray.

Spacecraft use 8-bit data, which means a computer has 256 shades of gray to choose from.





- This weather satellite image of hurricane Floyd from September 15, 1999, has been magnified to show the individual picture elements (pixels) that form most remote sensing images. (Image derived from NOAA GOES DATA)
- Colors are assigned later, by people.

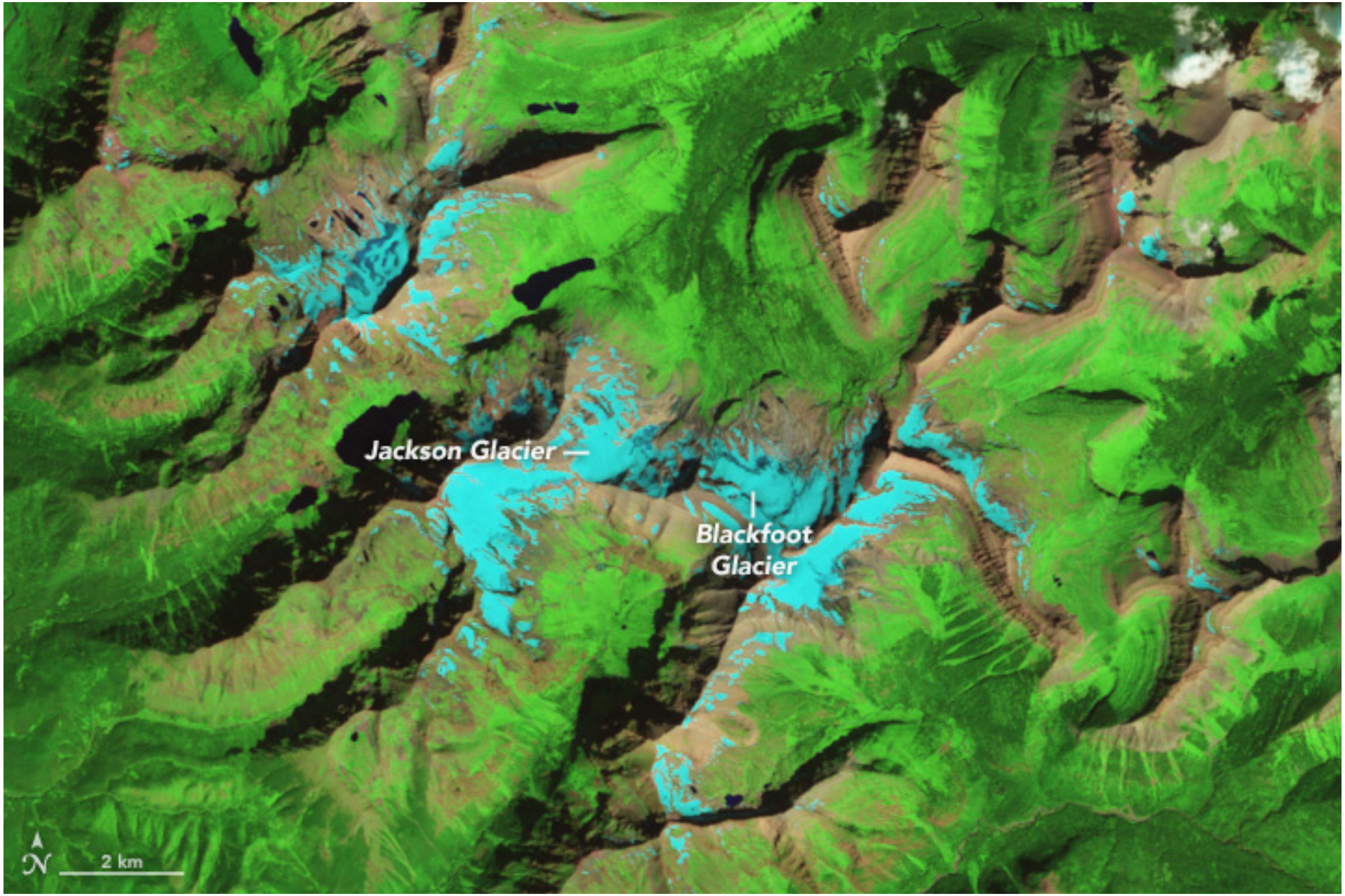
Would You Rather

Get your data from the air or on the ground?

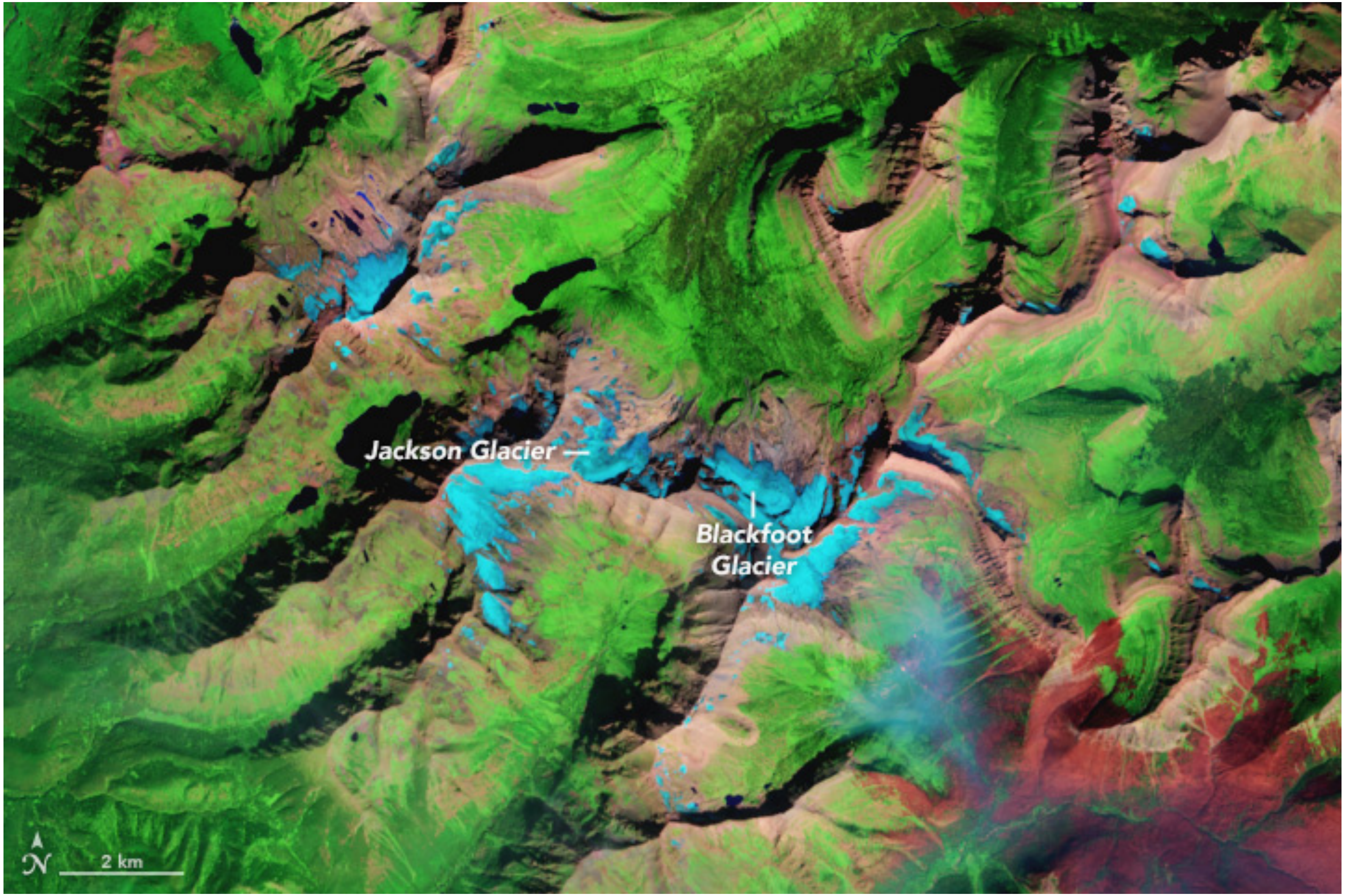
Let’s look at some examples.

What information can you gather from these next two slides?

1
9
8
4



2
0
1
5



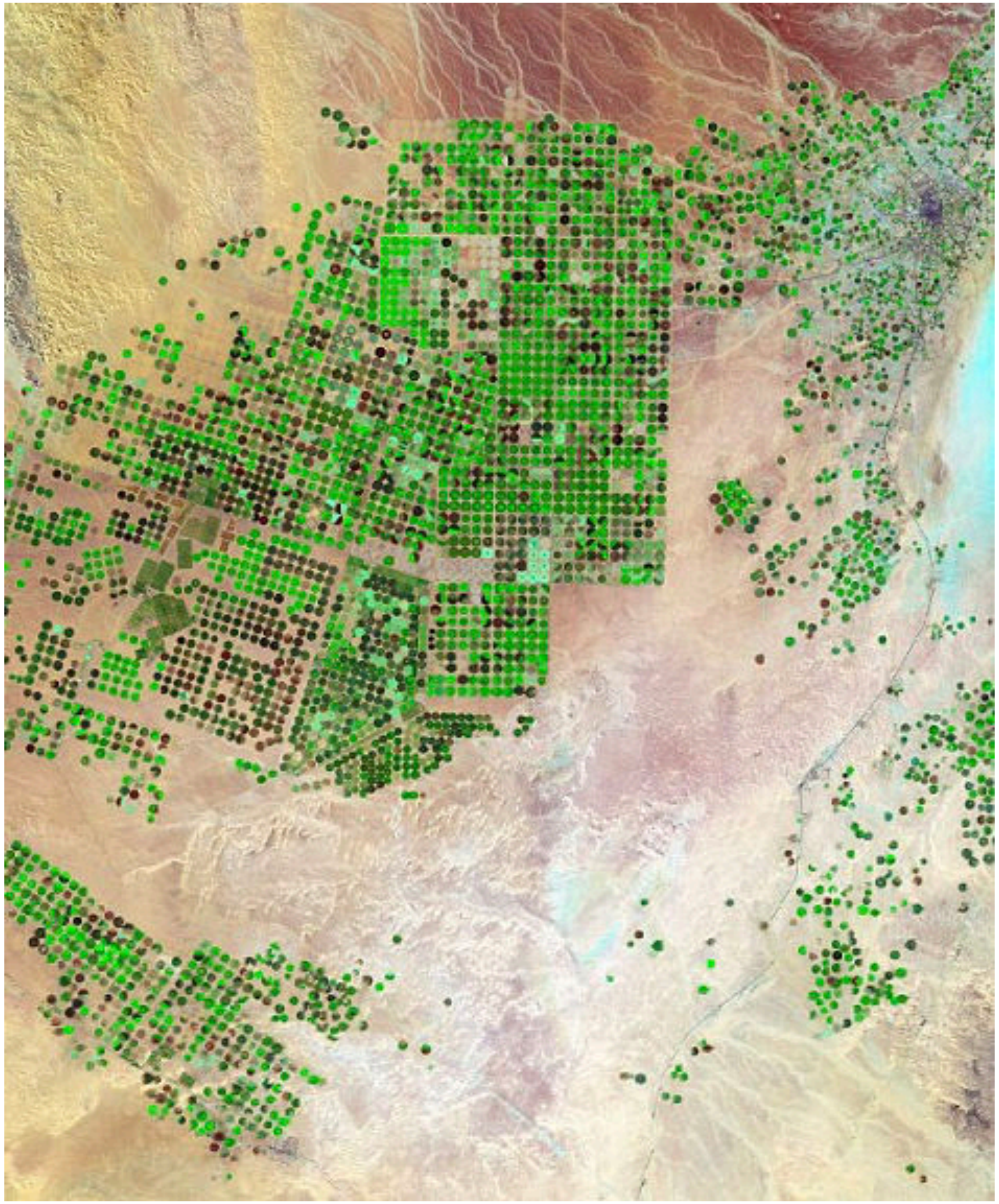
- If you search for information on Montana’s Glacier National Park, you will likely come across the date 2030. That’s the year by which this park will supposedly be glacier-free.

- Scientists arrived at the year 2030 through a simple geospatial model depicting the changes expected to occur to glaciers in the Blackfoot-Jackson basin.

Let’s say you are a farmer and these are your crops.

The brown circles are your crops that, for some reason, are dying.

Would it be easier to monitor them from above or on the ground?



Landsat satellite photographs of Santiago, Chile in 1985 and 2010. The comparison reveals how the city has expanded.
If you were a developer of a mall or a housing area, how would this be helpful to you?

Activity:

Put the pixels together!


White = 0
Pink = 1
Gray1 = 2
Gray2 = 3
Gray3 = 4
Gray4 = 5
Yellow1 = 6
Yellow2 = 7
Brown1 = 8
Brown2 = 9
Brown3 = 10
Cream1 = 11
Cream2 = 12
Cream3 = 13
Orange1 = 14
Orange2 = 15
Orange3 = 16
Orange4 = 17
Orange5 = 18
Black = 19

Pixel Size: 50

Pixel Size: 15

Extension Activity

Which team can walk away with the most points?

Pixel Size: 40

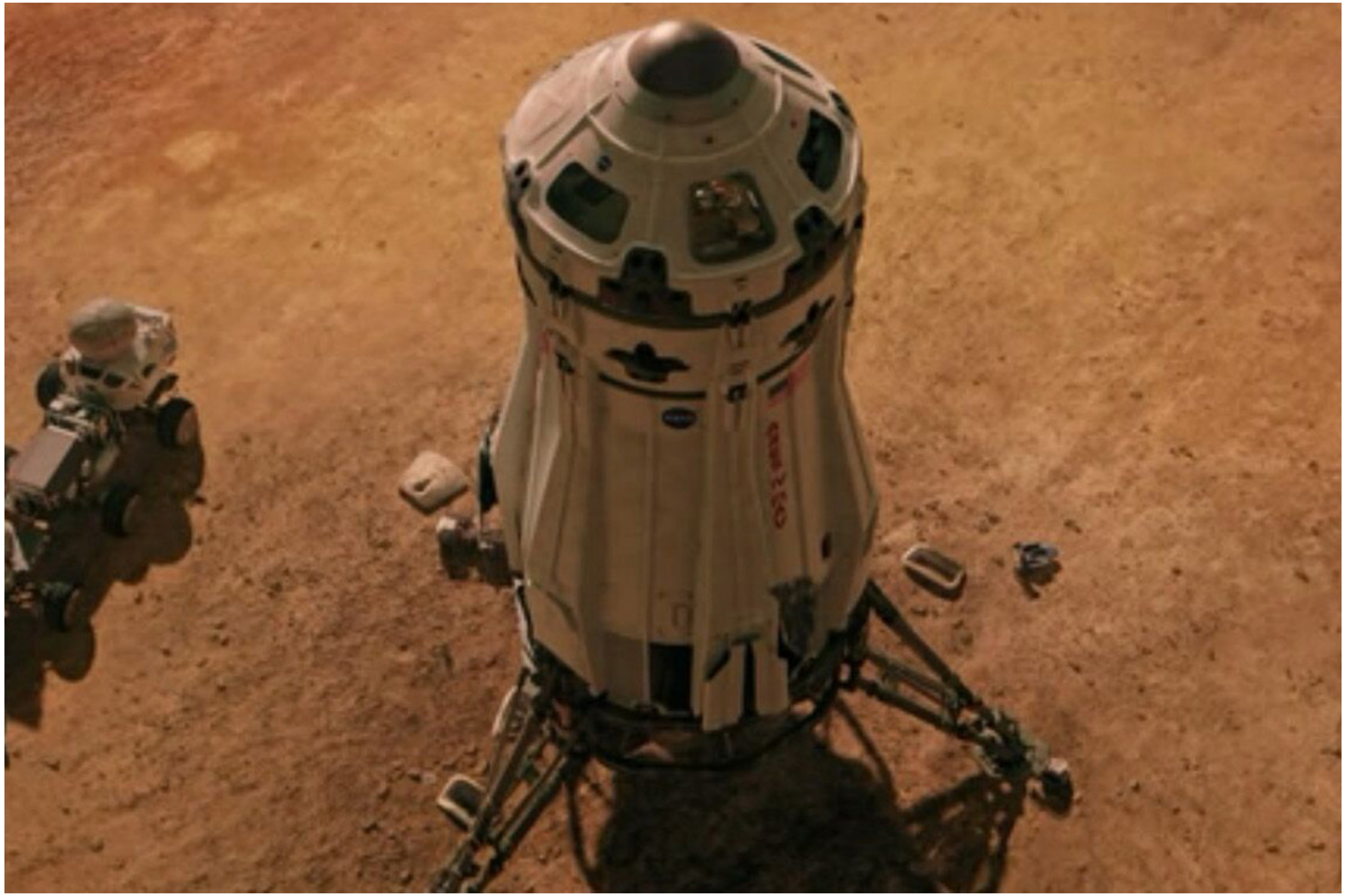
Pixel Size: 30

Pixel Size: 20

Pixel Size: 10

Pixel Size: 5

MAV



Pixel Size: 40

Pixel Size: 30

Pixel Size: 20

Pixel Size: 10

Pixel Size: 5

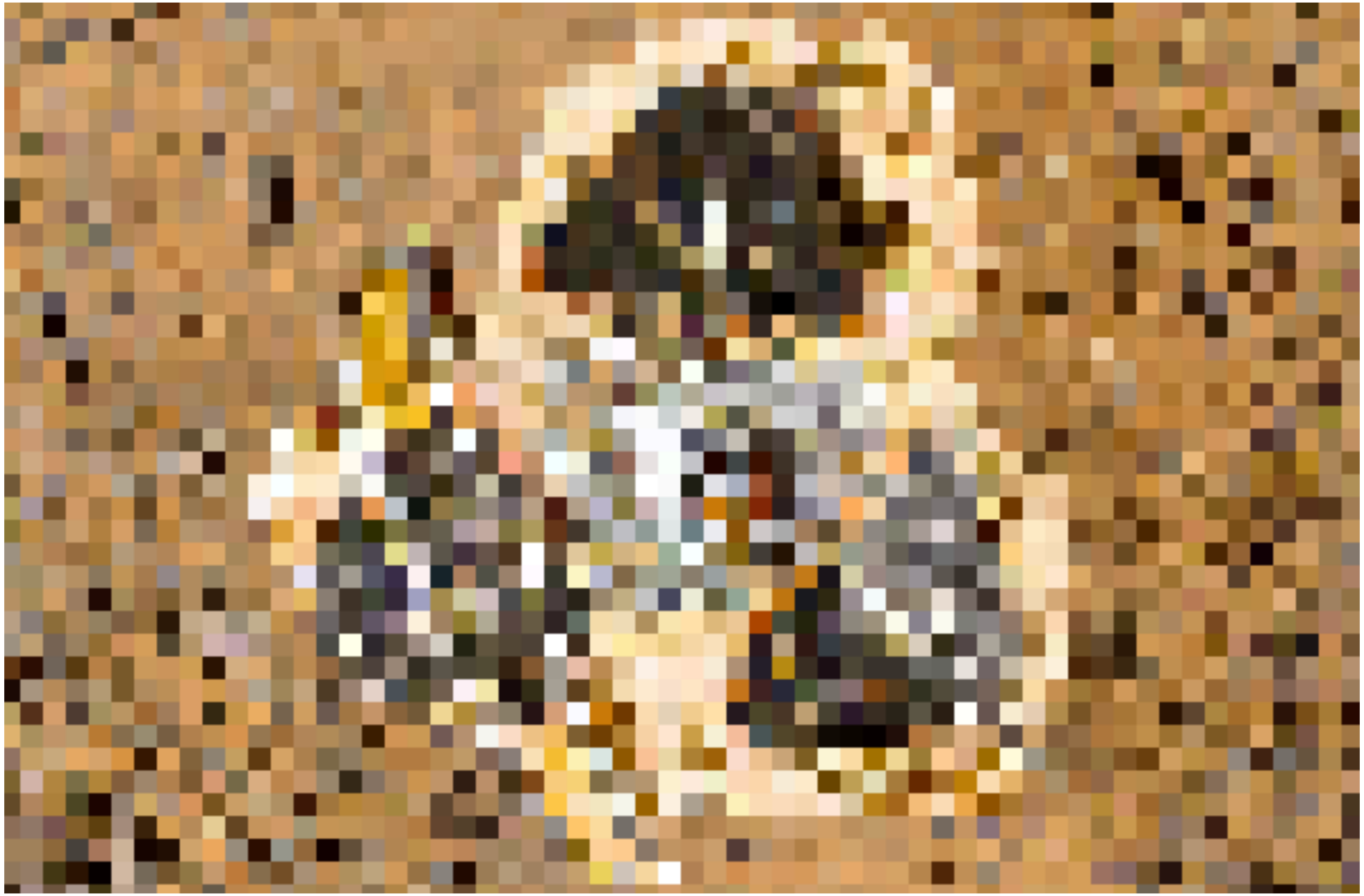
Hermes

Pixel Size: 40

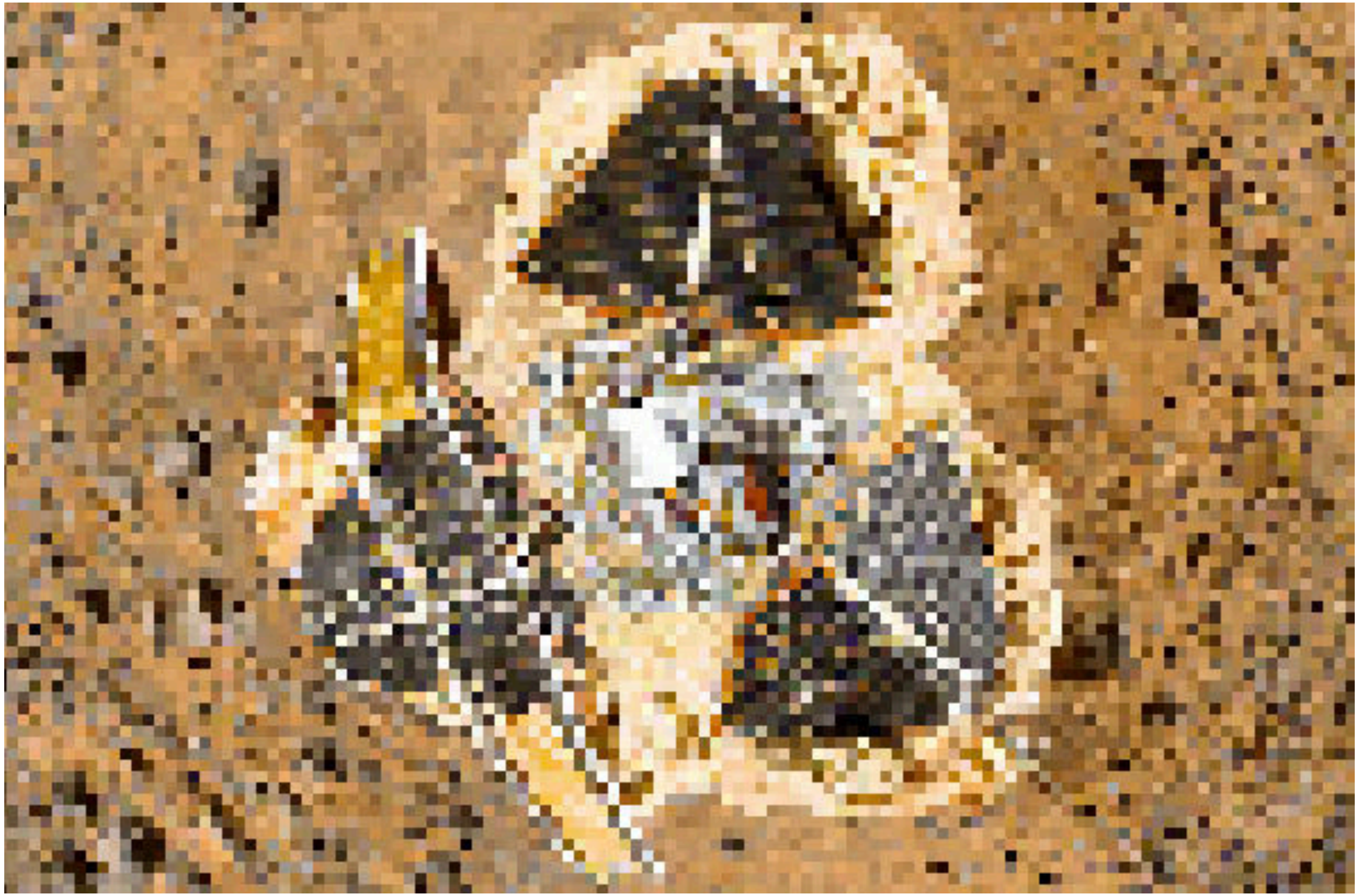
Pixel Size: 30

Pixel Size: 20

Pixel Size: 10



Pixel Size: 5



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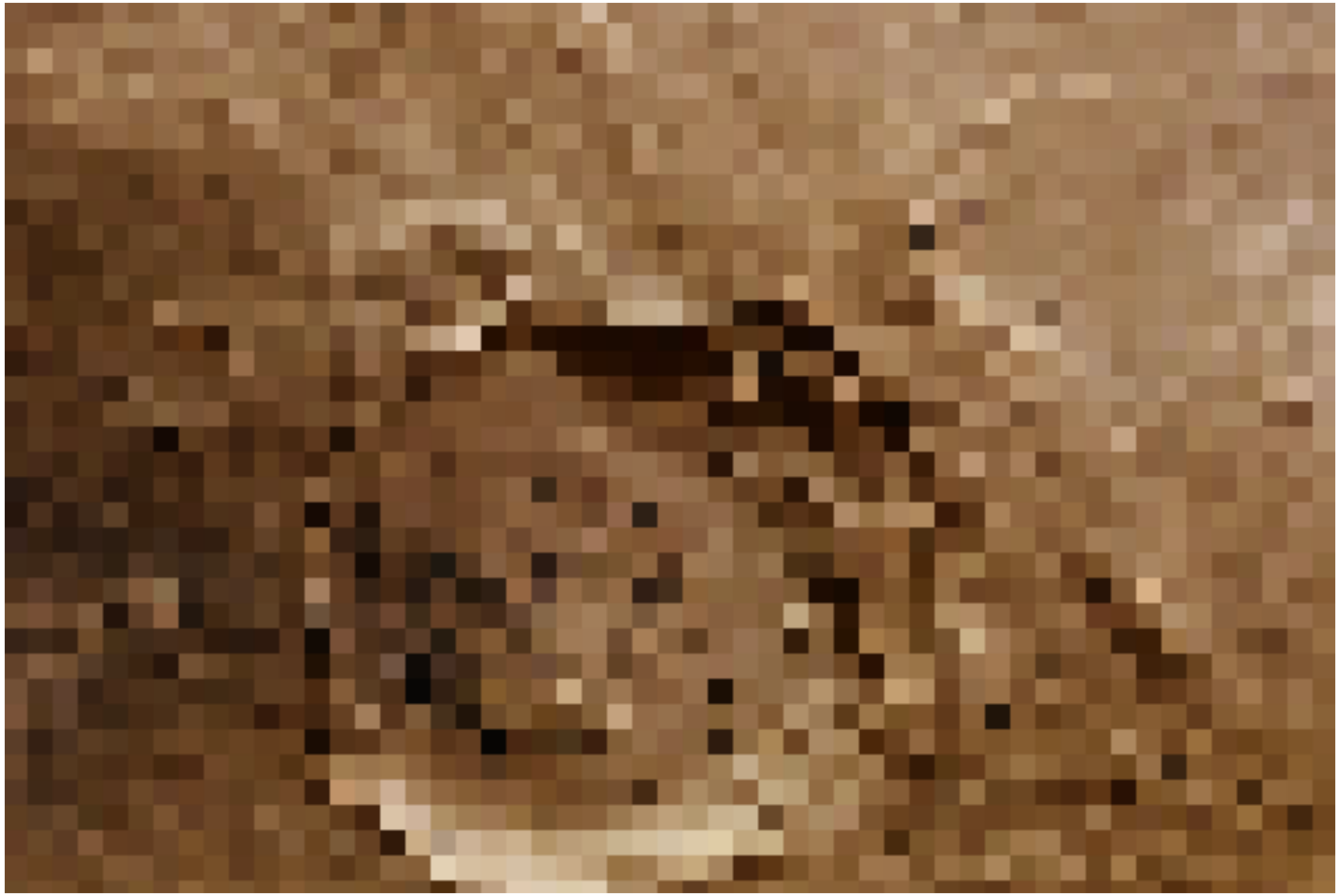
Pixel Size: 40

Pixel Size: 30

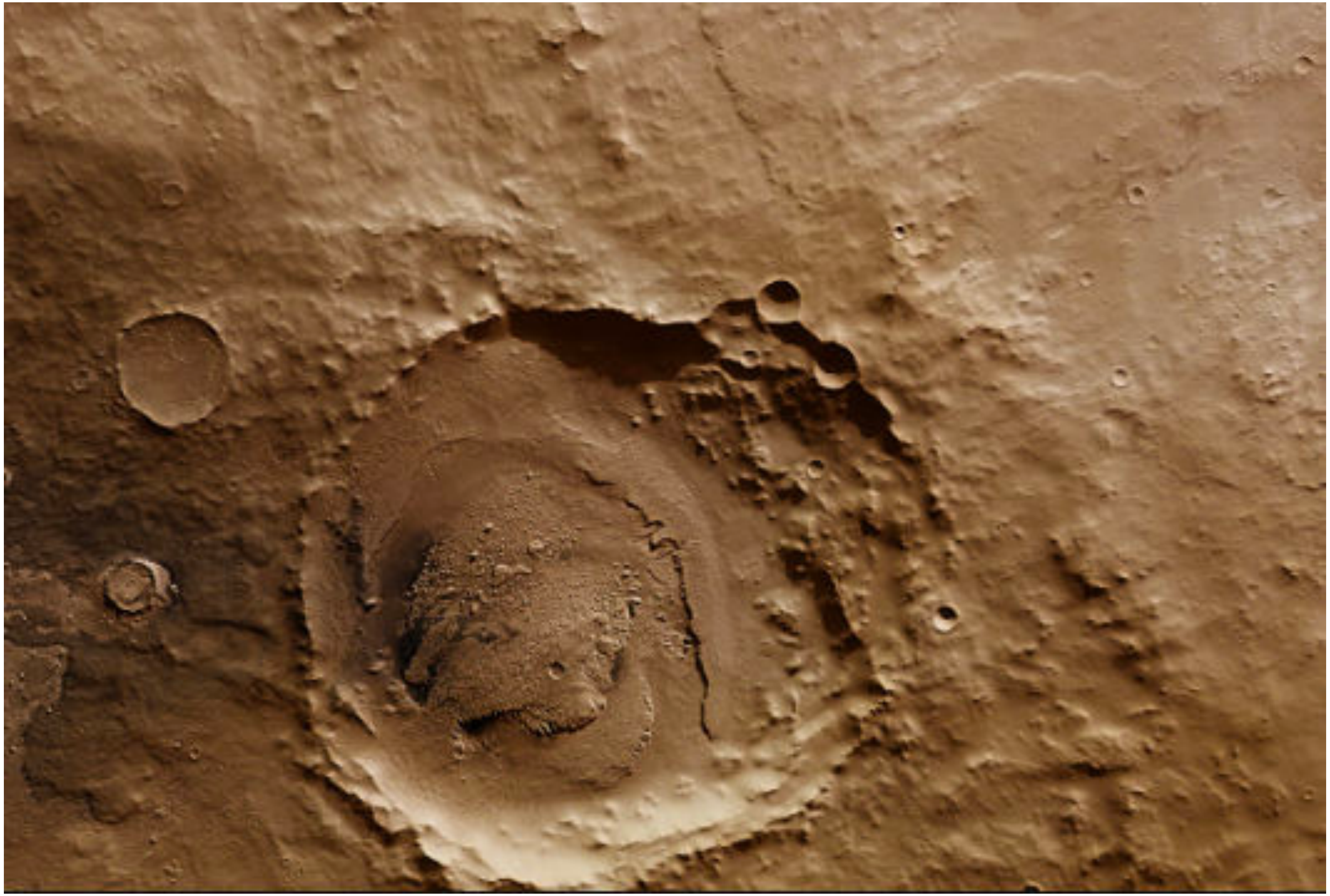
Pixel Size: 20

Pixel Size: 10



Pixel Size: 5

Schiaparelli Crater



Pixel Size: 40

Pixel Size: 30

Pixel Size: 20

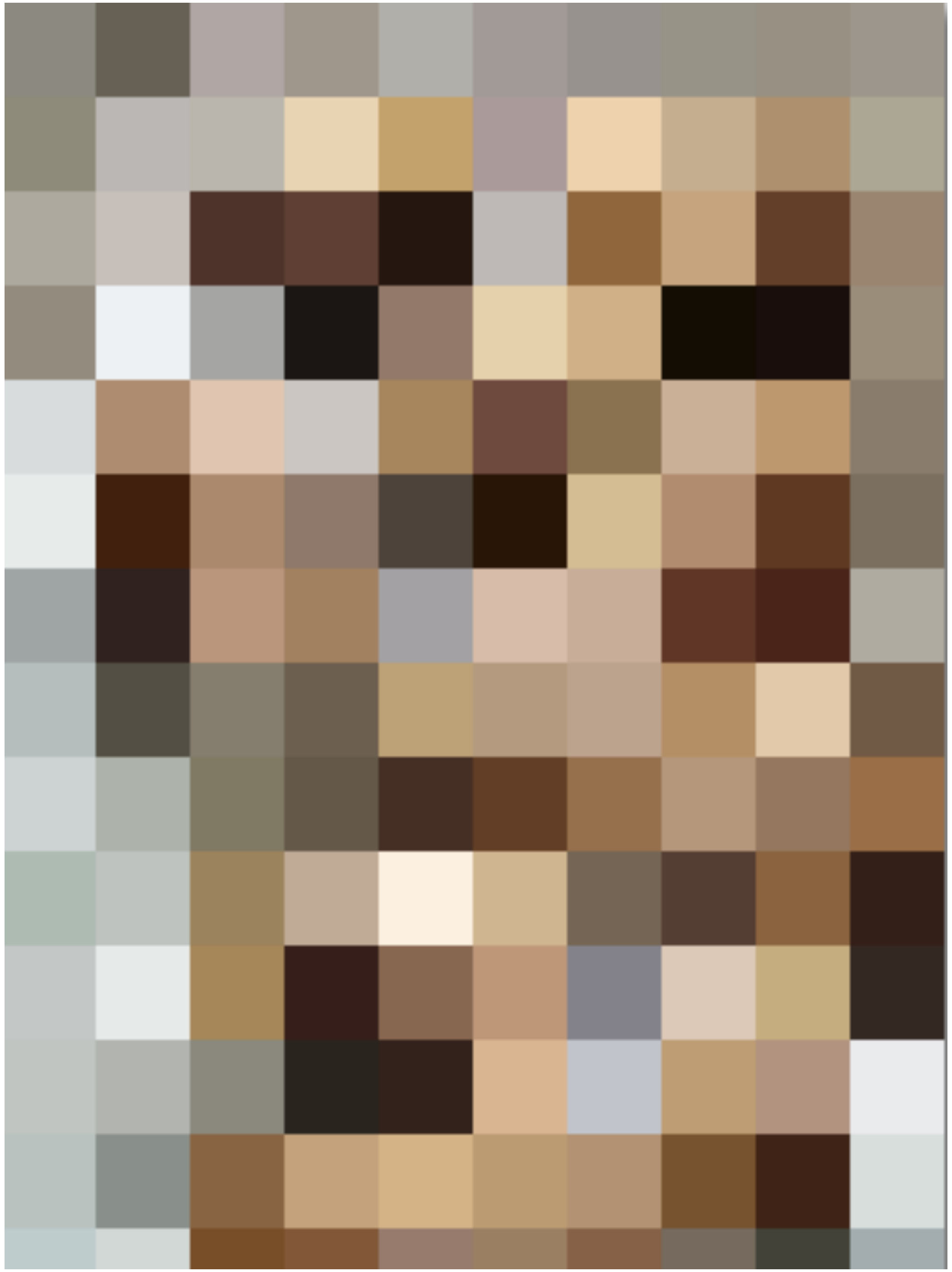
Pixel Size: 10

Pixel Size: 5


Proof that Watney Survived

Pixel Size: 40

Pixel Size: 30



Pixel Size: 20

Pixel Size: 10

Pixel Size: 5

Potatoes

Sources:

- http://bgr.com/2014/02/13/google-maps-satellite-images/
- https://earthobservatory.nasa.gov/Features/RemoteSensing/remote_06.php
- http://www.tech-faq.com/how-satellite-images-are-made.html
- https://landsat.gsfc.nasa.gov/pdf_archive/How2make.pdf
- https://earthobservatory.nasa.gov/IOTD/view.php?id=88190
- https://batworld.org/wp-content/uploads/2011/03/EchotheBat1.pdf
- http://www.dailymail.co.uk/sciencetech/article-2177202/The-changing-face-Earth-Dramatic-high-resolution-satellite-images-world-changed-decades.html
- http://pinetools.com/pixelate-effect-image

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	
1										19	19	19	19	19	19	19	19	19										1
2								19	19	19	19	19	19	19	19	19	19	19	19	19								2
3						19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19						3
4					19	19	19	19	19	19	3	4	11	19	4	3	0	19	2	2	4	19	19					4
5				19	19	19	2	0	2	19	2	0	4	19	3	19	5	19	3	0	5	19	19	19				5
6			19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19			6
7			19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	10	9	19	19	19	19			7
8		19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	7	19	19	4	13	19	19	19		8
9		19	19	19	19	17	15	15	15	16	17	19	19	19	19	6	9	6	19	19	3	3	11	2	19	19		9
10	19	19	19	10	15	16	17	14	16	14	16	9	7	19	7	6	19	19	19	19	2	0	12	0	19	19	10	10
11	19	4	6	18	16	15	16	16	15	16	18	15	17	7	19	19	19	19	19	19	19	13	2	19	19	19	19	11
12	19	19	15	14	15	16	15	15	16	15	16	7	16	15	19	19	19	19	19	19	19	19	19	19	19	19	19	12
13	19	19	16	17	16	17	18	14	7	16	15	18	16	14	19	19	19	19	19	19	19	19	19	19	19	19	19	13
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19		19	19	16	14	14	17	4	0	12	1	1	10	5	5	5	2	0	5	19	19	19	19	19	19	19		19
20		19	19	19	9	14	14	14	14	14	18	10	19	19	19	19	19	19	19	19	19	19	19	19	19	19		20
21			19	19	19	19	19	8	15	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19			21
22				19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19				22
23				19	19	19	19	19	19	0	19	19	19	3	19	19	19	3	19	19	19	19	19	19				23
24					19	19	19	19	19	4	19	19	19	4	19	19	19	4	19	19	19	19	19					24
25							19	19	19	19	19	19	19	19	19	19	19	5	19	19	19							25
26								19	19	19	19	19	19	19	19	19	19	19	19	19								26
27										10	19	19	19	19	19	19	19	19										27

Color Key:
White = 0
Pink = 1 (carnation)
Gray1 = 2 (silver)
Gray2 = 3 (magnesium)
Gray3 = 4 (nickle)
Gray4 = 5 (steel)
Yellow1 = 6 (gold, accent 4, lighter 40)
Yellow2 = 7 (gold, accent 4, darker 25)
Brown1 = 8 (gold, accent 4, darker 50)
Brown2 = 9 (orange, accent 2, darker 25)
Brown3 = 10 (orange, accent 2, darker 50)
Cream1 = 11 (orange, accent 2, lighter 80)
Cream2 = 12(orange, accent 2, lighter 60)
Cream3 = 13 custom from cream 2
Orange1 = 14 standard orange
Orange2 = 15 custom from standard orange
Orange3 = 16 (orange, accent 2, lighter 40)
Orange4 = 17 custom from standard orange
Orange5 = 18 custom from standard orange
Black = 19

	A	B	C	D
E	F	G	H	I
J	K	L	M	N

O	P	Q	R	S
T	U	V	W	X
Y	Z	AA		

	3	6	9	12
1	4	7	10	13
2	5	8	11	14

15	18	21	24	27
16	19	22	25	
17	20	23	26	

Row 1 Column A		0	1	3
	8	19	19	19
0	19	19	0	5

4	19	8		Row 1 Column J
19	19	11	4	
2	19	19	9	15

12	19	19	8	19
2	19	17	15	7
19	0	6	16	14

19	7	11	19	19
19	19	19	19	4
19	19	19	19	2

5	19	13	18	17
3	19	19	19	19
Row 9 Column A	3	4	19	19

19	19	11	19	19
19	19	19	19	3
19	19	19	2	Row 9 Column J

Row 10 Column A		17	19	19

3	10	11		Row 10 Column J


White = 0
Pink = 1
Gray1 = 2
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Gray4 = 5
Yellow1 = 6
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Brown1 = 8
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Cream2 = 12

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Orange1 = 14

Orange2 = 15

Orange3 = 16

Orange4 = 17

Orange5 = 18

Black = 19