Earth Science Everywhere

Exploring the Electromagnetic Spectrum

A Lesson for Middle School STEM

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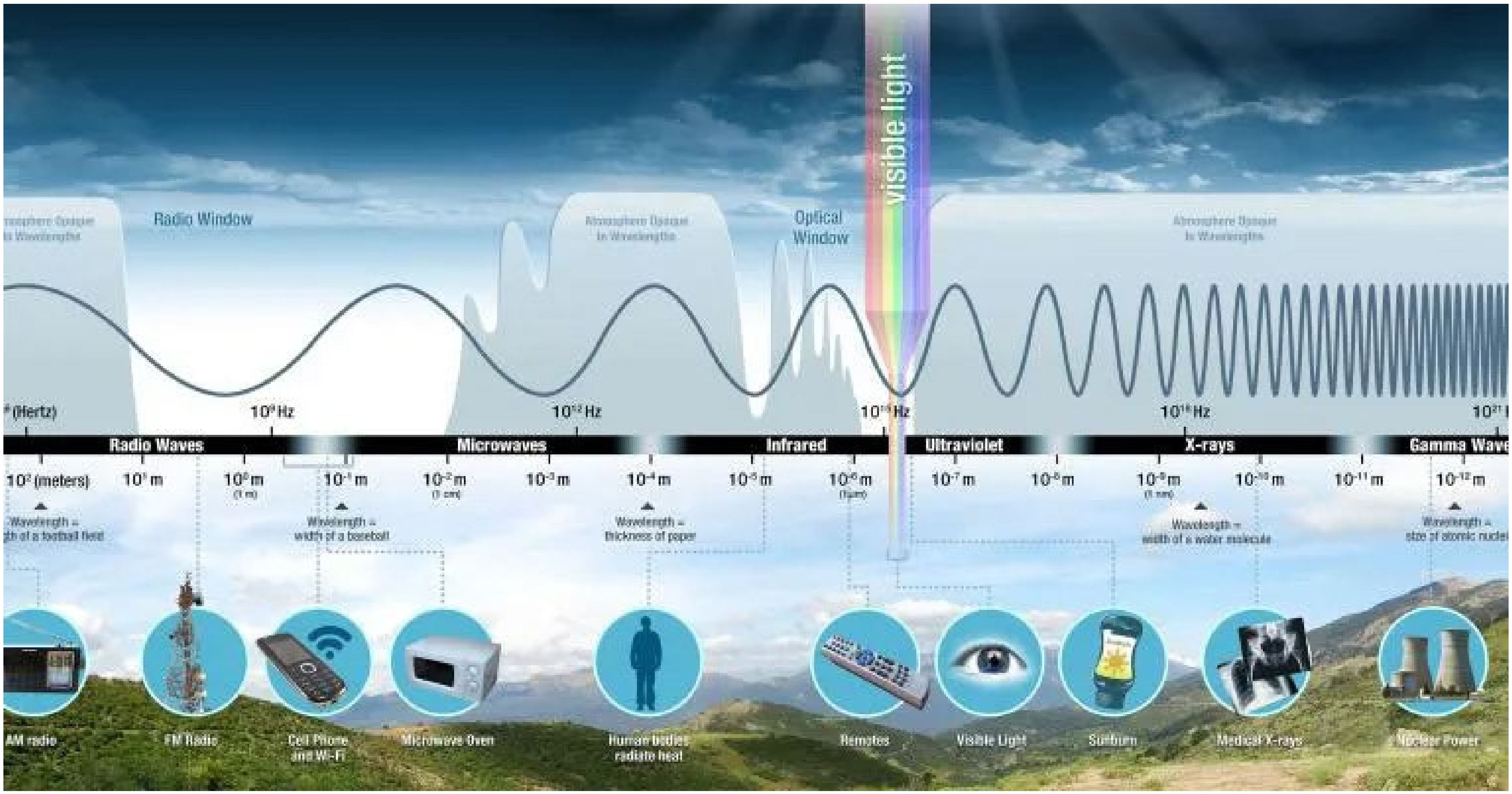

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This material is based upon work supported by the U.S. Geological Survey under Grant/Cooperative Agreement No. G23AP00683.

Introduction: This lesson seeks to engage students in an examination of the electromagnetic spectrum. This content provides opportunities for students to meet two NGSS performance expectations **MS-PS4-1 and MS-PS4-2**, see next page for details. This lesson is intended to be the first in a series of seven lessons as this provides introductory information that will be necessary for the subsequent lessons. These lessons can be used separately for a STEM enrichment class or as an enrichment activity included as part of a larger science curriculum. It was written as a two-day lesson with a middle school audience in mind but could be adapted for the high school level.

Keywords: Electromagnetic Energy, Electromagnetic Wave, Visible Light, Wave Behaviors, Remote Sensing, Landsat

Background Information: This lesson uses a NASA resource that is on the web, in print, and with companion videos. The lesson introduces electromagnetic waves, their behaviors, and how scientists visualize these data. Each region of the electromagnetic spectrum is described and illustrated with engaging examples of NASA science. The information provided on the website is more comprehensive that what is presented in this lesson. This lesson covers the first four sections of the NASA online content but you can continue the subsequent sections for a more comprehensive examination of the different regions of the electromagnetic spectrum.

Time Frame:

Two 45-minute sessions

Materials: In order to complete the activities in this Lesson, the following materials/resources are essential:

- Internet access
- One computer per pair of students (one-to-one is preferred)
- Smartboard or other projection system
- One jump rope per pair of students.
- Meter Sticks
- Light Meter or Light Meter App on a device

Next Generation Science Standards addressed:

Performance Expectation	Disciplinary Core Ideas	Crosscutting Concepts
MS-PS4-1: Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.	PS4.A: Wave Properties A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.	Patterns Graphs and charts can be used to identify patterns in data.
Evidence Statements Representation a. Students identify the characteristics of a simple mathematical wave model of a phenomenon, including: i. Waves represent repeating quantities. ii. Frequency, as the number of times the pattern repeats in a given amount of time (e.g., beats per second). iii. Amplitude, as the maximum extent of the repeating quantity from equilibrium (e.g., height or depth of a water wave from average sea level). iv. Wavelength, as a certain distance in which the quantity repeats its value (e.g., the distance between the tops of a series of water waves). Mathematical modeling a. Students apply the simple mathematical wave model to a physical system or phenomenon to identify how the wave model characteristics correspond with physical observations (e.g., frequency corresponds to sound pitch, amplitude corresponds to sound volume). Analysis a. Given data about a repeating physical phenomenon that can be represented as a wave, and amounts of energy present or transmitted, students use their simple mathematical wave models to identify patterns, including: i. That the energy of the wave is proportional to the square of the amplitude (e.g., if the height of a water wave is doubled, each wave will have four times the energy). ii. That the amount of energy transferred by waves in a given time is proportional to frequency (e.g., if twice as many water waves hit the shore each minute, then twice as much energy will be transferred to the shore). b Students predict the change in the energy of the wave if any one of the parameters of the wave is changed.		

Performance Expectation	Disciplinary Core Ideas	Crosscutting Concepts
MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.	PS4.A: Wave Properties A sound wave needs a medium through which it is transmitted. PS4.B: Electromagnetic Radiation • When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. • The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. • However, because light can travel through space, it cannot be a matter wave, like sound or water waves.	Structure and Function • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Evidence Statements

Components of the model

a. Students develop a model to make sense of a given phenomenon. In the model, students identify the relevant components, including:

i. Type of wave.

1. Mechanical waves (e.g., sound or water waves) and their amplitudes and frequencies.
2. Light, including brightness (amplitude) and color (frequency).

ii. Various materials through which the waves are reflected, absorbed, or transmitted.

iii. Relevant characteristics of the wave after it has interacted with a material (e.g., frequency, amplitude, wavelength).

iv. Position of the source of the wave.

Relationships

a. In the model, students identify and describe* the relationships between components, including:

i. Waves interact with materials by being:

1. Reflected.
2. Absorbed.
3. Transmitted.

ii. Light travels in straight lines, but the path of light is bent at the interface between materials when it travels from one material to another.

iii. Light does not require a material for propagation (e.g., space), but mechanical waves do require a material for propagation.

Connections

a. Students use their model to make sense of given phenomena involving reflection, absorption, or transmission properties of different materials for light and mechanical waves.

b. Students use their model about phenomena involving light and/or mechanical waves to describe* the differences between how light and mechanical waves interact with different materials.

c. Students use the model to describe* why materials with certain properties are well-suited for particular functions (e.g., lenses and mirrors, sound absorbers in concert halls, colored light filters, sound barriers next to highways).

Day 1
Warm-Up: 5 minutes
Have each student navigate to this NASA website. Have them click on, "Introduction to the Electromagnetic Spectrum" and watch the video that is at the top of the screen. You can also do this as a class if you project it on a screen.

Reading Activity: 15-20 minutes
Once they have finished watching the video, have them read the associated text for that section and the next section, "Anatomy of an Electromagnetic Wave."

Viewing the Electromagnetic Spectrum: 5 minutes
After each student has completed reading the first two sections, display the image of the EMS on page 7. Point out the different regions and the differences in energy and wavelength. Highlight the visible region as this will be part of activities in day 2 of the lesson.

The figure on page 7 shows the regions of the EMS where Landsat satellites acquire data. Landsat is a series of satellites, jointly operated by NASA and USGS, that have been imaging the Earth's surface since 1972. Landsat is the only satellite program that gives us this long record of the Earth's surface. Landsat imagery is used in the subsequent lessons in this series. Highlight to the students that sensors onboard Landsat satellites image in the Visible and Near-Infrared regions of the electromagnetic spectrum. Display the image on page 8 to show the Landsat Satellite timeline.

Frequency, Wavelength, and Energy Jump Rope Activity: 10 minutes
Have students' group into pairs and have one jump rope per pair. Have each pair illustrate different frequencies and wavelengths. Have them show that with increasing frequency and shorter wavelengths, more energy is required. With decreasing frequency and longer wavelengths, less energy is required.

Day 2
Warm-Up – What Can You See in a Satellite Image: 5 minutes
Display the Landsat 8 image shown on page 9 and have the students' group into pairs and discuss their ideas. After a few minutes, come back as a group to discuss their ideas.

Identifiable features in the image:
Barrier Island, ocean water, sediment from land mixing with ocean water, agricultural fields, roads, airport, forested areas, sand on the barrier islands.

Reading Activity: 10 minutes
Have the students navigate to this NASA website. Have them click on, "Wave Behaviors" and complete the reading for that section. Once finished, have them read, "Visualization: From Energy to Image."

Exploring Remote Sensing Activity: 25 minutes

For the remainder of the class, have the students complete the NASA Exploring Remote Sensing Activity. This activity illustrates how different colors are recorded as light energy. This activity can be completed outside, using different ground cover types. It can also be completed inside using paper or fabric of different colors. There are many light meter apps available for free that can be downloaded onto a device. It would be best to identify which app you plan to use prior to the class as some work better than others.

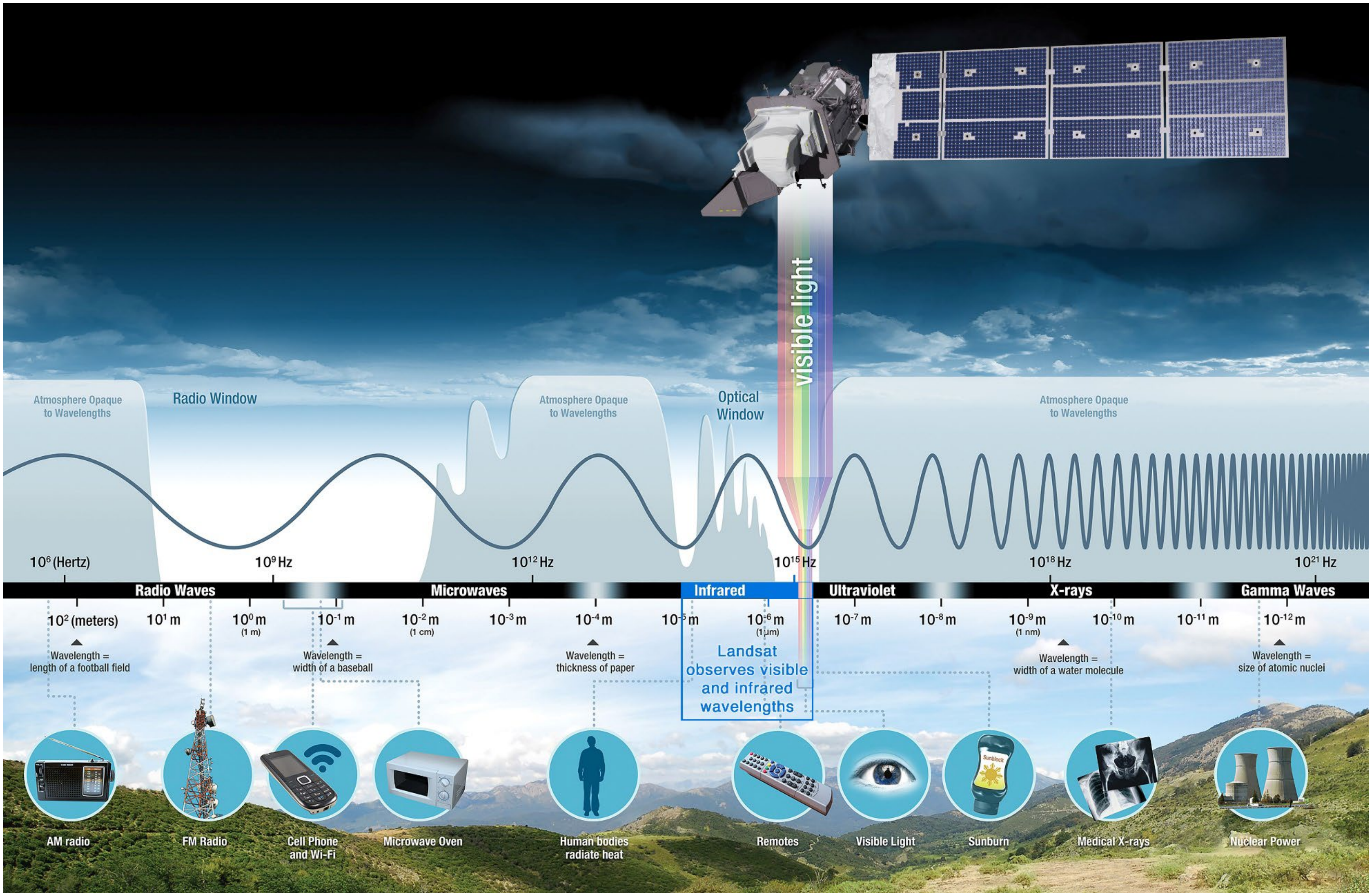
Exploring Remote Sensing with Google Earth Pro

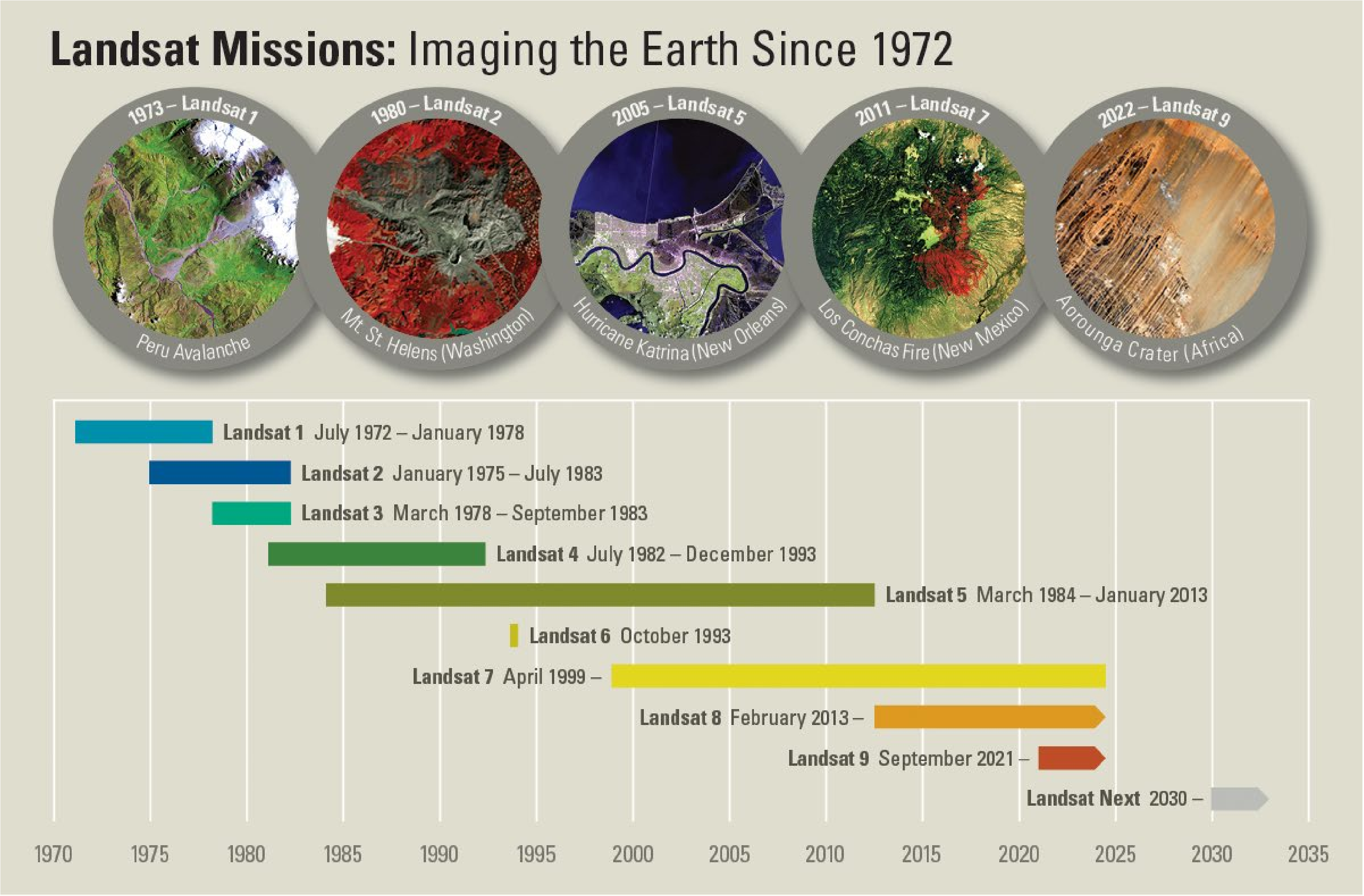
As an additional or alternative exercise to the NASA Exploring Remote Sensing Activity, each student can explore satellite imagery through Google Earth and Google Earth Pro. Have each student zoom to a location of their interest. What can they see for this area? If using Google Earth Pro, enable the historical imagery time slider.

This tool allows the user to see imagery that was acquired in the past. Have each student look to identify areas that have changed and note what changes have occurred. Have several students share their discoveries with the class.

Wrap-up: 5 minutes

Have the students play the online game to test their comprehension of the main topics of the lesson. The printable quiz is also provided on page 10.


visible light
Atmosphere Opaque to Wavelengths
Radio Window
Atmosphere Opaque to Wavelengths
Optical Window
Atmosphere Opaque to Wavelengths
10⁶ (Hertz)
10⁹ Hz
10¹² Hz
10¹⁵ Hz
10¹⁸ Hz
10²¹ Hz
Radio Waves
Microwaves
Infrared
Ultraviolet
X-rays
Gamma Waves
10² (meters)
10¹ m
10⁰ m (1 m)
10⁻¹ m
10⁻² m (1 cm)
10⁻³ m
10⁻⁴ m
10⁻⁵ m
10⁻⁶ m (1 µm)
10⁻⁷ m
10⁻⁸ m
10⁻⁹ m (1 nm)
10⁻¹⁰ m
10⁻¹¹ m
10⁻¹² m
Wavelength = length of a football field
Wavelength = width of a baseball
Wavelength = thickness of paper
Landsat observes visible and infrared wavelengths
Wavelength = width of a water molecule
Wavelength = size of atomic nuclei
AM radio
FM Radio
Cell Phone and Wi-Fi
Microwave Oven
Human bodies radiate heat
Remotes
Visible Light
Sunburn
Medical X-rays
Nuclear Power


Landsat Missions: Imaging the Earth Since 1972
1973 – Landsat 1
Peru Avalanche
1980 – Landsat 2
Mt. St. Helens (Washington)
2005 – Landsat 5
Hurricane Katrina (New Orleans)
2011 – Landsat 7
Los Conchas Fire (New Mexico)
2022 – Landsat 9
Aorounga Crater (Africa)
Landsat 1 July 1972 – January 1978
Landsat 2 January 1975 – July 1983
Landsat 3 March 1978 – September 1983
Landsat 4 July 1982 – December 1993
Landsat 5 March 1984 – January 2013
Landsat 6 October 1993
Landsat 7 April 1999 –
Landsat 8 February 2013 –
Landsat 9 September 2021 –
Landsat Next 2030 –
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035

What can you see in this Landsat 8 satellite image?

The Electromagnetic Spectrum

Date: ____________ Name: ____________

1. The Electromagnetic Spectrum region that human eyes can see.

   A ☐ Infrared B ☐ Visible

   C ☐ X-ray D ☐ Radio Wave

2. Longer wavelengths have ______ than shorter wavelengths.

   A ☐ more energy B ☐ higher frequency C ☐ less energy

3. Landsat satellites image in the ______ regions of the EMS.

   A ☐ visible and near-infrared B ☐ visible and ultraviolet

   C ☐ x-ray and gamma wave D ☐ Microwave and radio wave

4. What color combinations make a natural color satellite image?

   A ☐ yellow, brown, and white B ☐ red, white, and blue

   C ☐ red, green, and blue D ☐ white, black, and blue