Astronomy and Outreach at Arecibo Observatory STEM careers video

Teacher & Learner Guide

This guide provides background information about the setting and context of the short film, answers frequently asked questions, and suggests topics for student discussion or reflective writing.

Background Information

Arecibo Observatory, located on the island of Puerto Rico, is the largest radio telescope in the world, and one of the most sensitive. Its most striking feature is its reflecting dish for collecting radio waves. The circular reflector has a diameter of 305 meters and a depth of 51 meters. You may have seen it featured in motion pictures or TV shows, including the James Bond film *GoldenEye*.

The Arecibo dish is held stationary because of its immense size, but its antennas can be directed to look at different parts of the sky. They are located on a platform suspended in air above the reflector. Technicians who work on the telescope walk about on this platform, which hangs hundreds of feet above ground and is prone to swaying in the wind.

To obtain the curved shape needed for reflecting radio waves, Arecibo's dish was built inside a huge natural sinkhole, in a remote area of stunning natural beauty. The observatory is part of the National Astronomy and Ionosphere Center (NAIC), and, in addition to radio astronomy research, supports planetary radar and terrestrial aeronomy research. As mentioned on the video, the observatory is active 24 hours a day, seven days a week – even on Christmas Day. Scientists from around the world treasure the opportunity to conduct observations at Arecibo, and the data collected at the observatory are used by many people throughout the scientific community.

The observatory first opened in 1963 and has been upgraded several times since then. Its equatorial location was specially chosen so that, as the Earth rotates once a day on its axis, the telescope dish traces a wide circular path across the skies and through the twelve constellations of the zodiac. This allows a broad range of observations. If it had been placed at the North Pole instead, its view of the skies would barely change as the planet rotated, and it would be limited to observing a small patch of sky surrounding the North Star.

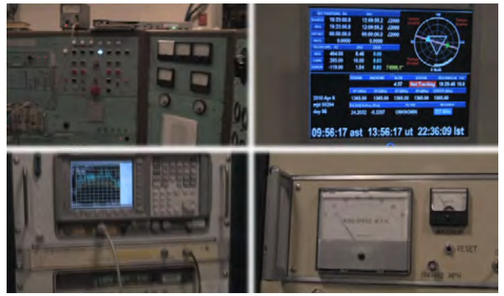
The observatory employs 140 people, in many different capacities. It is an important feature of the local economy and a source of great pride to the people of Puerto Rico. As you might gather from watching the video, it takes many people with varied skills to keep the observatory running. There are scientists doing research, technicians and engineers maintaining the telescope, and educators working with the public.

Frequently Asked Questions (FAQs)

How is a radio telescope different from an optical telescope?
When we hear the word *telescope* we usually think of an optical telescope, which greatly magnifies visible objects in the sky. A radio telescope, however, shows what is invisible, allowing us to "see" celestial objects emitting radiation at frequencies we can't detect with our eyes. Imagine driving a car in dense fog. Even with your headlights on, you aren't able to see very far in front of you. If your car could process and display radio waves, you'd be able to see through the fog! A radio telescope can similarly peer through dust and find shrouded objects in the sky. We are able to translate this information and use it to "see" distant planets, stars, galaxies, and other celestial bodies.

Are all radio telescopes set in the ground like Arecibo?
Because Arecibo Observatory is the largest radio telescope in the world, it has a different design from most. Arecibo's large dish makes it very sensitive to subtle changes in frequency, but it would be very difficult to support such a structure above the ground. Most radio telescopes have diameters of only 12 to 25 meters and can be tilted to look all over the sky, and many are mounted on tracks (like a train) so that they can be moved back and forth. Arecibo's dish can't be moved or tilted, but its focusing antennas can be directed to look at different parts of the sky.

How old is Arecibo Observatory? How long will it last?
Because we humans haven't had large radio telescopes for very long, it's hard to know exactly how long Arecibo will last. The observatory was built in 1963, and pieces of its physical structure and technology are continually being updated and replaced. The dish itself doesn't have to be modern or high-tech: it is simply a metal mesh (think heavy chicken wire) forming a reflecting surface to focus radio waves onto an antenna. It is made up of many small panels that are repaired or replaced as needed. The specialized computer equipment that translates radio waves into images is very expensive, however, and it is replaced infrequently, perhaps every couple of decades. Other electronic equipment is less specialized, and it is repaired or replaced more often.



What are the different parts of the telescope?
A radio telescope is made up of a dish, or reflecting surface (the most visible part of the telescope), and antennas/receivers, which can be positioned to collect radio waves from different areas on the sky. The dish focuses radio waves onto antennas, which are sensitive to certain wavelengths. A smaller reflector called a Gregorian dome also helps focus the radiation for the antennas to gather. The antennas then send data to a correlator, one of the less obvious, but critical, components of the telescope. A correlator is a dedicated computer that transforms data into an image or spectrum that can be used in scientific research. Other parts of the telescope include specialized computer hardware that traps the signals from the antennas and monitors local conditions, mechanical gearboxes that control the movements of the antennas, cryogenics to keep sensitive electronics cool, and fiber optics to transmit data.

Because Arecibo is so large, a 900-ton platform is suspended above the dish. Giant jacks allow movement of the platform, which holds the antennas and the Gregorian dome. Walkways let engineers access anything they need to work on to make sure that the antennas can be properly adjusted to point at different parts of the sky.

What purpose does the shape of the dish serve?
The curvature of the dish directs the radio waves onto the antennas. Because this curving surface is integral to the function of the telescope, Arecibo's location was chosen expressly to take advantage of a natural limestone sinkhole which cradles the dish from below.

Why is Arecibo so large?
Arecibo is 305 meters in diameter, almost the length of three football fields. Its large size enables it to gather information at very high frequency resolution. The larger the dish, the better the quality of the information it can focus onto the antennas. Just as a large bucket can hold a lot of water, a large telescope dish can collect a lot of photons!

Why is it important to observe outer space at many frequencies?
Knowing what is going on in outer space helps us to understand the history of our galaxy and the universe, how stars and planets formed, how the Earth formed, and whether other planets might have conditions capable of supporting life. Astronomers also study the mysteries of the cosmos out of pure curiosity, and discoveries made at Arecibo could give us clues to our planet's future as well. If life exists on other planets, it may be detected with radio telescopes. In 1974, Arecibo sent out a message towards a globular cluster 25,000 light years away in hopes of contacting an alien intelligence.

For More Information:
The National Astronomy and Ionosphere Center:
https://www.naic.edu/ao/

Questions for Class Discussion

1. In your opinion, how are facilities like Arecibo Observatory important? With so many problems science needs to solve, why should we worry about outer space?

Notes for the discussion
Scientific discoveries often occur while we are researching very basic questions. For instance, gene therapy for cancer and other diseases is being developed because of a discovery made while studying why a petunia that was expected to be purple turned out white instead. The more knowledge we can gather about planets and stars, the more we will know about our own planet. This knowledge could potentially help us understand climate change or the possibility of living on other planets in the distant future or help us solve some entirely different problem we haven't even thought of yet.

2. What kinds of tasks do the workers perform in order to support the astronomers and other scientists working at Arecibo? What would happen if the staff were not extremely skilled and reliable? Why do you think it's important to have the telescope operating continuously?

Notes for the discussion
Because Arecibo has many parts—from the antennas to the computers to the dish itself—people are constantly at work making physical repairs to the structure itself or replacing electronics and computer parts. As is mentioned in the video, when a storm or other occurrence disrupts the functioning of the antennas, a crew gets to work right away, day or night, rain or sunshine, and fixes it! Continuity in the data is important because it helps scientists to observe patterns and changes. With any kind of research that involves a lot of observation, it is possible to miss something if you aren't looking, and astronomers don't want to miss anything exciting. Individual astronomers and research groups apply for time on the telescope months in advance, and if conditions aren't right at the times set aside for their observations, or if something goes wrong with the machinery, they have to apply again and wait their turn. You can see why everyone has a stake in making sure the observing runs smoothly.

3. Who else do you think works at Arecibo besides scientists, engineers, and technicians?

Notes for the discussion
Museum Director Héctor Camacho talks a lot about education and inspiring children who come to visit Arecibo Observatory. One of the most important parts of his position is making exhibits, books, and videos that help people to understand what kind of work is being done at Arecibo and why it's valuable. Héctor can't do all of that alone! Teachers, writers, photographers, filmmakers, and a lot of other people are a huge part of scientific work.

4. How did Museum Director Héctor Camacho's childhood interests influence the path he took in his education and subsequent work?

Notes for the discussion
Héctor says that growing up he was interested in history and politics, especially the history and politics of Puerto Rico. He was also drawn to computers and to understanding how they were put together. By pursuing a career first as a telescope engineer and then as the director of the visitor's center, Héctor has combined these interests. Arecibo Observatory is a highly visible institution and landmark in Puerto Rico, and Héctor comes into contact with people in politics and government. He also plays a role in shaping the future for school children, by giving them a glimpse of science and technology and showing them how Puerto Rico is contributing to some of the most exciting fields of scientific endeavor.

5. Héctor Camacho began working at Arecibo in a technical capacity, but now his work is more related to education. How do you think his past experience is important to what he does now?

Notes for the discussion
Héctor's past job at Arecibo required both hands-on work and detailed knowledge of engineering principles. His current job requires him to think about what children and other visitors might be interested in, but he draws on his experience and knowledge to design educational programs. Héctor's depth of knowledge about the workings of the telescope means that he can interface with scientists, engineers, and the public and stay up-to-date with what's going on at the observatory. He can answer visitors' questions in depth and knowledgeably converse with young people when their curiosity runs deep.

Questions for Reflection

These can be used as writing assignments, as homework, or as in-class assignments.

1. What are your interests and passions? What are your career goals? Héctor Camacho mentions that in addition to being interested in technology, like radios and computers, he was interested in history and politics. List some ways that your interests could be useful in a career.

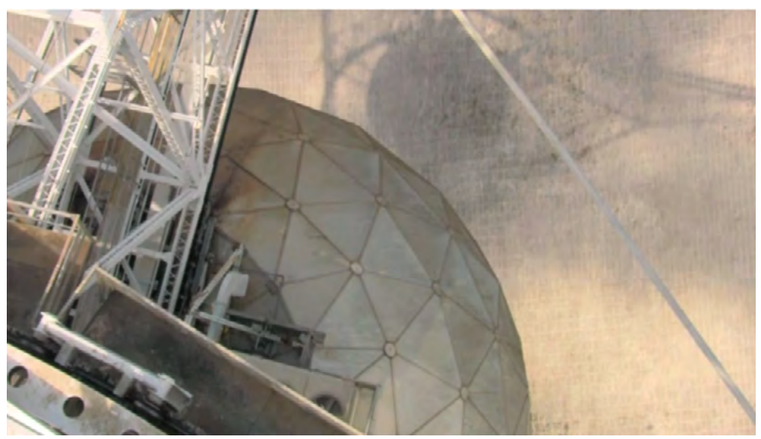
2. Do your parents encourage you to go far with your education? Do you talk with them about your educational and career goals? Héctor Camacho mentions that his father didn't quite finish high school, and his mother was only able to attend school through third grade. By attending college, Héctor and his siblings likely had many more opportunities than their parents. What are your plans for your own education?

3. Héctor Camacho mentions that many schoolchildren visit Arecibo, and his goal is to inspire them. Have you ever visited a place and wanted to work there? Make a list of some places where you wish you could work.

4. Before watching this video, you might not have thought that being at an observatory would require climbing to great heights or working on swaying catwalks. What unexpected skills or personality traits might be important to the jobs that you envision for yourself?

5. Do you have a bunch of interests that do not seem to go together? Think of some ways that you might combine your interests.

6. Héctor Camacho's background has made him value not only his own education but the education of the children who visit Arecibo Observatory. Is there an experience from your childhood or recent life that has had an impact on your goals and influenced what you'd like to do with your life?



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