Observing the Universe, and Tracking the Bits

How Many Astronomers and Engineers Does It Take to Build a Telescope Array? Part I **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

The National Radio Astronomy Observatory (NRAO) was founded in 1956. NRAO designs and builds radio telescopes, which are available for use by scientists from all over the world. These radio telescopes collect data 24 hours per day, seven days a week.

Radio astronomy allows scientists to see what is happening in distant parts of our galaxy. This is important because it allows us to gather information about the composition of other planets and celestial bodies by detecting what elements and other elements are present in and around them. This helps us to understand the galaxy's past and the formation of planets.

Many people work at NRAO to keep everything running smoothly, and to adjust the telescopes so that they are correctly positioned, programmed, and maintained. In addition to those whose daily work involves the telescopes, NRAO employs computer specialists, web designers, engineers, electricians, support staff, and administrators. NRAO also offers many students opportunities and grants to do research relevant to radio astronomy.

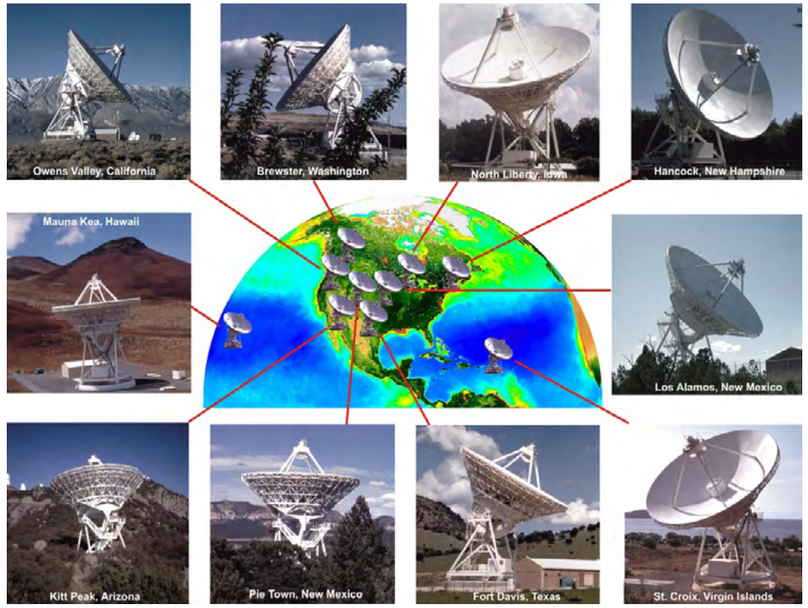
This video provides a look at two people who work at NRAO, Juan Cordova and Paula Metzner. Juan, in particular, has a job you might not think of when you consider jobs in the sciences or in astronomy.

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.



VLBA telescopes, ranging from Hawaii to St. Croix, Virgin Islands
Image courtesy of NRAO/AUI and Earth image courtesy of the SeaWiFS Project NASA/GSFC and ORBIMAGE

For more information:

VLBA website:
https://public.nrao.edu/telescopes/vlba/

ALMA website:
https://public.nrao.edu/telescopes/alma/

The Very Large Array website:
https://public.nrao.edu/telescopes/vla/

Visiting the VLA:
https://public.nrao.edu/visit/very-large-array/

See how interferometry works:
https://public.nrao.edu/interferometry-explained/

What is a telescope array?
A telescope array is a group of telescopes arranged so that, as a set, they function similarly to one giant telescope. This means that astronomers can gather higher quality information, generating high resolution data with great sensitivity to faint signals. One downside to having a number of small reflective surfaces (dishes) is that even though the collection of telescopes covers a large area, there are holes, or gaps, in the information they can gather. If one antenna in the array breaks or malfunctions, the array will lose some sensitivity. If that particular antenna is programmed to a certain frequency, the quality of the data at that frequency would diminish. If we were able to have one giant dish covering the entire area of the VLA, it would be stronger and more capable of detecting faint signals.

What is the VLBA?
The Very Long Baseline Array is the world's largest telescope array. It is made up of ten powerful radio telescopes that together span a distance of over 5,000 miles around the globe. The VLBA allows astronomers to examine quasars, black holes, and stars, and to track the movements of asteroids and other celestial bodies.

Why are VLBA telescopes located where they are?
One important factor in deciding where to put a telescope is topography. A high elevation, with less atmospheric interference, helps the telescopes to receive clearer signals. Siting the telescopes in remote locations is also important to avoid radio interference caused by proximity to human habitation, with its radios, televisions, cars, and cellular phones, all of which create noise at radio frequencies.

What does VLBI mean?
VLBI stands for Very Long Baseline Interferometry. If ten telescopes from around the world simultaneously observe a single object in the sky, they will all have slightly different data because of their different positions on the Earth. Interferometry is a way for all of those data to be combined for a more complete picture of the object being observed.

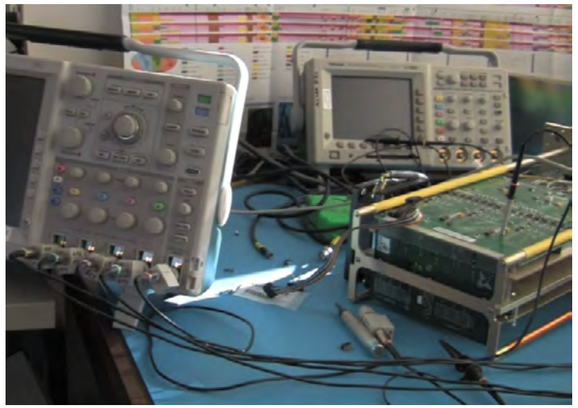
What is the difference between VLA, VLBA, and ALMA?
All of these acronyms describe telescope arrays. The VLA is the Very Large Array, a group of 27 radio telescopes located on the plains of San Agustin, near Socorro, New Mexico. ALMA is the Atacama Large Millimeter Array, which is located in the Atacama desert in Chile. Like the VLA, it is an array of radio telescopes positioned close to one another to act like one very large telescope, but ALMA includes even more telescopes, 66 to the VLA's 27. More importantly, the radio telescopes in ALMA are observing the skies at higher frequencies than those of the VLA. That means they can detect different gases and therefore study different celestial bodies and phenomena.

The VLBA is geographically quite different from the VLA or ALMA. It is still an array (a group of telescopes), but the ten telescopes that make up the VLBA are located all over the U.S. and its territories instead of being grouped in one place. In fact, the VLBA extends over a distance of 5,000+ miles! Despite the distance between the telescopes, the VLBA functions very much like the VLA or ALMA. The data from the telescopes can be combined to emulate the output from one massive telescope. Each telescope in the VLBA is tremendously powerful.

What is an FPGA?
An FPGA is a Field Programmable Gate Array, a small piece of electronic hardware which can be programmed to perform many different tasks related to the positioning of a radio telescope antenna or to processing the radio signals detected by a telescope. An inch-long FPGA contains enough reconfigurable logic blocks to match the fanciest computers from a generation ago.

What does being a librarian for the VLBA involve?
The individual telescopes of the VLBA each collect enormous amounts of data, which is transmitted to a specialized computer called a correlator. The correlator combines these data to form a coherent data cube, describing the strength of the radio signals at various frequencies observed across a patch of the sky containing the object of interest. Since the VLBA is made up of ten radio telescopes, this is like putting together the pieces of an enormous jigsaw puzzle to form a single picture. The VLBA librarian is responsible for archiving all of this information electronically – 24 hours of it every day, from ten telescopes. The data have to be organized so that scientists will know exactly where everything came from and how the pieces fit together. It's a complex job that requires a lot of organization.

Even with the high-speed fiber transmission we use today, the enormous amount of information collected at all the telescopes in the VLBA cannot be transmitted and combined while it is being collected. Therefore, a librarian like Juan captures each telescope's data separately on tapes, with precise time stamps, to be combined with other tapes from other telescopes to create a complete picture.



Questions for Class Discussion

Before watching:
1. Who do you think designs and builds giant telescopes?

2. How do you think astronomers collect information from telescopes? You might picture scientists traveling to use the telescopes themselves, but if they can't travel to a large telescope, how do you think they do their research?

After watching:
1. What is Paula Metzner's background? And what does she do that is so crucial to these telescopes?

Notes for the discussion
Paula studied electrical engineering, a field that encompasses aspects of computer science, robotics, and circuits. The electrical engineers who work on the telescopes for NRAO are making the electronics — all the wiring, circuits, and computer components — that go into the antennas.

2. Juan Cordova received a chemistry degree, and now he is a librarian. Why do you think Juan's science background is helpful to what he does now?

Notes for the discussion
By majoring in chemistry, Juan learned the scientific method, how to handle data, and how to make qualitative and quantitative assessments of data. These skills are useful because handling all the data from the various telescopes requires not only technical knowledge but extreme attention to detail and a high level of organization and logic.

Juan also mentions that before he was the VLBA librarian, he was an array operator, a job that involves tracking every aspect of the array and monitoring external conditions and how they might affect the operation of the telescopes.

3. Paula Metzner's engineering degree provided a strong science background, allowing her to choose to work in astronomy, a field that interested her. What skills do you think her degree provided? What other fields do electrical engineers work in?

Notes for the discussion
Engineers work in many fields and in different jobs depending upon what kind of engineering they studied. Electrical engineers might build robots or work in telecommunications, or they might build computer hardware or software, or they might or work with large systems, such as the ones powering cities or connecting us to the internet.

4. Paula Metzner mentions that she travels all over the world for her job. Juan Cordova doesn't travel for his job, but he works with team members from many other countries. Given that Paula and Juan interact with people from other countries, what other skills or aspects of their backgrounds (besides their scientific background) do you think are important?

Notes for the discussion
Listening to Paula and Juan, we can tell that they communicate in a flexible way with people who have different experiences than themselves. After all, they are able to explain their extremely technical jobs to us, the listeners, in a way we understand! Paula and Juan both have roots in New Mexico, a state with a history of bilingualism and biculturalism. Living in a community with people from various cultural backgrounds is good preparation for a job with international contacts.

5. Paula says that if she could give advice to students at the high school she attended, she would say: "Hang in there and keep going." At the end of the video credits, she says that "90% of success is just showing up." What do you think she means by these statements?

Notes for the discussion
It's important not to get discouraged if you can't achieve your goals right away! Neither Juan nor Paula went directly from college to working at the NRAO. Instead, over the years, they combined education and experience to gain the skills and knowledge necessary to obtain the jobs they currently hold. Paula says it took her five years from the time she found out about NRAO until she was finally able to work there. The paths Juan and Paul took weren't necessarily direct, nor did their college majors apply specifically to what they are currently doing. Instead, it was a combination of education, hard work, persistence, and the creativity to find opportunities in unusual places that led them to where they are.

Questions for Reflection

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

1. Write down a list of ten jobs or career fields that interest you. What types of challenges do you think you might face in these jobs?

2. Do you see yourself staying near to your family or hometown? Both Juan and Paula went to college and ended up staying in New Mexico to work. If staying close to where you are is important to you, are there any companies or organizations nearby that do work in a field that interests you?

3. Paula Metzner mentions that at the high school she attended, it would have been considered unusual to think about studying engineering. In the area where you live, are there certain cultural or social expectations about what you should do? What do you think of Paula's advice not to be afraid to pursue what interests you?

4. What useful traits do you think you would bring to a career you are interested in?

5. Both Juan Cordova and Paula Metzner took indirect paths to the places where they are now. Where are you in your educational path? Has this video given you ideas about how you might apply your skills or education to something you'd like to do, even if it's not the most obvious or logical path?

For more information about our educational film series or to discuss its use in a educational setting, please contact the GEAS Project at New Mexico State University.

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https://astronomy.nmsu.edu/geas