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# Going to the Ends of the Earth

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They call it the Dark Sector. It's upwind from the base, away from any bright lights, bulldozers, and radio beacons that could interfere with observing. The telescope buildings sit on stilts, so that snow drifts won't bury them. Here, a 5-minute snowmobile ride from the South Pole, is the most remote observatory on Earth.

Astronomers have a reputation for going to far-off places to watch the stars, but even their endurance is tested at the South Pole. On a nice warm summer's day, it might get up to -7 degrees Fahrenheit (-20 degrees Celsius). Refrigerators have to be heated, rather than cooled, to preserve food. The nearest major city is 11 hours away by military transport planes, which make economy-class airliners look like flying palaces: Passengers sit in nets amid boxes of cargo, wearing earplugs the whole way.



No frequent flyer miles, no in-flight entertainment, no free drinks. A U.S. Navy LC-130 Hercules transport plane gives new meaning to the term "bare-bones." Passengers going to Antarctica sit in the cargo hold and think about Tahiti. Photo courtesy of Robert M. Morse.

Except for outer space, Antarctica is the most challenging place to do scientific research. Working there demands teamwork: scientists, technicians, mechanics, carpenters, pilots, cooks. This is true of science anywhere, but in most places the discoveries get front-page attention while the behind-the-scenes support gets forgotten. At the South Pole, the need for teamwork is impossible to forget. Your life depends on it.

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### On the Top of the World

In many ways, the South Pole is similar to other premier observatory sites. They all tend to be at high altitude -- in the case of the South Pole, atop a 9,500-foot (2,900-meter) thick ice sheet. The height gets astronomers above the bulk of Earth's atmosphere, especially above the water vapor, which blocks certain colors of starlight. For the same reason, the best observatories are also in deserts, where water vapor is minimal and the full spectrum of starlight reaches the ground for astronomers to study. Antarctica is one of the driest places on Earth. In fact, it's so dry that, for some kinds of observing, the air is as transparent as outer space.

Major observatories also tend to be remote, in order to avoid the bane of modern astronomy: light pollution. Indeed, many observatories used to be remote, but then cities grew up around them, and now street lamps drown out the stars. But the South Pole doesn't have to worry about urban sprawl.

The South Pole has another crucial advantage over other telescope sites: Day and night work differently there. In most places on Earth, there are 365 days per year. Each day, the Sun and stars rise and set. But at the South Pole, the Sun and stars rise and set only once each year.

Look at a globe and the reason becomes clear. Pick out Hawaii, the location of the world-renowned Mauna Kea observatories, and spin the globe. If you stand in one place, you can see Hawaii only part of the time. The rest of the time it's on the side away from you. But as you spin the globe, you can always see the South Pole.

Each time the globe spins around represents a day. Suppose you represent the Sun. If a team of tiny astronomers in Hawaii wanted to look at you, they could see you for only part of the day. But a team of tiny astronomers at the South Pole could see you all day.

Because the pole is right on the axis of rotation, it stays put as the world turns. The only motion that affects the pole is that of Earth's orbit around the Sun. To simulate this, stand still and ask a friend to carry the globe in a circle around you. Your friend should keep the axis of the globe pointing in the same direction, just as the axis of Earth always points in the same direction. Each trip around you represents one orbit of Earth around the Sun -- that is, one year. Notice that those tiny astronomers at the South Pole would see you for only half a year.

The same is true for real astronomers at the South Pole. The Sun is above the horizon for half the year. It rises in September and sets in March. During these months, no matter when you set your alarm clock, you always wake up and go to sleep in broad daylight. But for the other half of the year, the Sun never rises. Similarly, other objects in the heavens are visible for months at a time. During those months, they remain at about the same distance above the horizon.

### The Middle of Nowhere

Solar astronomers were the first to take advantage of this weird day- night cycle. In the 1960s, solar astronomer Martin Pomerantz pioneered a branch of solar astronomy known as helioseismology, which relies on very long observations of the Sun. Antarctica provided the observing times Pomerantz needed.

Only in this decade, however, have researchers made a concerted effort to build observatories at the South Pole. Two groups have led the way: the Center for Astrophysical Research in Antarctica (CARA), which includes scientists from various institutions in the United States and Australia, and the



Welcome to the Dark Sector. The South Pole observatories are located about 800 meters (half a mile) from the main station, on the other side of the airplane runway. The mirror is for the AST/RO submillimeter telescope, which, appropriately, probes the cold gas in interstellar

Antarctic Muon and Neutrino Detector Array (AMANDA), built by a team of American, German, and Swedish scientists. Both groups operate from the Dark Sector, about a half-mile from the Amundsen-Scott South Pole station, the base maintained by the United States since 1957 (see photo).

CARA's telescopes look at wavelengths of light which the eye doesn't see: the infrared and radio [see "[There's More to Light Than Meets the Eye,](#)" *The Universe in the Classroom*, summer 1996]. Although each of CARA's telescopes looks at a different set of wavelengths, they all have the same basic structure. The first crucial element is the primary mirror, which collects the light from the sky and redirects it into the telescope. The other, secondary mirrors focus the light until it forms a greatly magnified image. In a backyard telescope, this image is seen through an eyepiece. In a research telescope, the image is instead focused on an electronic detector.

One of CARA's telescopes, known as AST/RO, is sensitive to submillimeter wavelengths of light, which are sandwiched between infrared light and radio waves. These wavelengths are given off by the cold gas in interstellar space which forms stars. Because submillimeter wavelengths are especially sensitive to water vapor, the South Pole is one of the few places on Earth where they can be observed. Other scientists use AST/RO to study our own atmosphere, particularly the ozone hole directly above the South Pole.

Another of CARA's telescopes, SPIREX, looks at infrared light. Although only 24 inches (70 centimeters) wide, it matches the performance of much larger infrared telescopes in other locations, where observing conditions are worse. SPIREX began working in early 1994 and viewed the collisions of comet Shoemaker-Levy with Jupiter in July of that year [see "The Comet About to Smash Into Jupiter," *The Universe in the Classroom*, spring 1994].

A third telescope, PYTHON, collects the microwave radiation produced by the Big Bang [see "The Biggest Bang of Them All," *The Universe in the Classroom*, first quarter 1997]. It produces high-resolution maps of the ancient universe, including the slight lumps that were the seeds for today's galaxies.

CARA has also developed a robotic telescope, which can be deployed in even more remote Antarctic sites to see whether they are better for astronomy than the South Pole.

## Look Down

While CARA exploits the dry air and the high latitude of the South Pole, AMANDA takes advantage of all that ice. It is an example of how modern astronomers are redefining what we mean by the word telescope. AMANDA doesn't look for light, but for neutrinos, subatomic particles that are created by supernova explosions and other cataclysms in space. It doesn't look up, but down, searching for neutrinos coming through the earth rather than from the skies. And it doesn't use mirrors, but special detectors embedded as far as 2 kilometers (over 1 mile) underground. These detectors watch for flashes of "Cherenkov radiation," an eerie blue glow produced when high-speed neutrinos interact with the ice.

It's easier to picture what AMANDA does by thinking of speedboats and buoys on a lake. As a speedboat races across a lake, it leaves a wake behind it -- just as neutrinos produce Cherenkov radiation as they race through the ice. As the wake passes the buoys on the lake, they bounce up and down, rolling with the waves created by the boat. If you could measure the height and timing of the waves at each buoy, you could deduce the direction and the speed of the boat. Similarly, from the brightness and timing of the Cherenkov radiation seen by each detector, AMANDA can determine the energy and direction of the neutrinos.

Neutrino astronomers are forced to use such a roundabout technique because neutrinos are impossible to capture by run-of-the-mill telescopes. To build AMANDA, they are lowering its strings of detectors into holes drilled using hot water. When finished, the holes are about 2 kilometers deep and 1 meter (over 3 feet) wide. They refreeze within a couple of days, so the AMANDA scientists have only that amount of time to install their detectors.

Despite the hazards of the South Pole, the research program continues to grow -- in large part because of the successes of the astronomy. Three years ago, the Amundsen-Scott station could support 120 people. Now it can maintain a population of 173, and in each of the past three years new laboratories, observatories, and sleeping quarters have been constructed.

Just a few years ago, most of the researchers worked in tents, affectionately known as Jamesways, left over from the Korean War. Each summer, the crews had to pitch the Jamesways and then take them down again. The tents didn't even have bathrooms; you either used a bedpan or walked outside, in -20 degree Fahrenheit weather, to the bathroom. Now, the observatories have permanent buildings. Scientists can observe year- round, and they don't need to spend weeks each year setting up camp.

## Down Under

Simply getting to the South Pole is an adventure. You take the first step of your journey months in advance by passing a thorough medical exam. When the time comes to begin the trip, you fly to Los Angeles and then on to Christchurch, New Zealand. That's a 12-hour flight over the Pacific, and because you cross the International Date Line, you lose another day -- if you leave the United States on Monday night, you arrive in Christchurch at noon on Wednesday.

In Christchurch, your next stop is the National Science Foundation's clothing distribution center. There you can leave any bags you don't want to take with you to Antarctica, and you receive special cold-weather gear: long underwear, pants, jackets, gloves, hats, parkas, and insulated shoes called "bunny boots." Then you're given a time to report for your flight, usually a day or two later.

The plane is a Hercules LC-130, a cargo plane equipped with skis. Before you board the plane, you need to put on all that cold-weather clothing as a safety precaution in case the plane crashes (see photo, top of page ). It takes eight hours to fly to McMurdo station, the main U.S. base in Antarctica, with a population of about 1,000. There you await your trip to the South Pole.

That trip usually comes within a day or two. You board another LC-130 for the three-hour flight. During the first hour of that trip, you'll pass over the Transantarctic Mountains, one of the most beautiful sights in the world. At the same time you're climbing from sea level to an elevation of about 9,500 feet (2,900 meters).

When you finally arrive, you notice two things: the cold, of course, and the elevation. Because the pole is at a high altitude where there's less oxygen, most people feel dizzy and short of breath. Newcomers don't sleep well for the first few nights and have a dull headache. Fortunately, your body gets used to the altitude after a few days.

At the South Pole you live with about 50 scientists and 120 support staff. Most people have a tiny room in a Jamesway tent. To save fuel, you're only allowed two 2-minute showers per week. Fortunately, it's so dry and cold that people don't get too smelly. The dining room, TV lounge, pool room, laundry, libraries, and bar are in three major buildings, which are protected under an aluminum dome. The dome connects to arches that hold the station's fuel, power plant, garage, gym, carpentry shop, and hospital.


Because the Sun is up all the time in summer, people adopt their own strange sleep cycles. Some people are sleeping while others are working. On the only day off, Sunday, friends get together to jog the 15,000-foot-long runway or, on New Year's, the "Race Around the World," a three-lap race around the metal stick that marks the exact location of the South Pole.

The dome also has facilities for the staff members who spend the winter at the South Pole in order to operate the telescopes and maintain the equipment. Most people come only for the summer, which runs from early November to mid-February. Outside that period, it's too cold for aircraft to land. Summer temperatures are



Taking out the trash. The line of cardboard boxes on the left are for sorting trash. All garbage has to be shipped back to Washington state in order to protect the

usually -20 to -50 degrees Fahrenheit (-30 to -45 degrees Celsius), but during the winter, temperatures can drop to -100 degrees Fahrenheit (-70 degrees Celsius). Eight scientists and 20 support staff stay the winter -- over half a year in total isolation.

delicate Antarctic environment. The boxy building at the rear houses the AST/RO submillimeter telescope. It is up on stilts so that drifting snow can slide underneath rather than piling up and burying the building. Photo  1994 Maohai Huang. Used by permission of Maohai Huang.

But probably the most remarkable thing about living at the South Pole is the camaraderie. Because there are so few people and they all realize how remote and far from help they are, there is a special teamwork there that you don't see in many other places. You'll be surprised when, on your final day as you board the LC-130 for your trip back, you'll feel like you're leaving a place that has become home.

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