The universe in your hands

In astronomy, a vision is more important than visuals.

Marc G. Airhart

It's a typical Wednesday morning at the SETI Institute in Mountain View, Calif. Kent Cullers strides into his office, casually brushing his hand over a marble plaque inscribed with the words, "Nothing is written in stone." Just before coming to the office, he had received an important phone call from a colleague in Australia, where it's already late at night, and now he needs to get working immediately. He throws his portable computer on the desk, plugs in the phone line and speech processor, and turns it on. The system responds with a tinny "Keynote main menu."

His office, he tells me in our phone interview, is minimalist. There are no pictures of planets, nebulae, or galaxies on the walls; no space-shuttle models; no sign that a physicist or astronomer works here. On the desk is a wooden sculpture of a dolphin. "I have a dolphin on the desk to remind me how difficult it is to communicate with other life forms," Cullers explains.

Suddenly a talking clock blurts out, "9 a.m." Cullers gets back up and flips on the light switch. "I turn it on to let the others in our office know I'm here," he says. But he doesn't need the light himself. He's blind. In fact, he tells people he's the world's only blind astronomer. "People can't figure out quite what that is and it makes them curious."

Blind Visionaries

Cullers, the project manager for the most intensive search ever conducted for alien radio signals, is one of an increasing number of blind or visually impaired people who have entered careers in science and engineering — and not just in paleontology and geology, where the subject of research might be easily turned over in the hand, but also in seemingly visual fields such as astronomy and microbiology.

Virginia Stern, director of a project on disabilities for the American Association for the Advancement of Science, credits the advancement of disabled scientists to several factors: federal laws that have opened up access to higher education; the availability of what she terms "assistive technology," such as speech-to-text software; and changing social attitudes. To infect students with a love for science at a young age, some planetariums and museums are beginning to offer programs and publications that can be experienced by the deaf and blind. Educators have realized that making a museum wheelchair-accessible is not enough to ensure that everyone has access.

But progress has been slow, and there is a downside to the new technology. Listening to computer speech is cheaper and easier than reading Braille, and that is not necessarily good: Many children are learning that it's all right, in fact preferable, never to learn to read. In other ways as well, the path of least resistance leads visually impaired students away from science. Gary Vermeij — a paleontologist, evolutionary biologist, and author of the recent book, *Privileged Hands* — spends much of his time outdoors collecting samples. Science, he tells me, requires "a flexibility of mind… to not mind taking risks," and this does not come easily. "The blind are already overprotected from the world," he says. "To be successful means not minding pricking your finger on rose bushes."

Not only must teachers and parents protect without overprotecting, they must themselves learn to be especially perceptive. "There are all sorts of people who have no idea of what a typical thing is like," Vermeij says. "For example, a city block is difficult for a blind person to grasp. For some, it's easier than others. My family was very good at describing the world around me."

Blind scientists talk about a shortage of role models for the visually impaired in science. When I ask Cullers who his role models were, it takes him quite a bit of thought to come up with one: Abraham Nemeth, the computer programmer who developed a generalized code for writing mathematics in Braille. "There were no ways to write higher mathematics," Cullers says. "[Nemeth's code] had many maddening properties, but I admired him nonetheless, because he essentially made it possible to learn things that we never would have." Today, it is he and Vermeij who have become the role models.

Touching a Planet

Cullers has no memory of sight. He was born with RLF — retrolental fibroplasia — a condition that many blind people in their 40s have. Doctors in the early 1950s were confused when a minor epidemic of blindness spread among newborns. We now know that RLF was caused by the doctors themselves. Premature babies were regularly placed in environments rich in oxygen to compensate for their weak lungs. As a result, vessels in the eyes swelled with blood. Then, when the oxygen levels dropped back to normal, the blood vessels destroyed the babies' retinas.

When I ask Cullers when he decided to become an astronomer, he pauses for a moment, smiling over the phone. "When I was 5 years old, my father read me a book called the *Golden Book of Astronomy*," he says. "It was mostly about the planets, but it also had a lot about the stars. I literally could imagine reaching out and touching those cold, or hot, or whatever, objects — and in my mind, I was right out there. I said, 'Gee, I've got to do something exciting like that.'

The dream still thrills him: "Even today I can imagine nanotechnology, where you can have molecularly thin space suits that hug the body so tightly that you can literally touch the surface of some planets and it would feel like you were doing it with your skin."

In college, Cullers faced special challenges in his chosen field. "As far as anyone can tell, I'm probably the world's first totally blind physicist," he says. "And I think the reason for that is coping with the physical world is hard when you're blind. Going through college, trying to figure out what diagrams the teacher is talking about is hard. So, although there are many blind mathematicians, there are practically no blind physicists."

While at the University of California in Berkeley, he became an expert in computer programming and data analysis to understand Earth's upper atmosphere. When he heard about NASA's SETI plans, he realized that he had devised computer algorithms that could help to extract an intentional signal from noise. Today, he manages the day-to-day operations of Project Phoenix, the privately funded reincarnation of NASA's original search [see "The Day After," March/April 1996, p. 23]. Cullers helped to develop the crucial technique of using multiple receivers on Earth to weed out human-made noise.

Auralizing

I was curious about how a blind person understands an entire world beyond his touch and hearing. Does he see, in his mind, stars and galaxies as three-dimensional objects? "I don't do that," Cullers tells me. "But I do visualize signals. In some sense, I'm just the right person to do the kinds of analysis that I do."

He elaborates: "I understand because my ear makes me in tune to those things, what the natural relationships are between frequency and visibility which exist in these kinds of simple signals. So I knew when I began this project what to tell the computer to do. I knew what kinds of mathematical forms to use — that Fourier analysis would work well for detecting signals coming from rotating planets. So I was kind of a natural. No human being can do the analysis anyway, so the fact that I couldn't see the screen didn't matter. And the fact that my ears influenced the way I thought made it pretty easy to imagine how signals can be. So I have lots of mental pictures of signals and not nearly as many pictures of the sky itself."

To do his work, Cullers relies on an arsenal of tools, both cutting-edge and traditional. He often relies on sound to read graphs. Computer software converts a two-dimensional graph of data points into a series of rising and falling tones —

a technique, incidentally, that has now found its way into widely used mathematical software such as *Mathematica*. Other software packages allow him to write programs by converting his speech into text.

Even though speech recognition and synthesis are increasing in importance, Braille is still essential for scholarly work. In fact, Cullers says he worries that computer speech is discouraging blind children from ever learning to read Braille.

"You cannot do good physics or good engineering with precision without good mathematics," he says. "And that precision means that you have to be able to control the speed at which you read in a micromanagerial way. That is, you might read three symbols fast and two symbols slow. You slow down, speed up, and reread. There's no possible way you can do that in speech. And you've got to be absolutely certain of whatever you read. When you're trying to understand what someone else has to say, you better be able to really read."

To address this need, electrical and mechanical engineers have developed a textural counterpart to the computer monitor: a soft display that forms a line of Braille text by raising and lowering a series of solenoids. When the reader finishes the line, the display changes to represent the characters in the next line. There's also the "opticon" — a camera that converts images on a computer screen or the printed page to a texture that can be felt on a small pad. As Cullers describes it: "You run the camera across the page, and a very small part of the page is displayed on one of your fingers, so something the size of a capital letter takes up the entire tip of one finger — all of the high-sensitivity area of a finger. And you learn how to scan this camera around so it feels like you're running your hand across the page and just feeling the image."

Cullers also relies on, as he puts it, "good old human slave labor" in the form of students and friends who make raised line drawings of graphs and images by using a pen and a rubber mat. As the pen is run over the image, it makes raised lines on a sheet of paper. These drawings have to be simple, Cullers says, because the standard tricks of visual art, such as shading and perspective, don't make sense to people who have only ever read with their fingers.

A Computer for the Rest of Us?

Yet every silver lining has a cloud. When computers become more intuitive for the sighted, they become more frustrating for the blind. "Five or six years ago," says Cullers, "there was a peak. Computers were most blind-friendly. Things were essentially text-driven. And you had menus with letters and numbers that let you do things. That was a very good environment for those of us with speech processors. Then everything went graphical, essentially Mac and Windows-like environments. It's taken the speech processors a while to catch up."

"I still don't have a good web browser," he continues. "My speech processor doesn't work well with Netscape. I have to battle the icons when I'm working in Windows. I have to first find out what the icon is, and then do something with it, whereas there is this sort of spontaneous eye-hand coordination that a sighted person uses."

Fortunately, various companies are beginning to make Internet browsers specifically for the visually impaired. And even if software for the blind were no longer catching up, it would still be way ahead of where it was a decade ago. "I live on the computer all day long," Cullers says. "If I have to battle it a little more, then it's not nearly as bad as in college when I had to take notes on tape in class and then Braille them all later on. Or where I had to first do my mathematics in Braille then type it all up so the professors could see my work. Nothing is as bad as it used to be. I can't complain very much."

Science educators are also starting to draw on a mix of computer technology and old-fashioned tools to include everybody in their programs. Blind people entering the Charles Hayden Planetarium in Boston are seated along with sighted visitors for a standard winter sky show. They are given a guidebook with four or five raised images of comets, planets, and constellations, along with Braille descriptions. In the dark planetarium, they read the raised dots with their hands, while sighted visitors watch the bright dots on the domed ceiling. They also turn over in their hands models of the *Hubble Space Telescope*, satellites, and the planetarium projector.

Noreen Grice, an education associate at the planetarium, prepares the Braille guides and helps to orient visually impaired visitors. For the deaf, she and engineers at the local public television station, WGBH, have developed a closed-captioned device.

"It's fantastic," Grice says. "The units look like shoe boxes… with stems that attach into the seat. With one minute's notice, we can install the units, click the computer on to the correct show, and the words are printed on the monitor." In the past, teachers had to use an interpreter with a lamp and a script, while simultaneously trying to look up at the effects on the ceiling. Needless to say, this was frustrating. Today, Grice says, "the Charles Hayden Planetarium is the only planetarium in the world that uses closed-captioning for the deaf."

Grice is perhaps best known as the author of the book *Touch the Stars*, a tour of the universe for the visually impaired. She printed the astronomical pictures in raised dots, and labeled each with Braille. Originally published in 1990, *Touch the Stars* is still available from the Boston Museum of Science.

So far, these programs and publications are the exception. Science is still a daunting pursuit for the disabled. It takes a rare mix of perseverance, access to technology, and the support of loved ones to enable a disabled student to become a successful scientist. But despite all the talk of obstacles, we should never underestimate the lure of the unknown. It can draw a child, any child, into such an adventure as SETI.

"It's something that I never thought I, as a mere physicist, with my training could participate in," Cullers says. "That's exciting. But on the other hand, every day I get to come to the office and play with computers, design things, and there are all kinds of good toys all over my desk. And so I'd have to say that getting there is at least half the fun. If I don't get all of the way there, I will still have a lot of fun." ***m***

MARC G. AIRHART is the assistant producer for the *Earth & Sky* radio series, produced by Byrd & Block Communications in Austin, Texas. He is currently participating in the Marine Biology Laboratory science-writing program in Woods Hole, Mass. His email address is mairhart@earthsky.com.

For more information on astronomy education for the blind, see "To Touch the Sky" by Karen Hartley, *StarDate*, July/August 1992, p. 8.