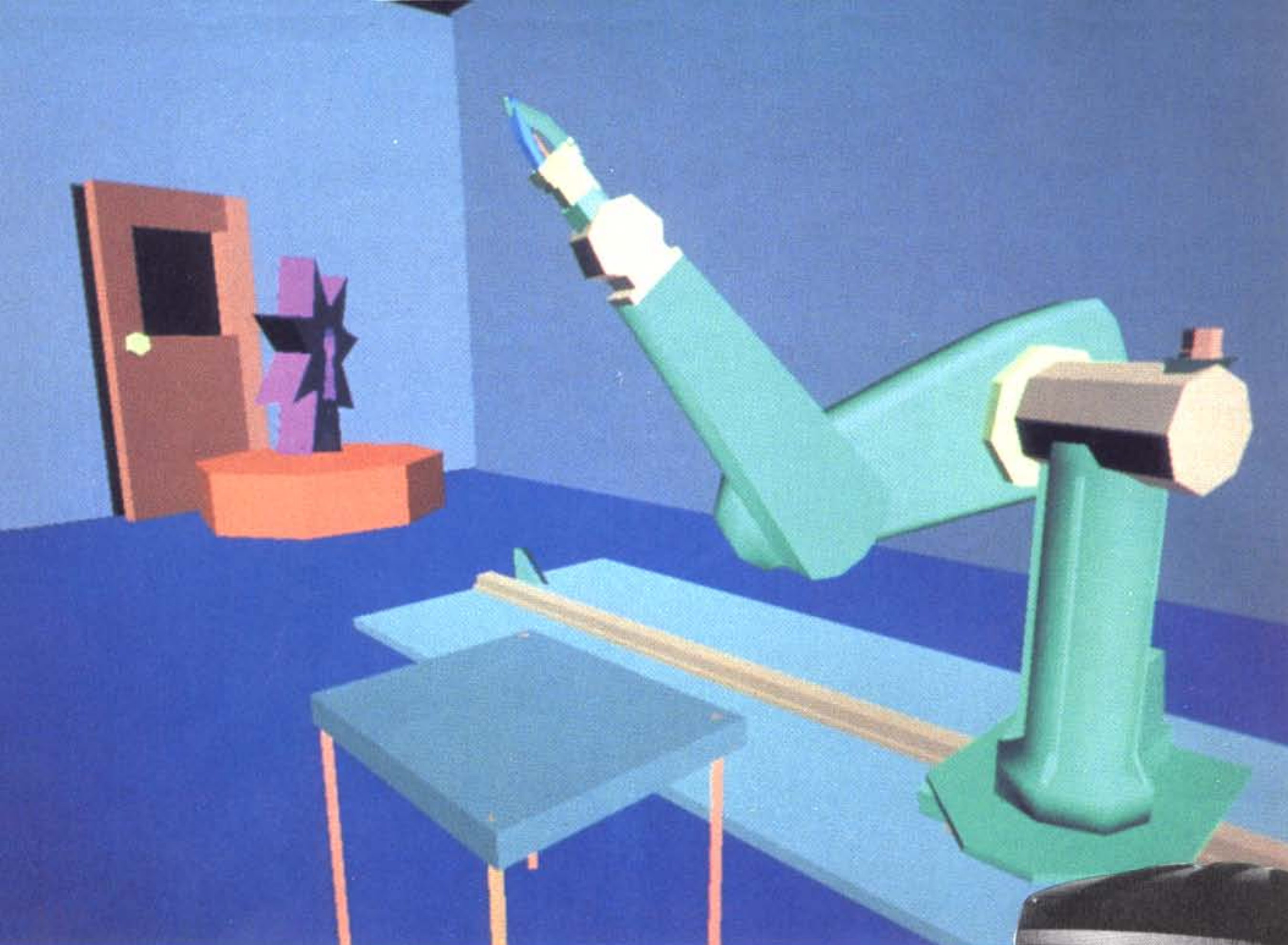
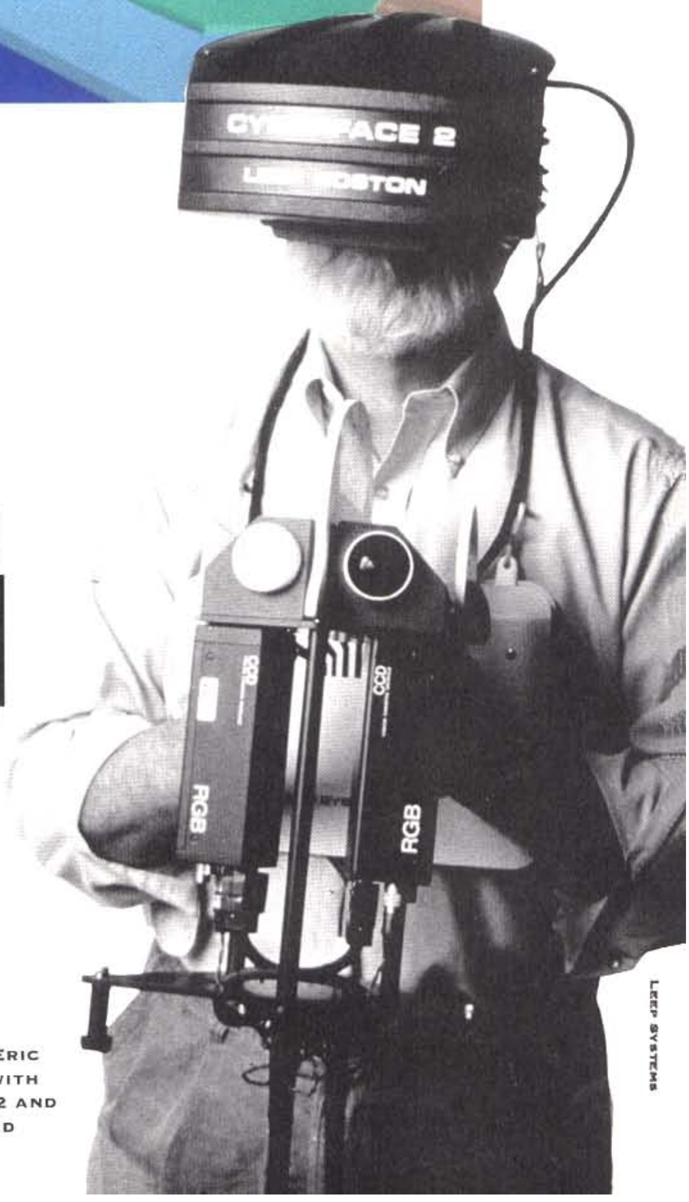


Sidney Stein for VPL Research Inc.

VIRTUAL REALITY

IS SEEING BELIEVING?



Leep Systems

FIGURE 1. ERIC HOWLETT WITH CYBERFACE 2 AND TELEHEAD

Tow missiles exploded overhead as our Bradley Armored Vehicle rolled over the Arabian Desert. Iraqi soldiers approached. Shots rang out. The soldiers crumpled into the sand. Tank commanders jammed the airwaves with staccato commands to move out. My heart pounded.

What I've just described was not a trip to the Middle East during the Gulf War, but a simulation of one of its battles. Shortly after the war, Col. Jack Thorpe of the Defense Advanced Research Projects Agency (DARPA) began recreating 73 Easting, a then little-known Gulf War battle. Using interactive simulation technology, Thorpe and his colleagues at the Institute for Defense Analysis (IDA) have developed an experience that leaves visitors with sweaty palms and dry mouths. Today, 73 Easting represents a state-of-the-art synthetic environment.

The DARPA simulation is just one of a growing number of synthetic environments often referred to as virtual reality (VR). Although the creators of these virtual worlds say that, given time, the difference between the real and the virtual will be unnoticeable, for now, only the most expensive systems can provide a reasonable approximation to the "real" world.

by Susan M. Reiss

THE GREAT DEBATE: WHAT IS VIRTUAL REALITY?

The road to VR has been dotted with pixel improvement and evermore intricate computer graphics. As the fledgling technology advances, the task of defining "virtual reality" may prove arduous. Few who create virtual worlds agree on just what "virtual reality" means.

VPL's Lanier says, "VR specifically relates to people with head-mounted displays and gloves who are networked together in a shared simulation that includes representation of their own bodies." More importantly, says Lanier, VR is a communication tool with increasing power and clarity.

In a product brochure, LEEP Systems defines VR as sights and sounds that don't exist as perceived. Deborah Silver, a VR researcher at Rutgers University, says the difference between computer graphics and VR is the total immersion of all of the senses with VR. "It's the natural extension of computer graphics and creativity," Silver maintains.

And for NSF's John Hestenes, virtual reality is one extreme on the spectrum of interactive visualization. He defines interactive visualization as any environment where a person visualizes data and interacts with it.

While the DARPA simulation, for example, provides a sense of "being there," viewers are not totally immersed in the battle. They can see chairs, light fixtures, and other mundane parts of the room in which the simulation is shown. The display quality is also cartoonish. However, the combination of battle sights and sounds allows the brain to synthesize a virtual world. To produce the hair-raising recreation, DARPA uses three large-size TV screens, data collected from the battle that is fed into a computer, and a "spaceball" to control movement during the battle.

In addition to the military's synthetic battlefields, the sciences, medicine, and architecture are benefiting from virtual environments. No longer will researchers scratch their heads wondering how molecules react. They can actually "walk through" a chemical reaction (see cover)—lifting molecules and positioning them as they desire. Geologists can explore the nooks and crannies of remote locations or "travel" to Mars and study its surface. By first scanning and digitizing a human knee, doctors can practice "virtual knee surgery" without even nicking the patient's skin. Some architects are tossing away the balsa wood models, so often used to win design contracts, in favor of virtual simulations that allow prospective clients to stroll through their creations.

Trying to pinpoint the beginning of virtual reality is like trying to find an atom with the naked eye. The origins of VR start at different times, depending on who you ask. NSF's John Hestenes, program director for Interactive Systems, says virtual reality dates back at least to Descartes and Michelangelo because they understood space. LEEP's Eric Howlett, founder of LEEP Systems—a Waltham, Mass.-based VR manufacturer—suggests virtual reality began with wide-angle stereoscopic viewing in 1924. Introduced by a Dutch scientist to the Optical Society of London, stereoscopic viewing involved placing a distorted image on film and using a lens to restore the image—a technique similar to that used in anamorphic art. Others say Ivan Sutherland, the "father" of computer graphics, gave birth to virtual reality in the 1960s. He built a head-mounted display that offered viewers what he described as "virtual worlds."

Several different projects during the 1960s gave way to powerful simulators. Thomas Furness, now director of the University of Washington's Human Interface Technology Lab, worked on a virtual display technology that was eventually used in the Air Force's Supercockpit program—a flight simulator. But NASA's Michael McGreevy says virtual reality goes back to prehistory. "Virtual reality is not a matter of technology, but of human desire," he suggests.

VR PARAPHERNALIA

To produce VR's "you are there" feeling, participants need several pieces of equipment: a visual display—either head-mounted with a tracking device or stand-alone; a computer with the requisite software; and a device to control movement—for smaller budgets, a joystick; for larger budgets, a glove covered with sensors and attached to the computer through fiber optic cables.

The visual displays require far more research before they can claim the realism associated with, for example, photographs. Images are currently jagged or, as with the DARPA simulation, cartoonish. Says one IDA official, "It's money that's holding the display technology back." But, he asks, "How good a system do you need?" Commanders and their troops may not need to see every grain of sand in the desert. Likewise, in other applications, the human brain's power to

LEEP SYSTEMS

FIGURE 2. LEEP VIEWER LENSES

synthesize sensory data may enhance visual displays just enough to create a close approximation to reality.

Columbia University researcher Steve Feiner explains that some display quality is about as good as that of the TV in your living room, but that this quality is unacceptable for detailed data displays. Another concern he voices is the display's inability to rebuild itself quickly when moving from scene to scene. "The state of the art in 1992 is not quite good enough," Feiner contends. But LEEP's Eric Howlett doesn't think a system needs super high resolution. "The eye needs only a few degrees of sharp resolution," he says. Howlett created the first video lenses used in NASA's virtual reality project at Ames Research Center in 1985.

Two head-mounted displays currently on the market are the Cyberface 2—built by LEEP Systems—and the EyePhone HRX and LX—produced by VPL Research Inc., Redwood City, Calif. The LEEP model is a general purpose head-mounted display that uses two 4-inch diagonal color LCD video panels for an extremely wide-angle stereoscopic view (see Figs. 1 and 2). The display can provide 140 degrees horizontal field of view. Cyberface provides 115,000 pixels per eye. The set-up requires three analog color signals for each eye and composite synchronization.

VPL's Eyephone HRX liquid crystal displays contain over a third of a million primary color pixels per display; proprietary compound Fresnel lenses, and diffusion elements. VPL's chief executive officer Jaron Lanier points out that describing the resolution associated with head-mounted displays is a problem because there is no standardization. "Describing resolution as $n \times n$ can be misleading," he says, "because viewers rarely see all of the pixels contained on a display." Obstructions such as the viewer's nose or optical distortion interfere with seeing all pixels.

Bottomline Reality

VPL's Lanier has been credited with being the first to see a market for virtual reality. But more research must be done to improve mediocre display quality and that research carries a price. "Virtual reality is at the top of the technology food chain," says Lanier. "The technology base must continue to improve and the price must be cheaper."

Because only a handful of companies in the U.S. are devoting their resources to manufacturing and marketing virtual reality systems and components, their costs are high. Systems stripped to the bare essentials begin around $30,000. Most researchers require a system and several components as well as software and hardware. The price tag: $55,000—a good chunk of a research budget. "Cost is the major problem," says Joel Kollin, an optical engineer for the University of Washington's Human Interface Technology (HIT) Laboratory. "A lot of people are building their own stuff."

With limited budgets, researchers must make hard calls about what they want from their equipment. "People have to decide if they want very high resolution or wide fields of view," says Reflection Technology's Ben Wells. Depending on what they choose, system costs increase as do computer memory requirements.

Despite poor displays and sometimes prohibitive costs, LEEP's Howlett contends that "because of virtual reality's extreme usefulness, industries will spring up." He rattles off a list of current users, including university labs, NASA, IBM, and IMAX, and notes that "virtual reality is just beginning to get attention in the electronics and software industries."

VR Fun & Games

Those in the entertainment business are convinced of virtual reality's bright future. London's Trocadero and a video arcade in Seattle are now home to virtual reality video games. For a dollar a minute, players don the clunky head-mounted displays, grasp a joystick, and whirl around in a computer-generated fantasy.

On a smaller scale, some toy manufacturers are at work developing $100 versions of virtual reality games. Reflection Technology, which develops and manufactures an ultra-miniature virtual display, has incorporated the display into a prototype game to rival current home video games, explains company president Allen Becker. Wearing the Private Eye® (see Fig. 3), players can drive through a city. If they turn their heads sideways, they see the sides of the buildings. If they look down, they see buildings below. Or they can look up and see helicopters flying. Using a joystick, they can "fly up" and chase and shoot the helicopters. According to Becker, "Players feel they are in a different world. Like watching a cartoon, it isn't a different 'real' world, but it is a consistent and enjoyable world."

The Private Eye®, which lists for $795, displays an image at a resolution of 720 × 280 pixels that appears to float a few feet in front of the viewer's eyes. Along with a computer, the Private Eye® can be used as an electronic field manual, a pocket computer, or as an electronic book. Based on the success of such products, the University of Washington's Kollin predicts "it will just a year or two before virtual reality is a consumer product." Others in the field disagree, suggesting virtual reality products are at least five years away.

A National Priority?

At the National Science Foundation, John Hestenes says there's been a lot of discussion internally about how virtual reality might fit into the directorate's charge. But "the discussion has yet to gel into a concrete program," Hestenes acknowledges. The directorate is currently funding several programs within the Computer and Information Science and Engineering directorate that support interactive systems. Future programs might examine what physical mechanisms in the human body are engaged during interactive visualization, as well as how a human being perceives the real world and a virtual world.

Hestenes predicts that scientists who use virtual worlds in their research will "gain a perceptual appreciation never before achieved." Whether virtual reality becomes a laboratory tool, however, depends on the "priorities of decision-makers in this country," he says. At NSF, virtual reality "is not on the back burner, nor is it accelerating."

At the National Research Council, Harold Van Cott is querying experts on the best way to proceed with a virtual reality program. Van Cott says the NRC program would examine future implications of the technology. Study areas might include the impact of VR on children, the philosophical question of 'What is reality?' and practical applications. But Van Cott warns: "We'll lose this technology if we don't have a national effort. To do it right, we need more money."

NASA's virtual reality program was built by Michael McGreevy, principal engineer of the Human Interface Research Branch at NASA Ames Research Center. During the mid-1980s, McGreevy pushed NASA to develop virtual environment workstations for advanced human-computer interfaces. He credits Eric Howlett with designing the optics for NASA's first head-mounted displays. "It's one thing to have a dream and another to have the hardware," McGreevy says. "Optics are the key to this dream."

In 1985, using a Radio Shack LCD display, Howlett's lenses, 100 × 100 pixel TVs that cost $79.95, two video cameras, a head and hand tracker, and a calligraphic computer graphics system, McGreevy produced a prototype to show NASA managers. His makeshift system convinced NASA to provide the initial $10,000 for system research.

Ensuring VR has real applications and isn't just a "gee-whiz" technology is at the heart of McGreevy's virtual reality crusade. To maintain NASA funding, McGreevy says the technology has to have real applications. Drawing on the agency's wealth of planetary data images obtained by Viking 2, McGreevy and his colleagues have developed a system that enables users to "walk" on Mars. NASA is also considering using virtual environments to train astronauts before they hurtle into space. According to Lee Holcomb, director of Information Sciences and Human Factors at NASA, "Virtual reality is another tool in NASA's toolbox used to explore the universe."

But the $1 million budget now allotted to the virtual reality program is just a fraction of what some feel ought to be spent. "Although virtual reality has been recognized as a major new paradigm in human-computer interactions, NASA is a very busy and harried organization and is not able to focus its attention on the new technology," McGreevy points out. But he predicts that passage of the High Performance Computing and Communications (HPCC) initiative in Congress will have positive affects for NASA's program.

Reflection Technology

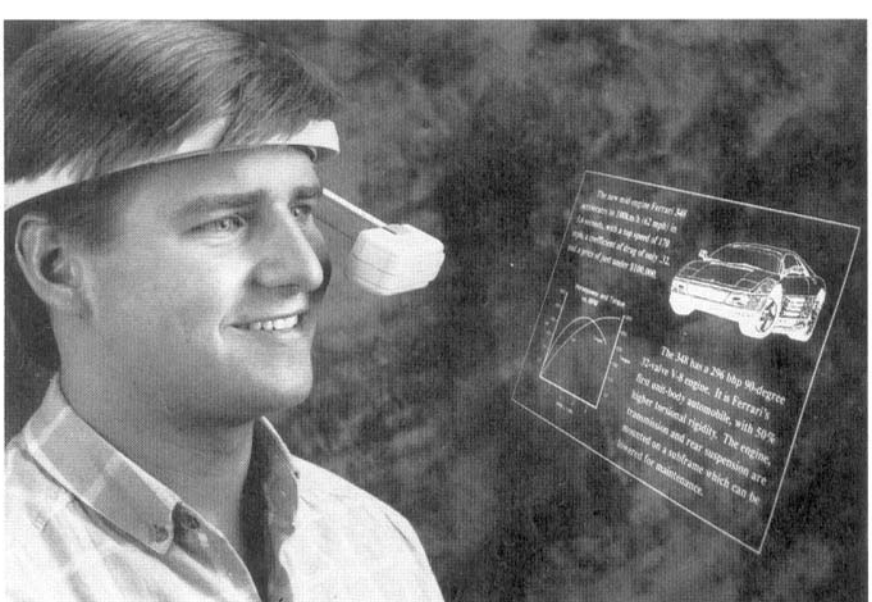


Figure 3. An ultra-miniature virtual display, manufactured by Reflection Technology, creates the full size image of a 12-inch monitor in a package measuring 1 × 1 × 3 inches and weighing 2 oz.

Senate science champion and author of HPCC legislation Albert Gore (D-Tenn.) wanted to find out more about virtual reality, so he held hearings last spring. Gore, characterized as a "VR-head" by VPL's Lanier, thinks the country should improve its efforts in this field. Despite inaction by the Senate during the year since the hearings, Gore is trying to publicize the virtues of virtual reality through other forums. A bicameral body—the Congressional Clearinghouse on the Future—scheduled a day-long event in March to highlight technologies that could be used to expand health care and education programs in rural America. Virtual reality systems headed the list.

Virtual Reality in Our Future? Is virtual reality another technological comet whizzing by on its way to stardom or just a here today/gone tomorrow blip courted by the media? Many in the field say it's too soon to tell. Lower costs and less cumbersome equipment are the keys to the future. But researchers at the University of Washington think the future is now. The University of Washington's HIT Lab is developing a system that scans virtual images directly onto the retina using a laser—providing resolution equivalent to or greater than high definition television (1280 × 1024 pixels).

But to succeed commercially, Kollin says virtual displays will require inexpensive laser or LED arrays, and "a good holographic or aspheric optics infrastructure on a commercial level." Although some systems provide limited tactile sensation, Kollin predicts this option won't be in widespread use until the year 2000. "Real reality won't have competition for a while," he says. But he adds that applications of virtual reality systems are "just waiting for the technology."

As consortia form (the Virtual Worlds Consortium is based at HIT) and the science of virtual reality finds application, the field will build credibility. Already, MIT publishes a scholarly journal called *Presence* to chronicle virtual reality research.

For the purist, virtual reality is a way to create worlds that otherwise would not exist. "VR has magic appeal. It represents a way of going back to the imagination and dreams of childhood," explains VPL's Lanier. "You can share the infinitude of imagination with others that you normally must give up." For NASA's McGreevy, virtual reality is "a way to make a hard copy of your dreams."

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