Virtual Reality

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Sun Microsystems Computer Corp.

"Virtual reality will affect just about everybody. It's inevitable."

- author of a book on VR

To the average Joe, virtual reality is about as real as the Holodeck room that Captain Jean Luc Pickard and his pals on *Star Trek: The Next Generation* visit to experience another environment while on board the Enterprise. To the lunatic fringe, it's a technology that will largely replace real experience. And between these two extremes are a growing number of businesses, organizations and computer firms like Sun Microsystems Computer Corp. (SMCC) that are exploring virtual reality as a new kind of computer interface that will simplify many current tasks and help create new applications as well.

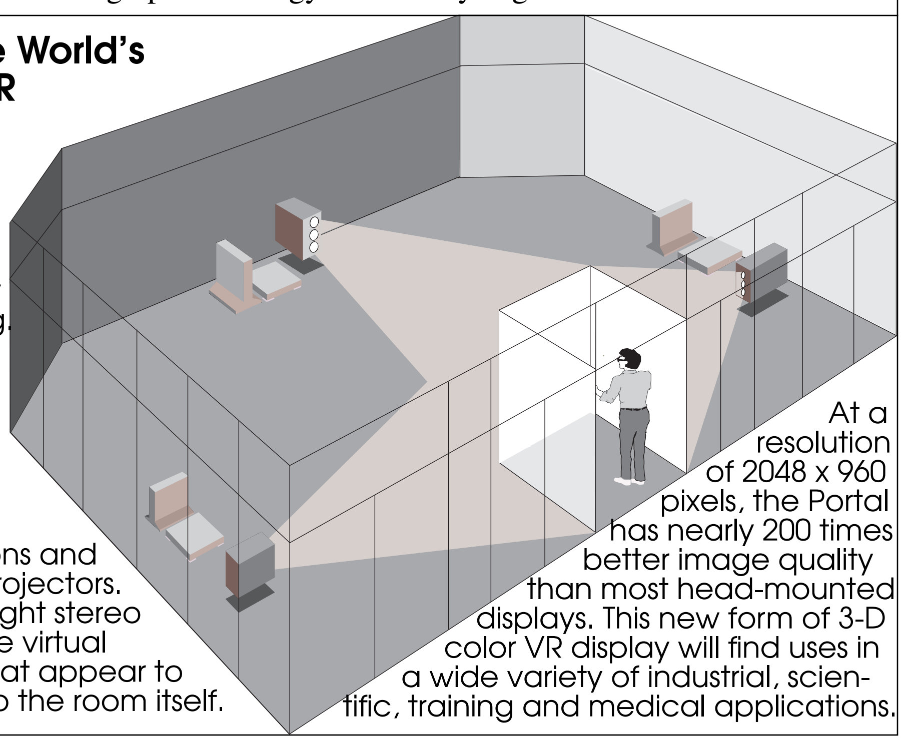
As the world's leading vendor of UNIX workstations, SMCC sees great promise in VR, since the technology requires a powerful, networked platform for good results. SMCC's first VR product was the Virtual Holographic Workstation, which offers 3-D VR on the desktop. The company later built the first permanent, three-screen VR environment (called the Virtual Portal), which is the highest-resolution VR system ever made. The company has also designed a breakthrough, very small VR system (including computer and head-mounted display) that has very high resolution and low cost. In addition, capabilities will be added to the Sun platform that will enable Sun users to develop VR applications.

VR: Is It Real?

Although VR is an emerging technology, the convergence of cheap, high-powered workstations, ongoing development of sensing interface devices (like head-mounted displays, gloves, etc.), and advances in graphics and software technologies have made VR more practical for real applications. And as computer technology continues to get cheaper and more powerful, VR will be an important beneficiary. While the real heyday of VR is yet to come, application of this fascinating technology has already begun. As the ultimate man/

The Virtual Portal: The World's Highest-Resolution VR Environment

This permanent three-screen VR demonstration displays immersive virtual reality scenes designed by VR expert Michael Deering. Viewers can tour virtual worlds, from high sea cliffs to the ocean depths, to wars in outer space. The Virtual Portal is a small room in a Sun engineering building with three SPARCstation graphics workstations and three rear-screen stereo projectors. Viewers wear only lightweight stereo glasses and are able to see virtual objects all around them that appear to come from infinity right into the room itself.



At a resolution of 2048 x 960 pixels, the Portal has nearly 200 times better image quality than most head-mounted displays. This new form of 3-D color VR display will find uses in a wide variety of industrial, scientific, training and medical applications.

machine interface, VR offers a way of performing certain tasks faster, easier and less expensively than they have been. Tasks for which rapid, accurate human visualization of three-dimensional data is a key component will gain much from VR. Inherently dangerous or expensive tasks are particularly appropriate, which is why flight training has been a focus of VR for more than 20 years.

Where Did It Come From?

The VR concept was born in 1965 when Ivan Sutherland (now a Fellow in Sun Microsystems Laboratories) published a paper called *The Ultimate Display* that laid out the basic concept of virtual reality. He did further work, developing the first head-mounted display and the first VR system. (See *History of VR* sidebar.) Dr. Sutherland's early work became the basis for most subsequent research in the field.

One of the milestones in the development of flight simulators was the 1982 unveiling by Thomas Furness of the most-advanced-to-date simulator. All contained in a Darth Vader-like helmet, it was created for the Air Force. Also in the early '80s, "artificial reality" got its name from Jaron Lanier, an early developer of sensing interface devices. Some aficionados use the term "Cyberspace" for virtual reality. A name for an alternate computer world, it first appeared in the popular science fiction novel *Neuromancer*, written by William Gibson and published in 1984.

In 1986, at Schlumberger's Palo Alto research center, computer scientist Michael Deering and physicist Howard Davidson worked closely with Sun Microsystems to develop the first workstation-based color head-mounted display -- on a Sun workstation. Two years later, both researchers moved to Sun. Dr. Deering designed VR capabilities into the company's GT graphics system, while Dr. Davidson worked on head-mounted displays. and at a low cost. Currently, additional VR

History of VR

Highlights/Milestones

1965 **Ivan Sutherland, a Sun Fellow who is called "the father of computer graphics, " writes the seminal VR paper, "The Ultimate Display."**

1966 **Ivan Sutherland develops the first computer-based, head-mounted display.**

1968 **Ivan Sutherland and David Evans create first scene generator, with 3-D images, stored data and accelerators. They also launch Evans&Sutherland.**

1972 **General Electric develops first flight simulator using computers, working for the Navy. Flight simulators will become an important area for VR.**

1983 **Jaron Lanier coins term, "virtual reality" and co-develops VR interface devices like gloves and head gear. He founds VPL Research in 1985.**

1985 **Researchers at NASA Ames develop the first practical head-mounted stereoscopic display system.**

1987 **NASA perfects the first computer-synthesized reality, combining stereo images, 3-D sound, gloves, etc., using some commercially available items.**

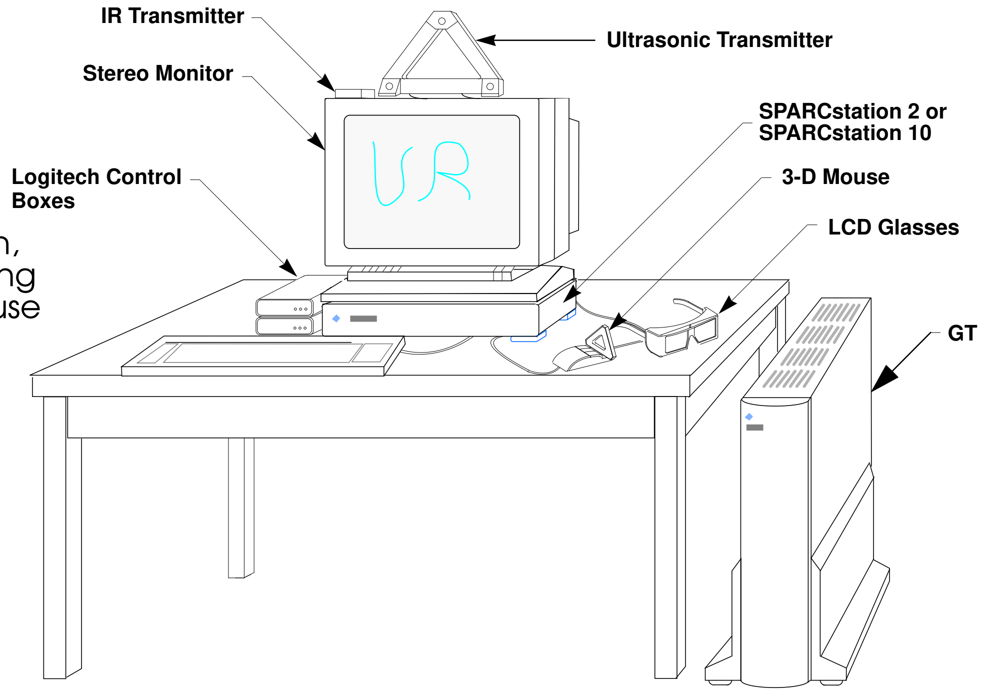
1989 **VPL, and later Autodesk, introduce or demo all-inclusive VR systems for a single user. VPL's is costly ($225K) while Autodesk's is not (under $25K).**

1990 **First commercial VR software firm, Sense8, is formed. Offers the first software tools for VR. The company begins porting to Sun.**

1992 **Sun first demonstrates the Virtual Portal, the highest-resolution VR environment yet developed.**

Sun Virtual Holographic Workstation

Includes realtime 3-D display based on SPARCstation graphics workstation, ultrasonic 3-D tracking system and 3-D mouse from Logitech. This system allows users to move freely and look at objects from diif-ferent angles, with a realistic stereo view. The fast GT hardware helps create the illusion of reality.



By the beginning of the '90s, VR research was being pursued all across the country. But the San Francisco Bay Area was the VR hotbed, spawning new companies, products and applications of the technology. At the same time that computers were rapidly becoming more powerful and less expensive, companies were developing VR goggles, head-mounted displays, VR bodysuits, and software development tools for VR applications.

Sun and VR

Sun Microsystems began doing on-site VR development when Deering and Davidson joined in 1988. The company unveiled a virtual holographic workstation prototype in 1991 that utilized the work of the two researchers. It offered remarkable freedom of head movement for the user and high resolution. Then, as now, the company often partnered with smaller firms that made various VR interface devices. The Virtual Holographic Workstation became a popular display at trade shows and events. By the end of last year, approximately 100,000 people had seen a demonstration of it, making it one of the most widely viewed VR systems in the world. An outgrowth of the holographic workstation was the Virtual Portal, a complete VR environment that was unveiled at a major graphics trade show in 1992. A permanent version of the Portal was built inside an SMCC engineering building at the end of 1992. *(See page 1 for information on Portal.)*

VR Systems for Everyone

The Sun Virtual Holographic Workstation is not just a research project. A complete system (including all add-on equipment like stereo monitor, transmitter, stereo glasses, etc,) costs $46,000 and has been purchased from SMCC and third parties by organizations in many sectors: aerospace, automotive, financial services, medicine, universities, the military and others.

Sun hardware is VR-ready. In addition, a special VR software developer's release for the Solaris 2.x operating environment for Sun workstations will be available in the very near future. This new software will sit on top of the XGL 3-D graphics libraries and will enable Sun users to create and run VR applications. SMCC's objective in VR is to offer the system support needed for VR -- as standard features projects utilizing sophisticated techniques are being undertaken that could become part of future Sun products.

Software is an important element in the emergence of broader application of VR. Currently, there are a number of companies making VR development tools for the Sun platform. There are also a number of companies developing in-house VR applications for Sun systems. In the future, commercial VR applications should become available that will increase the use of VR on Sun.

Computer-Augmented Reality

Computer-augmented reality is a version of VR that will find wide application. It allows users to freely mix live video with virtual objects created by a computer. For example, the Sun Virtual Holographic Workstation performs computer-augmented reality. In one entertaining application, users aim a real wand at a virtual spinning aluminum block (called the "virtual lathe") in order to grind it into the desired shape.

One future example of computer-augmented reality regards office computer use. Rather than accept the physical limitations of a CRT monitor, workers could use computer-augmented reality to extend their desktop workspace to include their entire field of vision. Wearing virtual reality goggles, the user would see virtual documents, stacks of paper, or file cabinets. Individual virtual documents could be manipulated, drawers could be opened and files extracted, documents could be edited as though they were hardcopy.

Some day, workers might be able to fix a broken copy machine themselves by following step-by-step visual and text instructions overlayed directly on the innards through virtual reality goggles. Even before this comes to pass, jet engine repair or assemly work might utilize this technique. Another potential exam-

VR Interface Technologies

Head Trackers are devices that inform the computer as to the 3-D location and orientation of the user's head. From this, the computer can derive the location of the wearer's sensory organs (eyes and ears).

Gloves or Data Gloves are devices worn like gloves over or on top of the user's hands that inform the computer as to their position and orientation and also provide information as to the extension and position of each finger.

Body Suits are like extended data gloves worn over more of the human body. Also called a datasuit.

3-D Mice are hand-held pointing devices. They are a 3-D version of the familar two-dimensional mouse. The 3-D mouse feeds the computer 3-D position and orientation data.

Head-Mounted Displays (HMDs) are small displays, typically liquid crystal displays (LCDs) or small CRTs, worn by the user. Since HMDs support a wide field of view, many times in excess of 65 degrees, the wearer can get a feeling of "immersion" in the virtual world. HMDs can be for a single eye (monocular), or one for each eye (binocular), and support stereo display. While HMDs give a good feel of immersion, they typically suffer from exceeding low resolution (on the order of 300x200 color pixels), below the threshold of legal blindness. Also, the wide field of view optics induce enough distortion to make the stereo view fairly innaccurate. HMDs are also sometimes called eyephones.

Stereo CRTs are variants of the typical 2-D workstation display, but many times augmented.

(see next page)

ple of computer-augmented reality is surgeons who can overlay CAT scans on the patient, or view additional patient information -- such as readouts from monitors -- in their peripheral vision.

Related to computer-augmented reality is “telepresence,” which adds 3-D images of real physical objects from remote locations to the real and virtual objects experienced by the user. One of the most exciting future examples of telepresence is video conferences that can take place around a virtual conference table -- even though the participants are all in different locations. As each attendee connects into the meeting, his or her image joins the virtual images of the others at the table. (See illustration on page 6.)

Uses of VR Today

Although in its infancy, VR technology is already finding uses today. Applications will grow exponentially as prices continue to drop and new breakthroughs take place. Following is a potpourri of VR applications:

• Mercedes Benz uses VR simulations to gauge a driver’s response to changes in the interior design of the automobile.

• The U.S. bobsled team used advanced VR simulations to practice for the 1992 Olympics.

• Japan’s Shinjuku department store uses VR to help cutomers design their new kitchen. Customers can even open drawers, turn on the water and control VR appliances.

• A VR simulation of the murder of San Francisco porn magnate Artie Mitchell helped convince a jury of the guilt of his brother Jim last year.

• VR has already appeared in games that allow users to battle rival space ships or dinosaurs. simulate possible systems for defense and see

Stereo Shutter Glasses are glasses that shutter left and right lenses that are synchronized with the left and right stereo display, thus making possible the realistic, 3-D effect.

Head-Tracked Stereo Shutter Glasses are stereo shutter glasses that have a head-tracking device built in.

Projection CRTs allow larger images to be displayed. Many projection CRTs are capable of displaying field sequential stereo.

Multiple-Projection CRTs can surround the viewer with computer-generated imagery, also potentially in stereo.

Sound Output -- 3-D synthetic audio can make computer-generated sounds appear to originate from a particular point in space, and via echoes aid in the illusion of spacial dimensions. Sophisticated audio processing utilizes knowledge of the location and position of the user’s head in space, often along with a detailed model of the acoustical properties of the particular user’s ear to create this effect.

Tactile Output -- Force feedback gloves let the virtual world push back at the user. Typically consisting of computer-actuated mechanical linkages, these devices simulate the sense of touch for virtual objects. Simpler tactile systems are more like digital joy-buzzers - they tap or vibrate on the tips of fingers when the user intersects a virtual object.

Flight simulators and some entertainment systems employ a form of whole body tactile feed-back -- by use of a computer controlled motion platform to shake the whole body in space, simulating acceleration of vehicles.

• In a project at the Graduate School of Architecture and Urban Planning at UCLA, VR was used to design the rebuilding after the Los Angeles riots.

• Researchers at the University of North Carolina are refining VR technology so that doctors will be able to examine a patient's internal organs in 3-D artificial space.

• At the Human Interface Technology Laboratory at the University of Washington, children are being brought in to play in "virtual playgrounds."

• Programmers are now working on VR systems that will allow home buyers to tour their homes before they're even built.

• Canadian power companies are developing robotic telepresence technology so that workers won't have to actually climb utility poles to repair dangerous high-voltage cables. Applications for firefighters, police and workers who handle radioactive waste disposal are also being explored.

• A Michigan software company is developing fully immersive VR systems for use in clinical psychology so that professionals can practice positive responses to situations, experiences and emotions.

• Researchers at Carnegie Mellon University have begun development of a "virtual art museum" that will be accessible via modem from two sites.

• NASA's Johnson Space Center in Houston has begun development of a virtual physics lab that will allow students to visualize and control physical phenomena.

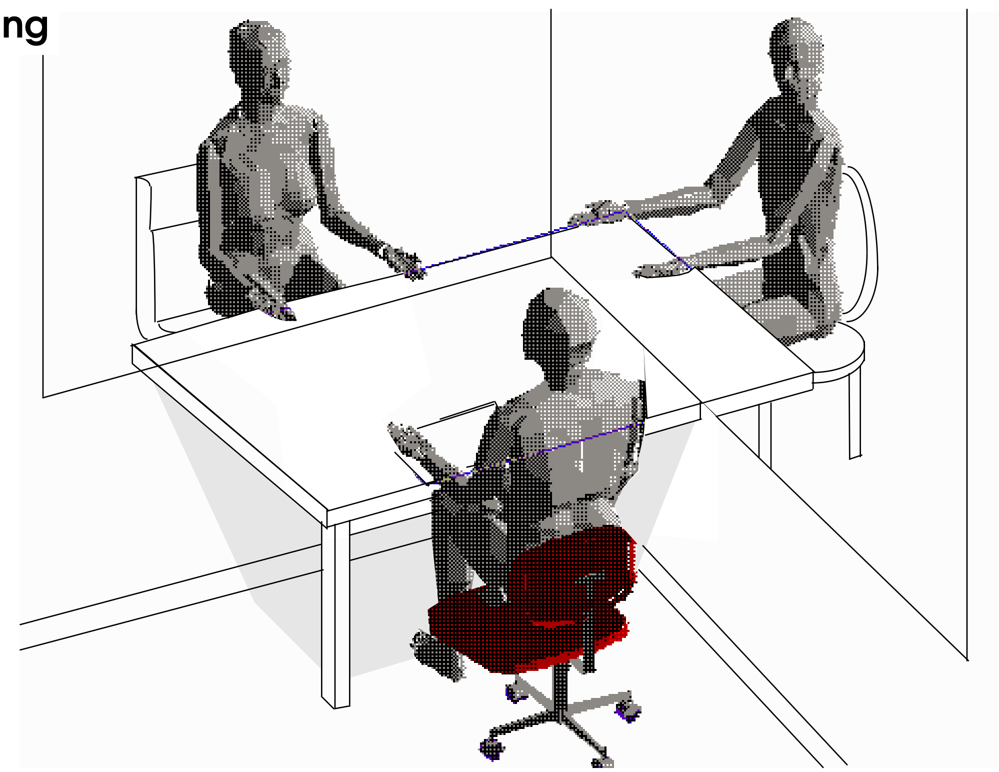
• The Institute for Defense Analysis is using VR to simulate an actual maneuver performed in the Persian Gulf war.

• A Wall Street firm is developing a VR application that will allow brokers to "fly" over a virtual trading floor. They can see differently colored virtual stocks and quickly select potential investment opportunities.

• The Department of Defense is using VR to

VR Conferencing

This interesting application of telepresence combines video (taken at remote site) and VR technology to give users a very realistic method of holding meetings. Superior to existing video conferencing techniques, it could conceivably change today's reliance on costly, time-consuming business travel.



how these might work with real systems that currently exist. This enables developers to improve the design and functionality before costly prototypes are built.

When Will It Hit?

The progress of VR since its invention may seem slow but is actually in line with other technologies that now dominate our workplace. PCs, fax machines and electronic mail are the most obvious examples. New technologies do not reach mass markets until their benefits exceed their costs; virtual reality is rapidly achieving cost effectiveness in a range of applications.

Within 20 years, the dominant computer interface could be the goggles of a VR system. In the 21st century, office workers, machinists, architects, doctors, factory workers, engineers and professionals in dozens of other fields will go about their business wearing a lightweight cordless headset that supplements their view of the "real world" with virtual reality -- 3-D or holographic images superimposed over or even substituting for physical objects.

Ten to fifteen years from now, much engineering and scientific work could likely be performed using head-mounted displays or computer-augmented reality. Software development is a good example. Five years out, the initial pioneering VR applications will break into the mainstream. These will likely be in high-end scientific areas or in training.

One thing is for sure: use of virtual reality *will* grow. After all, the qualitative and quantitative improvments in human perception of the computer world enabled by virtual reality are too real to ignore.

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GLOSSARY OF VR TERMS

6 DOF -- Six degrees of freedom; refers to the number of simultaneous directions or inputs a sensor can measure. Usually describes spatial position (X, Y, Z) and orientation (roll, pitch, yaw).

COMPUTER-AUGMENTED REALITY -- A form of VR in which elements of the real world are combined with the virtual world.

CYBERDECK -- The system that creates the VR experience.

CYBERSPACE -- The artificial world of VR.

EFFECTORS -- The input and output sensors that either communicate a user's movements or commands to the computer or provide sensory stimulation from the computer to the user.

EVENT LOOP -- The sequence of events the computer loops through to maintain a simulation. Must happen at least 16-20 times/second to create a sense of realism.

IMMERSION -- When one or more of the user's senses are fed only information from a VR system.

JACK IN -- To plug in; as to a VR system.

PARALLAX -- Difference in viewing angle created by having two eyes looking at the same scene from slightly different positions.

PORTAL MATHEMATICS -- Sun engineering term for a what was used to build the physical-to-virtual gateway in the Virtual Portal.

RENDER -- To decompose graphics primitives into individual pixels.

SUBMODALITIES -- The smallest categories into which one's senses can divide experience. For example, ears can differentiate by frequency, rhythm, tone and duration.

TELEPRESENCE -- The experience of being in another location; usually accomplished by transmitting the user's view through a camera.

TESSELATE -- To decompose complex 3-D shapes into graphics primitives (such as polygons).