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ABSTRACT

This booklet contains information about the Human Interface Technology Laboratory (HITL), which was established by the Washington Technology Center at the University of Washington to transform virtual world concepts and research into practical, economically viable technology products. The booklet is divided into seven sections: (1) a brief description of virtual worlds technology; (2) a description of HITL and how it interfaces with its parent institutions and surrounding community; (3) a list of HITL staff, fellows, and students, with a one-paragraph description of the activities of each; (4) a description of the Virtual Worlds Consortium, which works to enhance commercial applications of virtual worlds technology and a list of participating corporations; (5) lists of HITL core activities, enabling technologies, projected concept demonstration dates, and targeted markets; (6) an order form and a list of approximately 60 HITL technical publications; and (7) reprints from newspaper and magazine articles about virtual reality and HITL. A brief description of "sci.virtual-worlds," a multidisciplinary USENET newsgroup devoted to discussions of the subject, is given on the inside back cover. (KRN)

The Human Interface Technology Laboratory

of the Washington Technology Center

Human Interface Technology Laboratory
of the Washington Technology Center
University of Washington, FJ-15
Seattle, WA 98195
206 / 543-5075

Dr. Thomas A. Furness
Director

The Human Interface Technology Laboratory was established in October 1989 by the Washington Technology Centers to transform virtual world concepts and research into practical, economically viable technology products.

The overall goal of the Laboratory is to develop a new generation of human-machine interfaces by:

- *Investigating and understanding the fundamentals of human perception and interaction with computers, information, and complex systems.*
- *Pioneering new interface concepts focusing on virtual world technologies.*
- *Creating and demonstrating new applications for virtual world technology in aerospace, medicine, education, design, entertainment, and related fields*
- *Transferring advanced interface technology and research results to industry.*

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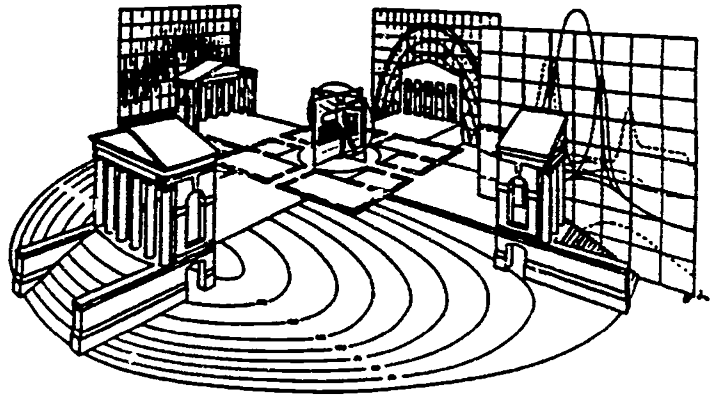
A new interface archetype, that of the "virtual" interface, permits us to revise both the way we think *about* computers and the way we think *with* them. These interfaces allow panoramic presentations in three dimensions to be made to the eyes, ears, and hands of the user. "Virtual" images presented directly to the senses provide a participant with a total, global experience. The human literally wears the computer. The participant is surrounded by a "circumambience" of computer-synthesized information, a spatial "world" in which the person and computer can more effectively communicate. The operator interacts with this inclusive medium by looking at objects, pointing his or her hands, and giving verbal commands. The medium permits virtual objects, which appear to be real but which are virtual projections, to be touched and manipulated by the participant.



To create the "virtual world" representation of information, the virtual-display hardware components are programmed with "mindware." Mindware is a special class of software that takes into account the perceptual organization of the human and dynamically creates the three-dimensional sound, video, and tactile images which surround the user.

A virtual reality is not limited to a single person. Virtual worlds can be shared by two or more participants. Each participant has the ability to customize the rendering to his or her particular needs and preferences. With the addition of telecommunication links, these worlds can be shared by many participants and at different times, creating a new medium of communication: televirtuality.

Virtual interfaces solve many existing interface problems and empower new and novel interfaces for teleoperation, computer-aided design, education, medical imaging, prostheses for the handicapped, and entertainment.

Virtual interface technology provides a bold new opportunity for solving many of the perplexing problems of interfacing human and machine intelligences. With systematic development, virtual interfaces can be one of the greatest advances of our age, and a boon to industry.

The Human Interface Technology Laboratory was established in October 1989 by the Washington Technology Center (WTC) to transform virtual world concepts and early research into practical, economically viable technology and products. The Laboratory performs basic research, develops interface technologies, and demonstrates applications for transfer to industry.

Initially, the Laboratory's research and development program is focused on revolutionizing virtual interface technologies and creating new approaches to couple our senses, intellect, and psychomotor capabilities with complex machines. Ultimately, this activity will provide solutions to pervasive problems of information interface, in a variety of domains.

The overall goal of the Laboratory is to develop a new generation of human-machine interfaces. This goal is expressed in the Laboratory's research agenda:

- ***To investigate and understand the fundamentals of human perception and interaction with the world, with computational machines, and with information systems.***
- ***To pioneer new interface concepts focusing on virtual world technologies.***
- ***To create and demonstrate new application areas for virtual worlds technology in aerospace, medicine, education, communication, design, and related fields.***
- ***To transfer advanced interface technologies to the commercial sector.***
- ***To provide an academic environment to train students, disseminate research findings, and provide a general resource base for the development of human-computer interaction.***

Washington Technology Centers

The state legislature created the Washington Technology Center (WTC) in 1983 as a catalyst for statewide economic development. Its goal is to attract private industry and federal research dollars to help finance commercially promising research at the state's universities. The WTC marries research and private enterprise to produce new companies and high-tech products. The WTC is located in the new 67,000 square foot Fluke Hall.

The WTC is producing technological developments in many areas including: advanced materials, compound semiconductors, computer systems and software, veterinary and medical biotechnology, microsensors, and plant technology. The intellectual property associated with these technologies is in the form of patents, copyrights, trademarks, service marks, and trade names. The WTC's laboratories develop new prototypes and provide the kind of applied knowledge that can lead to breakthroughs for many high-tech industries.

University of Washington

The University of Washington is the premier research institution of the Pacific Northwest, and a major contributor to research and development on a global scale. For the past 20 years, the University has ranked among the top five institutions in the United States in terms of total federal grant and contract support. With an annual enrollment of more than 33,000 students, the University provides a rich human resource base for academic research. The University ranks among the top ten in the United States in many fields, and most notably in the medical and engineering sciences.

Seattle and Washington State

Consistently related "America's No. 1 City," in terms of both livability and as a place to do business, Seattle is well-suited to the emerging global economy. The "Emerald City," located on the Puget Sound, has a mild climate with great scenic beauty, cozy neighborhoods, and proximity to natural areas. The region's burgeoning cultural scene and high-tech industry are making their mark on the Pacific Rim and beyond. The local scene is informal and friendly.

The State of Washington offers a unique blend of urban, suburban, rural, and wilderness regions, with lifestyles to match. Its economy, balanced among natural resources, agriculture, crafts, and high technology design and manufacturing, continues to expand. Washington's progressive politics has produced an unusual alliance between government and business that ensures the state's continuing development into the 21st Century.

Virtual Worlds *Consortium*

- Alias Research, Inc.
- American Express Company
- The Boeing Company
- Digital Equipment Corporation
- Division Ltd.
- Ford Motor Company
- Fujitsu Research Institute
- Franz, Inc.
- Insight Inc.
- Kopin Corporation
- Kubota Pacific Computer, Inc.
- Fluke Manufacturing Co., Inc.
- Microsoft Corporation
- Port of Seattle
- Sharp Corporation
- Stratos
- Sun Microsystems
- US Navy
- US WEST Communications
- Virtual Reality Inc.

Human Interface Technology Laboratory
of the Washington Technology Center
at the University of Washington
Seattle, WA

The Virtual Worlds Consortium supports the Human Interface Technology Laboratory as a forum for the advancement of virtual worlds technology; for educating professionals, students, and the general public regarding virtual worlds technology; and for enhancing commercial applications of virtual worlds technology.

The Virtual Worlds Consortium brings together industry, government, and academia to turn virtual world concepts into marketable technology. As a Member of the Consortium you will gain a strategic posture in promoting the development of an emerging technology. More specifically, you will:

- **Help guide the research and development agenda of the Human Interface Technology Laboratory**
- **Be in touch with emerging research through two working meetings each year**
- **Receive a semi-annual Consortium newsletter, timed for publication between working meetings, that includes news of the field, research-in-progress, and other items of interest**
- **Have prepublication access to the Laboratory's research findings**
- **Be able to recruit from our corps of graduate students who are directly involved in the development of virtual worlds technology**
- **Pinpoint areas of research specific to your strategic needs and contract with the Laboratory for their investigation**
- **Be informed of technological accomplishments of a non-proprietary nature as they occur, for possible commercialization of inventions and novel processes**
- **Be in the company of other organizations and professionals similarly interested in the emerging field of virtual worlds technology**
- **Work side-by-side with Laboratory personnel scientists and engineers as Industry Fellows and Associates**

Membership in the Virtual Worlds Consortium costs $50,000 per year. Annual sponsorship fees are pooled to support selected research projects at the Laboratory. Because Members have access to the research and development of virtual worlds technology at its initial stages, they enjoy a competitive advantage as they transfer VR applications into the commercial environment.

Staff

Thomas A. Furness III, Ph.D., Director. Dr. Furness brings to the Human Interface Technology Laboratory 23 years of virtual world research experience with the U.S. Air Force. Prior to founding the Laboratory, Dr. Furness was Chief of the Visual Display Systems Branch, Human Engineering Division of the Armstrong Aerospace Medical Research Laboratory (AAMRL) at Wright-Patterson Air Force Base, Ohio. His staff of 50 government and contractor scientists, engineers, and technicians pioneered advanced interface concepts for fighter aircraft including the Super-Cockpit, a virtual cockpit that the pilot wears. This system created a three-dimensional visual, aural, and tactile world enabling pilots to operate complex aircraft with natural hand and eye movements and voice control.

Dr. Furness is a Professor in the Department of Industrial Engineering at the University of Washington, where he conducts classes in human factors and the design of virtual world technology. Dr. Furness holds a Ph.D. in Engineering and Applied Science form the University of Southampton, England.

Colin Bricken, Software Engineer. Mr. Bricken received his B.A. in General Art from the University of Washington in June, 1992. His current project involves implementing the Universal Motivator, an evolving interface to V.R. that includes a V.R. database and dynamics specification, 3-D light and sound rendering, and midi drivers.

William Bricken, Ph.D. , Principal Scientist. Dr. Bricken was formerly Director of the Autodesk Research Laboratory, where he led the development of Cyberspace, Autodesk's CAD application of virtual world technology. He was also Principal Scientist at ADS, where he pioneered the development of high performance inference engines, visual programming languages, and intructable interfaces. Dr. Bricken holds a Ph.D. in Research Methodology and an M.S. in Statistics from Stanford University, and a Dip.Ed. from Monash Unviersity. He has taught at all levels, including principal of an innovative primary school and an Assistant Professor of Social Psychology of Education.

Robert Burstein, Research Engineer. Mr. Burstein manages the Laboratory facilites and plays a major role in the fabrication of virtual-worlds presentation hardware. He holds a B.S.E.E. from the University of Dayton and has contributed to other pioneering WTC enterprises, including most recently the Materials Fabrication Laboratory. Mr. Burstein is a trained musician who works on synthetic generation of three-dimensional sound.

Marc Cygnus, Research Engineer. Mr. Cygnus received his B.S. degree in Computer Science from the University of Delaware in 1991. He is currently pursuing his M.S. in Industrial Engineering (Human Factors) and working on biomedical projects involving the development of input devices utilizing biopotentials at the HIT Lab.

Ann Elias, Program Support Supervisor. Ms. Elias coordinates the Laboratory's administrative activities. She has worked with local high-tech firms in the Seattle vicinity, been involved in Northwest politics as a campaign manager, and is an active fundraiser for the arts community. Ms. Elias holds a B.S. from Oregon State University.

Alden Jones, Program Assistant. Ms. Jones received a B.A. in Art History and English from the University of California at Santa Barbara and then worked in the design and museum fields and the film industry. She coordinated the Lab's most recent Industry Symposium on Virtual Worlds Technology and is currently working on the Lab's next issue of the HIT Lab Review.

Arthur Kerr, Business Manager. Mr. Kerr received his B.S. in Mathematics and Mechanical Engineering from the United States Air Force Academy in Colorado, his M.B.A. from Harvard University Graduate School of Business Administration and completed post-graduate studies at the Royal College of Defense Studies in London. Prior to his work at the HIT Lab, Mr. Kerr directed national-level communications programs in the Air Force, and supervised international sales in Cairo, Egypt. He also taught on the faculty of the Air Force Academy and managed development, test and evaluation activities on the Airborne Warning and Control System (AWACS) in Seattle.

Brian Karr, Research Engineer. Mr. Karr has a B.S. from Evergreen State College. His degree is a combination of Physics and Computer Science. Mr. Karr has two years of graduate studies in the E.E. Ph.D. program at the University of Washington. His past VR experience includes designing and building a system that converts motion into musical instrument contol data (MIDI). He is presently researching 3-D (spatial) sound and developing applications for demonstration and research for inclusion in virtual worlds.

Joel Kollin, Research Engineer, Optical Systems. Mr. Kollin is responsible for the development of new Virtual Worlds display technology as well as other optical systems at the Lab. He holds a M.S. from the MIT Media Laboratory, where he pioneered research on Holographic Television, and a B.S.E. (Electrical Engineering) from the University of Michigan. At KMS Fusion, he worked on interferometry systems for laser-plasma interaction experiments and conducted design studies for a Real-Time Holographic Stereogram Display. Mr. Kollin has also worked on short-term projects for the Polaroid Corp. and the Industrial Technology Institute.

Andy MacDonald, Research Engineer. Mr. MacDonald is the primary systems administrator at the HIT Lab. He graduated from M.I.T. in 1988 with a degree in Mathematics and Computer Science and his current interests include distributed computing and artificial life.

Kymerie Riggs, Administrator, Virtual Worlds Consortium/Administrative Assistant. Ms. Riggs is currently administrator of the Virtual Worlds Consortium, a corporate enterprise committed to the research and development of virtual worlds technology. Her other duties involve proposal/funding support, administrative details, public relations, and coordination of the graduate and undergraduate student activities at the Lab. Ms. Riggs has a B.A. in English and a B.A. in Communications from the University of Washington.

Suzanne Weghorst, Research Scientist. Ms. Weghorst brings a combination of expertise in computer science and behavioral science to her work. Her most recent project, with the Department of Radiology at the University of Washington Medical Center, evaluated the clinical acceptability of a comprehensive computer system for acquiring, storing, and displaying digital images. She holds an M.A. in Psychology from the University of California at Riverside and an M.S. in Computer Science at the University of Washington. Her thesis examined user perception of graphical interface displays.

Industrial Fellows

Ben Childers, Orbis International. Mr. Childers received a B.S. in Environmental Design from Texas A&M University in August of 1990. During the past two years he has been involved with Orbis International in the design of their new DC-10 Flying Eye Hospital. He is now using graphic imaging and animation, which was used to help in the design of the DC-10, to help design an eye surgery simulator and teaching aide to be deployed on the DC-10.

Bernard Ulozas, Ph.D, US Navy, Training Specialist, Navy Personel R&D Center. Dr. Ulozas received a Doctor of Arts degree in History and Curriculum Development from Carnegie-Mellon University in 1980. He began work as an Education Specialist with the U.S. Navy at Service School Command, Great Lakes, Illinois and managed the Curriculum and Instructional Standards Office. He later established and directed the Training Department at the Naval Ship Systems Engineering Station in Philadelphia, PA. Presently Dr. Ulozas is working at the Navy Personnel Research and Development Center in San Diego, CA and is an industrial fellow at the HIT Lab. His research efforts include development of interactive courseware, intelligent tutoring systems and virtual environments for the U.S. Navy Damage Control personnel.

Students

Chris Byrne, Research Associate. Ms. Byrne received a B.S. in Industrial Engineering and an M.S.E. in Design of Experiments and Quality Control from the University of Washington. She spent four years working for US West and is currently pursuing her Ph.D. in Industrial Engineering. Her interests include using virtual reality for holistic solutions to engineering problems. Ms. Byrne is working on the development of the education project at the HIT Lab.

Geoff Coco, Research Assistant. Mr. Coco received a B.S. in Computer Science from Dartmouth College and then worked in the field of Graphics Application for Apple Computers. He is currently pursuing an M.S.E. (Human-Computer Interaction) at the University of Washington while working at the HIT Lab designing the Virtual Environment Operating System.

Paul Danset, Research Assistant. Mr. Danset graduated in 1981 with a B.S. in Physics and is currently a graduate student in the Electrical Engineering Department at the University of Washington. He has ten years work experience in software and hardware, primarily in a research environment. His research interests include signal processing and pattern recognition applications to VR.

Fernando Diaz, Student Aide. Mr. Diaz completed a Computer Information Systems curriculum at the University of Alaska in 1984. Additional studies included cognitive psychology, philosophy, management information systems. Mr. Diaz completed an engineering internship at General Electric Aerospace Division and was System Administrator at the Sony Advanced Video Technology Center. Currently, Mr. Diaz is pursuing a B.S. in Computer Science & Cognitive Science at the University of Washington. His degree program includes research in software tools for virtual world design at the HIT lab.

Toni Emerson, Lab Associate. Ms Emerson has a B.A. in Drama and a B.A. in Spanish Literature from the University of Washington. She expects to receive a Masters of Library Science in the Fall of 1992, and plans to pursue a Ph.D in Library and Information Science. Ms. Emerson is our HITL "Cybrarian" and high-tech information gatherer on the internet and various commercial databases. She wants to specialize in the creation of multi-media information systems (specificaly virtual information systems) and hopes that her research will help to empower the end-user

Daniel Henry, Research Assistant. Mr. Henry received a B.A. in Architecture from the University of Berkeley focusing primarily on the understanding of human behavior in space design. For several years he developed interactive computer animation for kiosks and expositions. Mr. Henry's work in the Laboratory involves helping enrich the existing Virtual Worlds using Swivel 3-D for modeling and Body Electric for interactive programming.

Ari Hollander, Research Assistant. Mr. Hollander received his B.A. in Astrophysics from the University of California at Berkeley in 1991. He is currently pursuing his M.S. in Industrial Engineering at the University of Washington and working on position sensing at the HIT Lab.

Jeff James, Research Assistant. Mr. James received a B.S. in Psychology and a B.S. in Electrical Engineering from the University of Illinois at Urbana-Champaign. He is pursuing his M.S.I.E. and working on extending boundary mathematics into visual programming.

Karen Jones, Research Assistant. Ms. Jones has a B.S. in Industrial Enigeering from the University of Washington and is currently in the M.S. Engineering program. She has worked on evaluating eye tracking devices for the laboratory for further research and is working on developing manufacturing applications for VR.

Dav Lion, Research Assistant. Mr. Lion attended Brown University where he majored in both Studio Art and Computer Science. He helped design and is now currently writing the Virtual Environment Operating System for the HIT Lab. Mr. Lion is also pursuing an M.S.E. (Human-Computer Interaction) the University of Washington.

Max Minkoff, Research Assistant. Mr. Minkoff received an Information Systems degree from Drexel University in Philadelphia and spent two years working in industry on microcomputer user support. He is currently pursuing his M.S. in Industrial Engineering at the University of Washington. Mr. Minkoff is developing world-building tools for the Virtual Environment Operating System at the HIT Lab.

Daniel Pezely, Lab Associate. Mr. Pezely completed a B.S. in Computer Science with a Philosophy minor at the University of Delaware and has worked in the computer industry as a programmer and consultant since the age of 15. He attributes his CAD experience, his fascination for telecommunications and his artistic abilities to his help in developing the Virtual Environment Operating System.

Daniel Pirone, Lab Associate. Mr. Pirone has a B.S. in Computer Science from the University of Delaware and has worked in the field of Artificial Life. After working in a robotics lab at Hewlett Packard, he was invited to study at the Santa Fe Institute. He is planning to pursue an M.S.E. (Human Computer Interaction) at the University of Washington while working at the HIT Lab designing tools for the Virtual Environment Operation System.

Jerry Prothero, Research Assistant. Mr. Prothero received a B.S. in Physics and Computer Science from the University of Washington. He expects to receive his M.S. in Industrial Engineering in 1993. His projects at the lab include 3D graphics and bio-medical visualization.

Jesus Savage, Research Associate. Mr. Savage graduated in 1984 with a B.S. in Computer Engineering and a M.S. in Electrical Engineering in 1990 from the National Autonomous University of Mexico. Mr. Savage, a Fulbright Scholar, is currently pursuing his Ph.D. in Electrical Engineering at the University of Washington. His project involves researching voice recognition for inclusion in virtual worlds.

Mark Takacs, Research Assistant. Mr. Takacs received his B.S. in Computer Science from Miami University in Oxford, OH in 1991 and is currently pursuing his M.S. in Industrial Engineering. His interests include multiple participant virtual worlds and body icons.

Kevin Welton, Research Associate. In 1977, Mr. Welton graduated summa cum laude from U. of California's Davis campus with a B.S. in Agricultural Engineering. Next came a 14 year stint with Weyerhaeuser conducting research and doing prototype equipment development to improve log and lumber process systems and equipment. His primary roles covered that of project manager, staff engineer, and computing specialist; his primary technical foci included EE R&D and design, and operations research. Mr. Welton is now working towards a PhD in EE. At the HITLab, his focus is on Head Up Display hardware, and on how to improve the user's perception that the viewed virtual objects are part of the real world.

Ryoko Williamson, Student Aide. Ms. Williamson expects to receive an interdisciplinary B.S. degree in Cognitive Science with an emphasis on computer-human interface in December 1992. Her research interests at the HIT lab include human factors issues and cognitive aspects of V.R.

HITL PROGRAM RELATIONSHIPS

WTC + CONSORTIUM FUNDING

LAB CORE ACTIVITIES

- Virtual Simulation Lab
- Knowledge Base
- Project Support
- Consortium Admin.

CONSORTIUM + INDUSTRY CONTRACTS + WTC FUNDING

ENABLING TECHNOLOGIES

INDUSTRY CONTRACTS + CONSORTIUM FUNDING

CONCEPT DEMONSTRATIONS

Enabling Technologies	Head-up Display	Protospace Workstation	Presence	Virtuphone
HALO Display		●		
Virtual Retinal Display	●		●	●
3D Audio Graphics			●	●
3D Position Sensing	●		●	
Virtual Envir. Oper. System	●	●	●	●
World Design Toolkit		●	●	
Virtual World Generator	●	●	●	●
Human Factors Metrics	●	●	●	●
IOC →	1992	1993	1994	1995

SPONSORS

- <u>Boeing</u>, <u>Port of Seattle</u>, <u>Fluke</u>, FAA <u>Insight</u>
- <u>Boeing</u>, Searle, NOAA, <u>AMEX</u>
- <u>US West</u>, <u>Boeing</u>, NSF
- <u>US West</u>, <u>Fujitsu</u>, Bellcore, AT&T

TARGETED MARKETS

- Manufacturing/Instrumentation Air Traffic Control
- Aerospace/Automotive/Medical Design & Visualization
- Industrial/Medical Training K-12 Education
- Broadband Telecommunications

FUNCTIONAL ENHANCEMENTS

- Operations
- Enhanced Creativity
- Accelerated Learning
- Hyper-Communications

HITL TECHNICAL PUBLICATIONS

The Human Interface Technology Laboratory has produced a list of technical publications that are available to the public for a nominal fee. All publications are authored by HIT Lab staff, with the exception of the video "Welcome to Virtual Reality," which was produced by US West Communications Corporate Television Division. The cost for *each* are as follows:

Memorandums	$5.00
Reports	$10.00
Presentations	$10.00
Videos	as noted

To order any of the following publications, please fill out the order form below and mail with check payable to the Human Interface Technology Laboratory to:

Kymerie Riggs
Human Interface Technology Laboratory
University of Washington, FJ-15
Seattle, WA 98195

Please note: Publications will not be mailed until check has been received

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HITL Technical Publications **Order Form**

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HITL TECHNICAL PUBLICATIONS

MEMOS: $5.00

ID	TITLE	AUTHOR	PAGES
M-86-1	The Super Cockpit and Human Factors Challenges	Thomas Furness	5
M-88-1	Harnessing Virtual Space	Thomas Furness	4
M-89-1	Configuring Virtual Space for the Super Cockpit	Thomas Furness	7
M-89-2	Inventing Reality	Meredith Bricken	8
M-89-3	Creating Better Virtual Worlds	Thomas Furness	4
M-89-4	Virtual Places: Strolling the Electronic Neighborhood	Robert Jacobson	11
M-90-1	Televirtuality: "Being There" in the 21st Century	Robert Jacobson	16
M-90-2	Virtual Environment Operating System: Preliminary Functional Architecture	William Bricken	8
M-90-3	Human Interface Technology Laboratory Research Agenda	William Bricken	5
M-90-4	A Description of the Virtual Reality Learning Environment	Meredith Bricken	3
M-90-5	Learning in Virtual Reality	William Bricken	6
M-90-6	Virtual Reality, As Unreal As It Gets	William Bricken	3
M-90-7	Extended Abstract: Complexity, Ambiguity, and Learning in FiberSpace	Meredith Bricken	2
M-90-8	The Virtual Conference Room: A Shared Environment for Remote Collaboration	Meredith Bricken	4
M-90-9	Building the VSX Demonstration: Operations with Virtual Aircraft in Virtual Space	Meredith Bricken	2
M-90-10	Extended Abstract: A Formal Foundation for Cyberspace	William Bricken	4
M-90-11	Coordination of Multiple Participants in Virtual Space	William Bricken	5
M-90-12	Virtual Worlds, Inside and Out	Robert Jacobson	13
M-91-1	Inclusive Virtual Reality Demonstrations	Meredith Bricken	7
M-91-2	Bringing Virtual Worlds to the Real World:	Robert Jacobson	12
M-92-1	VEOS Design Goals	William Bricken	3
M-92-2	A Boundary Notation for Visual Mathematics	Jeffrey James	3

REPORTS: $10.00

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R-86-2	A Deductive Mathematics for Efficient Reasoning	William Bricken	38
R-86-3	A Simple Space	William Bricken	30
R-87-1	Designing in Virtual Space	Thomas Furness	18
R-89-1	An Introduction to Boundary Logic with the Losp Deductive Engine	William Bricken	68
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R-90-2	Virtual Worlds: No Interface to Design	Meredith Bricken	15
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R-92-4	The Design of TopoSeattle	Daniel Henry	5
R-92-5	Combination of Two Methods for Isolated Word Speech Recognition	Jesus Savage	7
R-92-6	Using Large-Scale Operating Systems' Designs for an Eclectic Design	Daniel Pezely	11
R-92-7	MIVE: Multi Interfaced Virtual Environments	Johan Andersson	42

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PRESENTATIONS: $ 10.00

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P-90-2	Exotic (but available) CAD (copy of overhead transparencies)	William Bricken	31
P-90-3	Boundary Logic (boundary implementations) (copy of overhead transparencies)	William Bricken	65
P-90-4	Software Architecture for Virtual Reality (copy of overhead transparencies)	William Bricken	56
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P-91-3	A Calculus of Creation	Meredith Bricken	22
P-91-5	Virtual Reality Learning Environments: Potentials and Challenges	Meredith Bricken	7
P-91-6	Gender Issues in Virtual Reality Technology	Meredith Bricken	11

VIDEOS

ID	TITLE	AUTHOR	COSTS
V-91-1	Welcome to Virtual Reality	Staff	$50.00
V-91-2	Industry Symposium on Virtual Worlds Technology (5 tapes)	Staff	$500.00
V-92-1	Discovering Virtual Reality (PSC Technology Camp)	Staff	$25.00

ONLINE

Volume 16 - Number 6

November 1992

ONLINE Interviews Dr. Thomas A. Furness III, VIRTUAL REALITY PIONEER

......what will virtual reality mean to online searchers?

SEE PAGE 14

ALSO IN THIS ISSUE:

- Cutting Your Online Search Bills
- Bailouts And Brutal Disconnects
- After The Fat Man Jumped

Plus 15 Other Articles And Features

VIRTUAL REALITY AND ONLINE DATABASES: WILL "LOOK AND FEEL" LITERALLY MEAN "LOOK" AND "FEEL"?

by Carmen Miller
Carmen Miller Resources

Virtual reality transforms data into things you can see, feel, and even touch. The implications for new insights and new perspectives are huge.
—*Christopher Barr [1]*

Virtual reality (VR) has become a buzzword in the media of late. For those who may not have heard about it, VR involves technologies that promise to revolutionize the human-computer interface, as well as the way we search, display, and assimilate the information we have stored in databases.

By donning VR's "goggles-and-glove" hardware, you enter a three-dimensional world generated from real-time computer graphics. The goggles or head-mounted displays (HMDs) contain two, tiny video monitors that immerse you in a 3-D virtual world. The glove allows you to use natural, pointing gestures to navigate your way through this virtual world, manipulate objects, and receive tactile feedback. Earphones in the HMD transmit three-dimensional sound. While state-of-the-art VR hardware looks a bit like a S.C.U.B.A. mask and glove, the trend for the future will be hardware that is less intrusive.

Although VR is still in its infancy, it is likely to become the ultimate multimedia computing experience. Virtual reality game arcades already exist. VR's potential in the areas of architectural design, medical imaging, and scientific visualization are gaining acceptance. The benefits of being able to walk through a building and change things during the design phase, superimpose an X-ray over a patient in surgery, or manipulate molecular models when testing drugs are obvious to people working in those areas. You can do all of these things and much more in virtual reality.

I first heard about virtual reality a few years ago from Steve Cisler, Apple Computer Senior Scientist and former MAC MONITOR columnist for this journal. He mentioned that a laboratory to develop this technology had opened up at the University of Washington, which is literally in my backyard. When Steve described how you could move through a virtual world using your own gestures, I dismissed the technology outright. Since I am one of those people who gets lost easily in the real world, I assumed I would get lost just as easily in a virtual world. This sounded like a technology with limited appeal, at least for those of us who don't have a high degree of spatial and visual awareness.

WHAT CAN WE LEARN FROM ARTISTS?

I ignored most of the VR media hype until the spring of 1992 when I heard Dr. Thomas A. Furness III speak to a group of special librarians. Dr. Furness is Director of the Human Interface Technology Laboratory (HIT Lab), the lab that Steve Cisler had told me about a few years earlier. Dr. Furness' lecture had an intriguing title, "Virtual Museums, Knowbots and the End of Steelcase," and his enthusiastic delivery surpassed my expectations.

In addition to showing slides of the high-tech world of virtual reality, Dr. Furness incorporated slides of his own portrait drawings into his presentation. The drawings were from a class he and his wife had taken which was based on the principles of Betty Edwards' book, *Drawing on the Right Side of the Brain*:

> *By studying this book, you will learn* how to see. *That is, you will learn how to process visual information in the special way used by artists. That way is* different *from the way you usually process visual information and seems to require that you use your brain in a different way than you ordinarily use it [2].*

If you are one of those people who thinks he can't draw, buy this book. Don't just *read* about the exercises. *Try* them. After just a few exercises you will probably realize you are using a different part of your brain, a part that you don't ordinarily tap into. I guarantee you will be amazed at how these exercises can change your perceptions and expand your awareness, not to mention teach you how to draw.

THE ORIGINS OF VIRTUAL REALITY

The premise of virtual interface technology at its most basic level seems obvious. We live in a three-dimensional world. However, in order to convey information about this world, we translate it into two-dimensions such as words and symbols. Then we have to translate this 2-D information back into 3-D, at least in our own minds, in order to use it in the real world. Why not speed up the learning process by eliminating the intermediate 2-D translation wherever possible?

This is a radical idea, particularly for folks in the information industry who tend to be verbally-oriented. We have become so accustomed to poring over hundreds of pages of downloaded text and numbers to glean a few relevant facts, that we forget that only the most highly motivated have the inclination or patience to gather information in this way. The obstacle to selling data to the end-user is not merely the interface. The presentation of the data could do with some sprucing up.

However, there is a far more important and pressing issue here than a convenient interface for accessing information or displaying it in a pretty package. Who among us can deny that we have reached the point of information overload? Granted, with all of this information literally at our fingertips, participants in the online information industry might be the worst of the information junkies. Am I alone when I say I read more than almost anyone I know? Just reading e-mail can become a full-time job if you're not careful. The point is, we have just about reached the limit of the amount of information we can assimilate *unless we change the way we think.*

> *User interfaces and computer technology . . . are part of an evolutionary process. Designs that work change the way we think.*
>
> —Don Norman [4]

This was precisely the problem Dr. Furness was faced with solving when he was director of the Super Cockpit program at Wright-Patterson Air Force Base, where he worked prior to starting the HIT Lab. The amount of information fighter pilots had to assimilate from the cockpit's radar, instruments, and command communications had become too much. The slightest error by a pilot who was fighting G forces while flying one of these expensive machines through enemy territory could make for a very bad day! The solution was a virtual cockpit that gives the pilot back his three-dimensional capability; it uses audio, visual, and tactile feedback to transmit information to him. Experienced pilots loved it, and it turned out to be an incredibly fast and efficient means of teaching new pilots to fly. This was the first application of virtual interface technology.

VIRTUAL REALITY AND ONLINE

So what does virtual reality have to do with the online industry? Virtual interface technology may well be the means by which we interact with databases in the future. Instead of being limited to a keyboard that we use to "dialog" with the computer, i.e., type in commands, keywords, numbers or menu options, our body and all or most of its senses may be the central component of the interface.

> *I believe that conversation is the wrong model for dealing with a computer—a model that misleads inexperienced users and invites even experienced software designers to build hard-to-use systems. When you are interacting with a computer, you are not conversing with another person. You are exploring another world.*
>
> —John Walker [3]

Virtual worlds technology may provide a key to assimilating complex information stored in databases. Instead of displaying the results of a database search on a screen, we may be able to step "through the looking glass" [3] and immerse ourselves in the data. This presentation of data could take advantage of all of our senses.

FROM SKEPTIC TO TRUE BELIEVER

At the end of Dr. Furness' lecture, I asked a question. Since most of the applications of this technology that I had heard about seemed to have something to do with manipulating physical reality, I wondered if there were other types of applications. Being a business information specialist, I specifically asked if there were applications that someone like a stockbroker or accountant might use.

Dr. Furness gave an example that I have since come across in the literature. I think it is a particularly good example and warrants repeating. He explained that virtual reality is well-suited to representing complex numeric data. For example, you could portray the stock market as a wheat field, with each stalk of wheat representing a different stock. Price fluctuations or other factors could be portrayed by the stalks growing and shrinking. You could literally walk through this virtual field of real-time stock data.

Do any of you who read the stock market pages or search stock market data in online databases agree that this is an amazing application? Personally, I follow about fifteen to twenty stocks. That's really about my limit. However, if I had a 360-degree view of this data represented pictorially and in three dimensions, I am certain I could follow many more. Obviously, this type of representation would also make it much easier to identify patterns and trends. While some would argue that you can do almost the same thing on a computer screen, I take exception to that. I think that the 360-degree field of vision and being able to interact with the data in a three-dimensional virtual world make all the difference.

This example made me a convert. I do believe this technology has enormous potential to change the way we think and learn. I also think it has enormous implications for the online industry. We are the keepers of huge amounts of data, which will be crucial information in virtual worlds.

This example also prompted me to request an interview with Dr. Furness. Read on to find out about the activities of the HIT Lab, how online information companies can participate in this emerging industry, and what it all may mean for the future of online databases.

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ONLINE INTERVIEWS DR. THOMAS A. FURNESS III, VIRTUAL REALITY PIONEER

by Carmen Miller
Carmen Miller Resources

"VSX Demo" is a project the HIT Lab did in conjunction with Boeing Computer Services.

(Author's Note: This is a recorded interview with Dr. Thomas A. Furness III, Director of the Human Interface Technology Laboratory, a division of the Washington Technology Center located on the University of Washington (Seattle, WA) campus. This interview took place on May 27, 1992. —CM)

CLM: Let's begin with the terms "virtual reality," "virtual world," and "virtual interface." Could you give brief definitions?

TAF: Sure. First of all, let me explain what a "virtual image" is. "Virtual" comes from a term in optical physics that describes the type of image that you see from a particular location in space where there is no object in that location. For example, when you see a reflection in a mirror, you see a person that's on the other side of the glass looking through, but there is no actual person there on that other side of the glass. That is what we call a virtual image.

> Virtual reality is an environment that you create using a combination of visual, auditory and tactile images...

What can be created with virtual displays are not only visual, but auditory and tactile images—things that you see, things that you hear, things that you feel—that appear to be coming from a location in space, but aren't really there. The beauty of this is that with image projectors you can project this into your eye so that you can surround yourself with these images without taking up a lot of space. It's projected in 3-D; you have separate images going into each eye, which gives you a stereographic-type display.

Virtual reality is an environment that you create using a combination of visual, auditory and tactile images so that it becomes an alternative, sort of an artificial, environment or reality. We call it a "reality" because you perceive it as if it is a world. It's just like you're walking into another world, and you're perceiving it as if it becomes reality itself.

CLM: Is "virtual reality" synonymous with "virtual world"?

TAF: Well, it's very difficult to define all of these terms, but we've defined what a virtual image is. The world that you create or what you perceive is the medium—the virtual medium that creates virtual images for your eyes and ears and hands. But then the message that is in that medium is what we call an "environment," e.g., a room with chairs and tables and objects in it. Now, in that regard, "virtual environment" and "virtual reality" are the same thing. The "virtual world" is the model that you are playing inside of. So, basically, "virtual world," "virtual reality" and "virtual environment" are the same thing.

Then there's another term called "cyberspace." We define cyberspace as a network of people who are linked together to form a virtual community. This is where people come together in a virtual place, like a real place, only it doesn't exist anywhere. Yet all these people from different geographical locations are coming into this one space and interacting with each other as if it were a real place. This is what we call a "virtual common," and the linking of people together this way is "cyberspace."

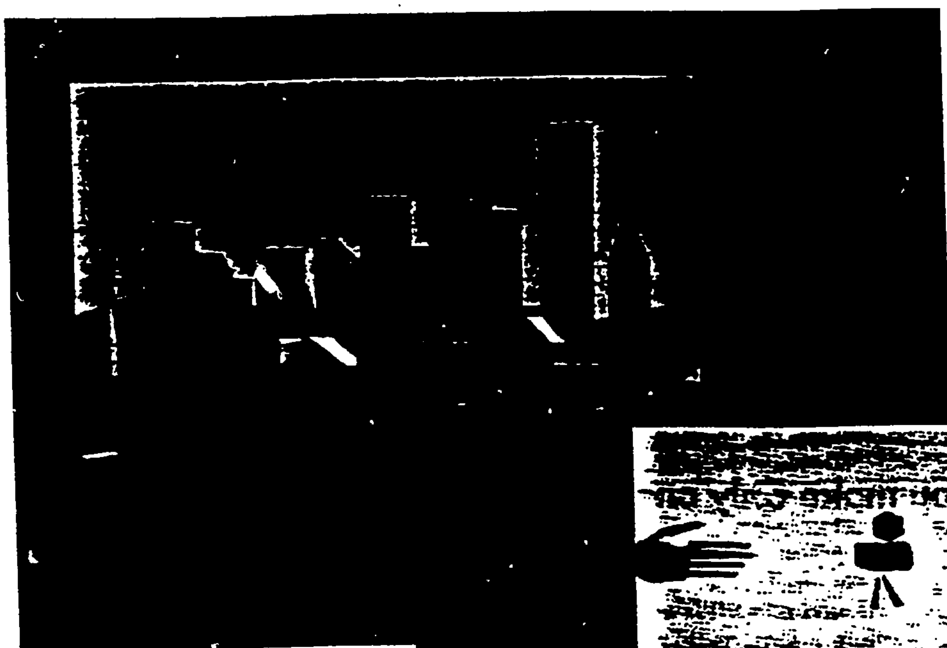
CLM: Dr. Furness, would you give me a brief summary of your background?

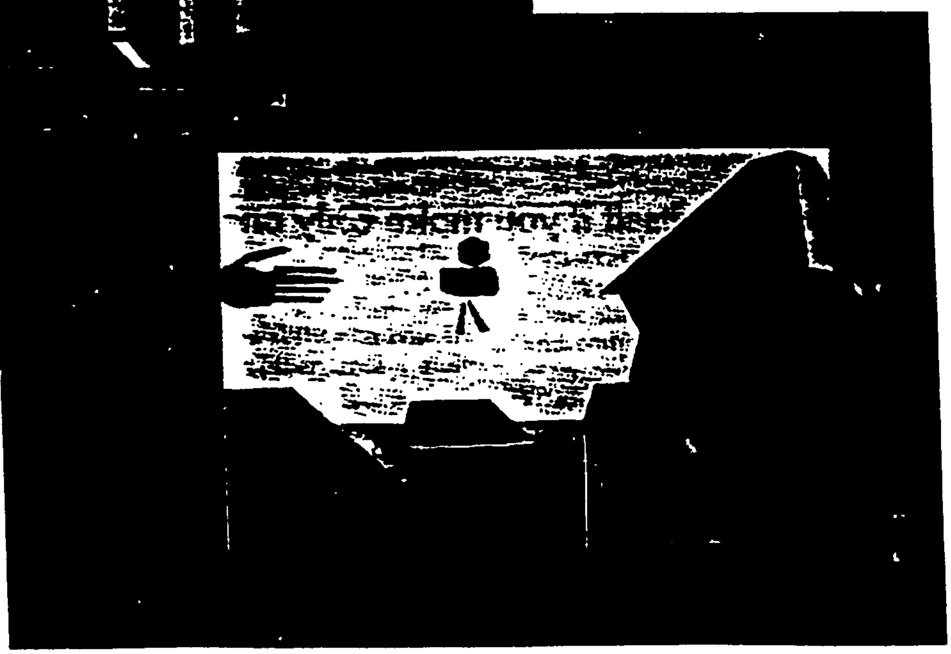
TAF: After graduating from Duke University in Electrical Engineering in 1966, I started working for the Department of Defense, Department of the Air Force at Wright-Patterson Air Force Base. I was an officer in the Air Force for five years, and then I converted to civil service. I worked at Wright-Patterson for 23 years.

It was there that I became involved with virtual interfaces, primarily trying to solve problems of how humans interact with very complex machines, in this case, fighter airplane cockpits. I was trying to build a cockpit that the pilot *wears*, that would *directly* input information into the senses—visual, auditory, and tactile senses—thus enabling the pilot to more effectively interact with the world. This was a three-dimensional presentation that took advantage of the way humans are organized. I worked on this technology until 1989.

CLM: How did you make the transition to the Human Interface Technology (HIT) Lab?

TAF: In 1986 the Air Force asked me to hold a news conference about the work we were doing in VCASS (Visually-Coupled Airborne System Simulator) on the virtual cockpit. This was about the time that the Navy had these $800 toilet seats and $500 hammers, and the military needed something good to relate. I guess they felt that our work would help out. We did a news release and David Martin, the CBS Pentagon correspondent for Dan Rather, spent all day in our lab, and we ended up on the "CBS Evening News." After the segment we were inundated with calls from the press. NBC came in, and then ABC, BBC, CBC, and Australian television and New Zealand television. Nova came in and did "Top Gun and Beyond." Then came *Newsweek* and *U.S. News and*





"Virtual Seattle" (top left) demonstrates the viewing and movement capabilities of virtual reality, allowing both flying and instantaneous changes of perspective.

"Planetscape" (bottom right) is a virtual world created by children at the Pacific [illegible]ience Center's Technology Dayc[illegible]ring the Summer of 1991.

→

World Report, the *New York Times*, *Washington Post*, all the trade journals. We didn't get any research done after that. We just did show business.

I also started getting phone calls from people around the country who had seen these programs on television. I got a call from a mother whose child had cerebral palsy, and she asked if there was anything this technology could do to help her child. I got a call from a surgeon who was trying to perfect a new surgical procedure, and he wanted to be on the inside looking out, rather than on the outside looking in. Another surgeon, a thoracic surgeon, was interested in how he could project the X-ray into the patient and use that as a navigational system to find his way around the patient. A firefighting company called and wanted to know how this technology could be used to build a display for firefighters to use when they were going into burning buildings to show where the firemen were located so that the fire chief on the outside could direct them. An anesthesiologist called and wanted to know how he could use the technology to monitor patients and see all the vital signs and other information concurrently. In answer to all of those questions, I said, "Well, yes, you can do that. As a matter of fact, it would be sort of easy compared with what I've been working on!"

Our main objective is to empower humans through building better interfaces between them and computing machines.

CLM: Was it this interest from the private sector that made you decide to move out of the military applications?

TAF: Yes. That's when I started looking around and realizing we were on to something really wonderful in terms of better interfaces between humans and computers. So I started formulating a plan to start a national laboratory which would transfer the technologies we had been working on in the DoD to the private sector where they could make a difference.

I put together a plan and shopped around the country for a place to put this lab. I went to a number of universities including MIT, Carnegie Mellon, University of Texas, University of Utah, Berkeley, Stanford, and so forth, and ended up here at the University of Washington. I came to Washington because I was given the opportunity to work on the technology from an academic side as a tenured faculty member in the College of Engineering; and from a business side as a director of a new laboratory that was part of the Washington Technology Center. The Center is an industry-oriented laboratory and it's ecumenical—it isn't associated with or locked into one department. That means it can be an interdisciplinary program with a mandate to build from a multifaceted agenda. That's what I want to do—not just write papers and crank out graduate students.

I started the HIT Lab in September 1989—one person, no furniture, no equipment, and $250,000 in the bank from the state of Washington. Now, mind you, I left a laboratory that was the best in the world. I had 60 people working for me and a budget of around $12 to $13 million a year, not counting the people. I basically wiped the slate clean and started all over again.

CLM: What are the objectives of the HIT Lab?

TAF: Our main objective is to empower humans through building better interfaces between them and computing machines. We focus on five areas to enable this empowerment to take place:

1) accelerating learning

2) enhancing creativity

3) extending our ability to communicate with each other from a multisensory standpoint

4) providing a means for rapid information assimilation in jobs that need it, e.g., air traffic control and flying airplanes

5) recapturing "lost world" citizens—ones who are unable to interact because of physical disabilities or cognitive disabilities or illiteracy.

FIGURE
Virtual Worlds Consortium

Alias Research, Inc.
American Express
The Boeing Company
Digital Equipment Corporation
Division, Ltd.
Ford Motor Company
Franz, Inc.
Fujitsu Research Institute
Insight Inc.
John Fluke Manufacturing Co., Inc.
Kopin Corporation
Microsoft Corporation
Port of Seattle
Sharp Corporation
Sun Microsystems, Inc.
U.S. Navy
U S West Communications
Virtual Reality, Inc.
VPL Research, Inc.

CLM: How is the HIT Lab funded?

TAF: We basically have four sources of funding. The state of Washington provides seed funding through the agency of the Washington Technology Center. The Department of Trade and Economic Development actually provides the funds to the Washington Technology Center. Another source of funding is the grants and contracts, where we go out and write proposals for doing this work, primarily with industry. The third area is gifts that come through foundations or companies, which is the best funding source because there are no strings attached, and we don't pay university overhead on that money. The last area is through the Virtual Worlds Consortium, which now has 19 members (see Figure). Each of these 19 members, as subscribers, provides $50,000 a year or the equivalent to join the Consortium. Some provide equipment and some provide services in lieu of the cash.

CLM: There may be companies in the online industry that are interested in becoming Consortium members. What benefits do Consortium members have?

TAF: Consortium members have front-row access to the research and →

Photo courtesy of the HIT Lab.

A demonstration of the virtual reality hardware.

development of virtual worlds technology. They enjoy a competitive advantage as they transfer VR applications into the commercial environment. Membership becomes a window for them to see what's happening and to decide what their own strategic plan should be. It is really an information source for these companies. There is no exchange of intellectual property.

The Consortium is also a gateway for these companies to have contracts with us to work on specific areas. We make the Consortium membership a prerequisite before we do any contract work. The Consortium funds are used to build our generic capability, our laboratory infrastructure, and things like that. The specific contract funds are usually used to develop the applications of the technology for a particular customer.

CLM: Then your relationships with individual Consortium members are proprietary?

TAF: Yes.

CLM: Do members have opportunities to share information as a group?

TAF: Most definitely. We have two Consortium meetings a year, at which time we get into the technical details of the work. So far we've had three meetings. They all have been highly successful and a great endorsement of the quality of our work and the appropriateness of our research agenda.

One of the main benefits that comes from Consortium membership is not only watching this technology evolve, but interacting with other companies, all of whom are interested in birthing a new industry. They are forming their own liaisons with each other—it becomes a forum for discussing the evolution of a new industry.

CLM: So companies may form alliances with each other?

TAF: Yes. And in a way, we act as matchmakers, bringing companies together.

CLM: I noticed in your newsletter that Fujitsu Institute is a member. Are there other members from different parts of the world?

TAF: Sharp is also a member and we hope to see European companies joining as well.

CLM: A little earlier you mentioned some of the applications of this technology. Most of the examples I've read about—designing buildings, modeling molecular interactions, teaching surgeons how to operate, even helping people improve their golf swing, which I might be interested in—have something to do with manipulating physical reality.

Can you give a few examples of how businesses are currently using this technology, including an example in which manipulating physical reality may not be the primary objective?

TAF: Well, there are three types of virtual worlds or virtual realities. There's the virtual reality where you are overlaying information over the real world. Let's say that you have a physical reality and you're superimposing virtual images over the top of it to help you perform some task in the real world. An example of that would be if you were driving around in your car and you looked out at the highway and could see your speed projected. This is done with headup displays now, where you're projecting on the windscreen. That is a virtual image, at optical infinity or some distance, where you are presenting alphanumeric information over the top of your space where you're driving, the outside world.

Another example is a project we're doing with Boeing. The intent is to provide a superimposition of virtual wiring onto a form board for production line workers who make wiring harnesses that go into airplanes. They just follow where a virtual wire is located, stringing out the real wire over this virtual wire. So that's one type of virtual reality where you have a superimposition of a virtual image over a real world image.

The second category of virtual reality is where you are trying to represent a real world scene virtually. That's where you want to either take a scan of the real world scene or build a model of it, for example of the room we're in now, and then represent it in a virtual world so that you can change it. Let's say that you want to shift the chairs around, or change the color scheme or the lighting. You can do that without having to do it physically. That type of virtual reality is using a real world source to begin with, then modeling it so you can interact with the model rather than have to work with the real world source. That is a representation of the world in some way either by scanning the real world or building a model of that world.

The third type of virtual reality is completely abstract. It's where there are no analogs, necessarily; where you have fields of numbers, for example, as you would in a spreadsheet. Or you have a computational fluid dynamics model, where the computer is just cranking out numbers based upon

VIRTUAL REALITY GLOSSARY

by Linda Jackson

—excerpted with permission from the *Virtual Reality Special Report*, published by *AI Expert* 415/905-2200

artificial reality
Coined by arts scholar Myron Krueger in the mid-1970s to describe his "computer-controlled responsive environments," which took an aesthetic approach to the human/computer interface. "An artificial reality perceives a participant's action in terms of the body's relationship to a graphic world and generates responses that maintain the illusion that his or her actions are taking place within that world."
—M. Krueger, *Artificial Reality II*, Reading, Mass.: Addison-Wesley, 1991.

bandwidth
Measurement (typically in Hertz, or cycles per second) that indicates a system's transmission capacity. The wider the bandwidth, the greater the amount of information that can be transmitted in real time.

cyberspace
Coined by science fiction author William Gibson to describe a shared virtual environment whose inhabitants, objects, and spaces are comprised of data that is visualized, heard, and touched. It is "a consensual hallucination experienced daily by billions of legitimate operators in every nation, by children taught mathematical concepts... a graphic

equations. How do you look at the results of that? Well, this is where you have to build an abstract world that somehow represents this information. There are various ways to do that. In the case of a computational fluid dynamics situation, you would create a flow that mimics the way the air would really be flowing over an object, let's say the wing of an airplane. You put the wing there and you visualize the air flowing over it. This is again using the computational model but playing the data back in real time and providing a sort of abstract visualization of that.

Another area is where there aren't necessarily any correlations between the data and any kind of real world object. One example would be if you were trying to determine if a person could qualify for a loan for a house, and you have all these disparate numbers and you're trying to make a judgment. You can build a virtual world that represents this information in a unique way, instead of looking at columns of numbers and trying to sort out in your head or through some kind of algorithm whether or not this person should be awarded a loan or credit. Let's say you have 26 different parameters. How in the world would you do that without a very complex formula?

Well, one of the ideas that has been suggested is that you build a virtual image or a virtual world that shows a person trying to go through a cave. The amount of debt of this person would change the size of the person; the greater the debt, the larger the person. The amount of the loan would change the size of the cave; the greater the loan, the narrower the cave. You might also have other protuberances, rocks that stick out in the pathway, depending on other things this person has to do. For example, he may have a child getting ready to go to college, or he may have a car that he just bought and have other payments to make on that, or other cash flow issues. Rather than looking at all these separate numbers and columns of numbers, you just see if this person can fit through the cave! It becomes really intuitive. And in a way, the timing is a part of this, because the cave is three-dimensional and these protuberances may occur at different times, so they may be able to squeak by some of them. But if there are several occurring at once, they can block the passage and the cave that this person has to go through is too small for the size of the person at that time. So those are ways to take abstract information and represent it using metaphors that we can relate to.

Rather than looking at all these separate numbers and columns of numbers, you just see if this person can fit through the cave!

CLM: It seems like this application of representing abstract and complex information in three dimensions might be an area where companies in the online industry could be players. While I was researching virtual reality, I was trying to think how this technology could be applied to the kinds of data the companies in the online industry own. One example I thought of was the information in medical databases. Take chemotherapies for breast cancer as an example. There are all these different drugs, and different doses, and different frequencies, and nobody really knows what works.

Could something like that be represented in a three-dimensional way to try to ascertain what the most effective chemotherapy is?

TAF: Yes. Let me mention two areas. The first is called "infomatics." There is a discipline now called medical infomatics. This is how you can take these complex statistical analyses, or even real-time data coming from a number of transducers monitoring a patient's status, and provide a representation of the state of that patient or the state of that data field. Humans are marvelous pattern recognizers. You can change those numbers into certain patterns, and then look quickly for changes of patterns just by searching a visual field if you represent these numbers as little icons.

For example, if you have a field of X's and you're looking for one O, or several O's and patterns of those O's, you can detect that quickly, whereas if you're just trying to look at numbers within a particular range, you'll never catch it. That is a very simple representation. But medical infomatics, or infomatics in general, takes capabilities that we have as humans, especially our pattern-recognizing abilities, and represents information so that we can see patterns and see the changes in those patterns.

The other area has to do with "knowbots." I believe ultimately that this is the way that humans are going to relate to very complex databases. Rather than searching databases with keywords, the function of a knowbot, especially a virtual knowbot, would be as an assistant, an intelligent assistant, an electronic associate, that you can send off to do things for you. Let's say that you're working on a particular task, and you're interacting with your virtual world, building a building or something like that, and you want to know the soundness of building at a particular site, based upon the geological formations and the history of earthquakes in the area. Well, what you'll do is take your knowbot—you're an architect and it would take you a long time to search through those databases yourself...

CLM: (Laughing) I know.

TAF: (Laughing) You know. Yes.

CLM: Much less read what you've gotten out of them!

TAF: That's right. Now you take your knowbot. The knowbot is a virtual object, but you actually pick it up and give it a command, a verbal command. You say, "Knowbot, I'm going to build a building of this size at this particular location, and I'm interested in knowing its history and the likelihood that we are going to have disturbances in the foundation of this building over the next twenty-five years. Would you go find that out for me?" You're making a verbal input to the knowbot.

CLM: In natural language?

TAF: In natural language. Now this knowbot already knows you. He knows your personality, your academic background, the kind of work that you do, the kind of information that's going to be necessary for you to meet the code, and so forth. So you pick up this knowbot and you throw it into a virtual portal. This is just like a star gate. The knowbot goes out on its own searching through all these databases with its mission in mind, and also with some intelligence in terms of how to represent this information to you.

> So you pick up this knowbot and you throw it into a virtual portal....[and it] goes out on its own searching through all these databases...

You wait for a while and go off and do your other tasks, and this knowbot comes back. It may take all of three milliseconds (chuckle). No, it might take longer than that. Bu' anyhow, it's gone for awhile. It comes back. What you have waiting for you is . tting there glowing. It's full of information waiting for you to access it. You put this object aside while you finish what you're doing. Then you say, okay, I'm finished with that, and you take the knowbot and you put it on, virtually put it on. So you pick this thing up and now you go inside of it.

What it has done is create an alternative world for you. This world lets you take a tour of the underground structure of this particular area as a geologist understands it. You are able to see like you're walking through a museum, and you see the history of the seismic disturbances in the area. You can correlate that with sunspot activity, with the time of the month that it occurred, with the cycles of the earth. This is all shown to you in a graphic form. You can also have your intelligent assistant there, who visits with you and has been created by the

representation of data abstracted from the banks of every computer in the human system."
—W. Gibson, *Neuromancer*, New York, NY: Ace Books, 1984.

DataGlove, VR glove
Gesture recognition device that enables navigation through a virtual environment and interaction with 3-D objects within it. A lightweight glove lined with sensors that detect motion and send signals to the computer, the VR glove has fiber-optic cables along fingers and wrist and an orientation sensor for navigation and virtual object navigation. "DataGlove" is a trademark of VPL Research.

enabling technology
Technology that makes another technology possible. "The vacuum tube was the enabling technology for both radio and television. Virtual reality based on computers and head-mounted displays has been dreamed of for decades, but had to wait for enabling technologies of electronic miniaturization, computer simulation, and computer graphics to mature in the late 1980s."
—H. Rheingold, *Virtual Reality*, New York, NY: Summit Books, 1991.

gesture
A movement that conveys symbolic information. Usually refers to hand movements, but may not always require hands; for example, severely handicapped individuals may use foot or eye gestures to convey symbolic information.

HMD; head-mounted display
A "helmet" with goggles containing a tiny video monitor in front of each eye so the image is seen by the wearer as three-dimensional. Often coupled with

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earphones to carry 3-D sound, the HMD is the most popular device for placing people in virtual worlds.

input devices
Tools that transfer data into a form recognizable to the computer; common input devices include keyboards, position-trackers, voice recognition systems, joysticks, and VR gloves.

position tracker
A system that tracks the movements of parts of the body and sends information about position and orientation to the computer for processing. Typically attached to the head-mounted display, but other hardware sensors such as VR gloves, joysticks, and yolks also provide digital signals generated by the physical actions of the participant in the virtual world.

stereoscopic glasses
Wireless, battery-operated, stereo-viewing glasses used for "viewing in stereo" to look at 3-D computer-generated graphics. Most glasses are infrared-controlled from an emitter on a stereo-ready display monitor.

tactile feedback/force feedback devices
Output devices that transmit pressure, force, or vibration to provide the VR participant with the sense of touch. Tactile feedback simulates sensation applied to the skin. Force feedback simulates weight or resistance to motion.

telepresence
The experience of immersion in a remote (or simulated) environment; or, the remote operation systems that translate human

knowbot. This is a person who comes and talks to you and tells you about these things as you are going through this museum.

CLM: A virtual person?

TAF: Yes. This is a virtual person. You can even select the personality of this person. This can be a really laid-back person that just sort of monitors what you're doing, and says,"Well, you really should look over here and see what this has to say." Or it can be a compulsive person that's really on your back all the time to make sure that you're getting all this stuff assimilated.

CLM: In my opinion, the major problem with information at this stage in history is that there is too much. After searching all these databases, will the knowbot filter the information so I don't get the same thing or almost the same thing twice?

> Well, I believe that the expert searcher will continue to exist, but maybe in the form of a machine.

TAF: Yes. The knowbot is your filter.

CLM: I'm wondering if the databases that the knowbots access will be somewhat like the online databases that exist now, or will they be quite different? Will they be multimedia?

TAF: I believe that they will be multimedia. We will have visual databases from imaging platforms like the LAMSAT, various NASA databases, acoustic databases, film libraries, encyclopedic databases, all of the above.

CLM: So some text databases still, perhaps, but also multimedia?

TAF: Yes.

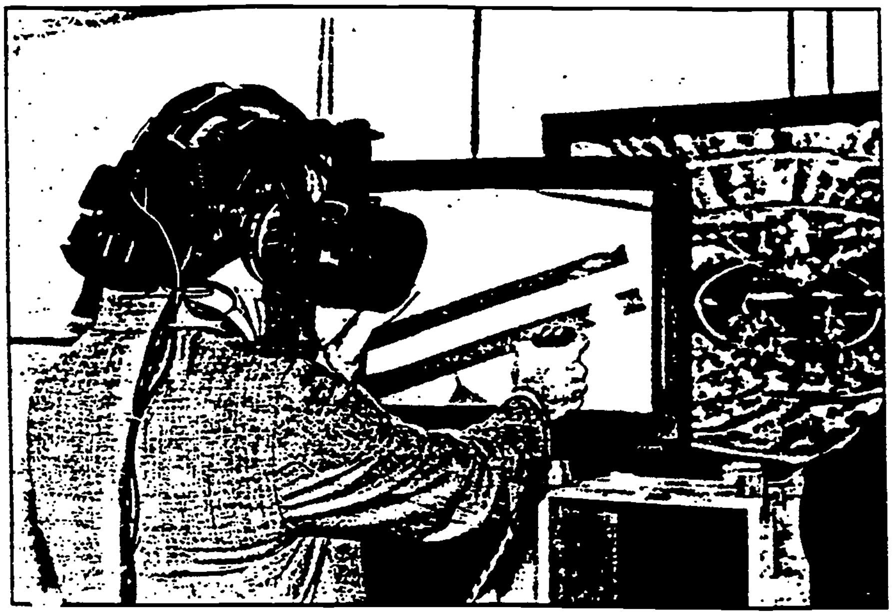
CLM: Today online databases frequently require expert searchers to search them, either because they are so complicated or so expensive to search. Is the knowbot going to replace the expert searcher or will there be a need for some new kind of expert navigator in a virtual world?

TAF: Well, I believe that the expert searcher will continue to exist, but maybe in the form of a machine. Basically what you want to do is incorporate, as much as possible, the attributes of that expert searcher into an intelligent entity that goes and searches these databases. On the other hand, there is an element of associative thinking of humans or inductive logic that is very difficult to get from a machine. A machine may be good at deductive logic, but not good at inductive logic, making cognitive leaps, getting feelings about things, and so forth. So I don't ever pretend to think that machines will truly replace an expert, but a machine will be able to accomplish 90% of what an expert can do, much faster. It's that extra 10% that's probably going to take a human in the loop and it's probably going to be irreplaceable. However, if you can get your job done with 90% of it, that may be good enough.

CLM: Will the knowbot be gathering text data and turning it into three dimensions? I'm still trying to see what place our old text kinds of databases will have in virtual reality.

TAF: It will. You are going to have your virtual filing cabinet and your virtual library where your knowbot has actually packaged and extracted pieces of information. If you wish, you can pull your virtual book off the wall or open your virtual filing cabinet. When you open your virtual filing cabinet you have all the topics the knowbot has accumulated for you. You can pull out a file folder and put it on your desk, and read the text. And you have this museum tour as an initial exposure to the things that are going to be important. Then you can go to your filing cabinet and pick out the specifics. After that, if you want to, you can jack-in to the particular database it came from, and go get further information.

Photo courtesy of the HIT Lab.



A goggled man immersed in a virtual world.

The important thing to remember is the *way we store information*. Have you ever had the experience of reading a book, and you remember where a particular statement was on a page, but you don't remember the statement?

CLM: I have to think about that. I know what you are getting at. I think I usually remember the words, but not where they are.

TAF: Okay, well that's interesting because there are two different kinds of people. You have people who are spatially-oriented and others that are verbally-oriented. Left brain, right brain kind of thing. I'm a right brain kind of person. I can remember where it was, but I can't remember what it was, specifically.

CLM: Well, this gets to some really interesting questions. When I first heard about virtual reality somebody described the glove and goggles very briefly to me, and mentioned moving through a virtual world by pointing with the glove. I said, "Oh, you know what's wrong with that? It's suited for people who have good spatial orientation, but I'm someone who gets lost going around the block." I said, "I think I might get lost in that kind of environment." Will I?

TAF: Yes!

CLM: So is this kind of technology not going to be suitable for people like me who are not that visually- or spatially-oriented?

TAF: If you were just going to be walking around the block, yes. But the advantage, remember, of a virtual world is that you can see various perspectives at one time. Not only can you be trying to find your way around the block, you'll have a miniature world in front of you showing you where you are while you're going around the block. The beauty of it is that it gives you a way to optimize the interface, adapt the interface to your particular abilities.

You can take a database that was formerly just a column of numbers or descriptors, a card catalog in a library, or something like that, and you can represent it as icons, as windows, as doorways into other rooms. You'll be able to, many people at least will be able to, access that much more quickly by remembering the spaces where the cluster of information is located, rather than trying to do it the old way with the card catalog.

Now there is another important thing that has to do with databases. How do you find your way from one to the other and then retrace your steps? This is true especially with hypertext. You can get lost forever in hypertext.

movements into the control of machinery.

virtual (-reality, -community, -space, -world, -environment)

According to Webster's, "being such practically or in effect, although not in actual fact or name a virtual impossibility." IBM started using the word in the late 1960s to refer to any non-physical link between processes or machines, such as "virtual memory," random-access memory being simulated using disk drives.

VR; virtual reality

According to VR theorists William Bricken and Brenda Laurel, VR is, respectively, "an electronically mediated experience" and "a multisensory representation." As generally agreed, virtual reality refers to having the ability to interact with data in a way that provides the ability to "enter" and navigate through a computer-generated 3-D "world" or environment and change your viewpoint and interact with objects within that environment. Virtual reality is characterized by "immersion" (it feels as if you are "inside" it). Virtual reality is interactive and the participant enjoys autonomy, or freedom to move around and manipulate virtual objects at will.

Today, in virtual reality, you can see and hear, point and move, pick up things and throw them, and sometimes touch and feel. The popular concept of VR involves interaction with a computer-generated head-mounted goggles, body suits, VR gloves and joysticks. VR and cyberspace are not the same time.

visualization

Formation of an image of (something not present to the sight; an abstraction); envision; graphical representation of data that normally appears in the form of text and numbers.

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CLM: Right! Is there some way to help the user so he doesn't become so disoriented?

TAF: Yes. What you do is you create virtual breadcrumbs that you drop along your way. These may be sonic breadcrumbs. In other words, they are little sound beacons that you trail behind you as you go, which are associated with a spatial representation of the database. You take this very complex database, and you trace a pathway down so you can follow it and come back out again, or go in other directions and come back to various points. It's very intuitive, easy for you to do, rather than just searching through text. It allows you to build mental models more easily. That's what virtual reality does. It gives you a chance to build more effective models in your head that allow you to interact rapidly, in a higher bandwidth.

CLM: Can you explain how three-dimensional models and visual perception help people assimilate information faster?

TAF: Well, again it goes back to, how do you build mental models? Because that's what humans do. We build mental models from the things that we see, and we extract from that visual experience an understanding or at least a representation of the world that we are experiencing.

We also build models from abstractions, from highly symbolic environments. For example, with reading we take written symbols and translate them into models. We create worlds in our head when we read. Reading in a way is a guided fantasy. The world that we are creating is in our imagination, but we remember it. So in a way, what we are always doing is building models in our head of these places or realities.

The real issue about learning and understanding is how much input does it require for us to be able to build models that are effective in helping us. When we learn we are creating better ways of interacting with the world so it does not require as much energy to do something as it might with an unlearned way. Or we accomplish something we would never be able to accomplish otherwise, like fly a jet airplane. So how in the world are we going to do that?

What we're doing is providing a means, via building these models, of going back and refining those models and doing these particular tasks. Now the question becomes, if learning is building models and interacting with those models to perform particular tasks, how can you accelerate learning? Well, we believe that learning is accelerated when you have a way to provide high semantic content in the learning process. That usually means an experiential, multisensory input where you remove as much abstraction as you can.

For example, if you are trying to learn about the harmonic motion of bodies in physics, you can read a book and take those words and translate those words into a model in your head. Then you can observe that model in your head working and come up with an understanding of what harmonic motion means in physics. Alternatively, if you go into either the real world or a virtual world—because there are many things you can't do in the real world (for example, you can't necessarily see electrons, but in a virtual world you can represent electrons)—you are not only able to observe the motion of these objects represented in the virtual world, but you are able to interact with them, and change them and see the effect.

You would never be able to do that otherwise, except in your own mind by looking at the equations and the words, and guessing about what is really going on. This ability can substantially accelerate your understanding of a particular concept. This is what we call high semantic content, high bandwidth—it's high bandwidth to the brain. You are really getting stuff in and out of the brain, because it's more tailored to the way we understand and interact with the world. So one of the values of virtual reality is accelerated learning—it makes it much more efficient to get information in and out of the brain.

CLM: Are you aware of any companies in the online information industry that are researching or developing a virtual interface to access commercial databases?

> What you do is you create virtual breadcrumbs...sonic breadcrumbs...which are associated with a spatial representation of the database.

TAF: Not really. There have been a lot of people who have speculated about it, but I believe the feeling in the community is that it is still a way-out, long-term kind of thing, rather than being a short-term, here-and-now technology.

CLM: Can you make any predictions about what the status of virtual worlds and virtual interface technologies will be in, say, five years or ten years?

TAF: Well, I believe we will see a very interesting pattern emerge. Now the

TONI EMERSON: THE HIT LAB'S CYBRARIAN

One of Dr. Furness' goals for the HIT Lab is to make research information on virtual reality as widely accessible as possible. While visiting the HIT Lab, I had an opportunity to talk to Toni Emerson, who is the coordinator of the HIT Lab's Knowledge Base Project.

Toni became involved with the HIT Lab quite by chance. In the summer of 1991 she was attending the Graduate School of Library and Information Science at the University of Washington. She was working as a research assistant at the Odegaard Undergraduate Library, when a young man from the HIT Lab came to the reference desk and asked for a book on how to organize a library. Toni volunteered to help, not having any idea what she was getting into. As it turns out, her background in audio-video production, her interest in multimedia databases, and her experience as a library research assistant were a perfect fit for the HIT Lab, and she's been working there ever since.

A VIRTUAL LIBRARY

One of Toni's primary roles in the Knowledge Base Project is to act as an information gatherer and disseminator for the HIT Lab. In addition to developing a hardcopy collection, she is building a library in cyberspace. Members of the HIT Lab fondly refer to her as the "information goddess" and "cybrarian."

When Toni joined the Lab she knew about database searching on services such as DIALOG, BRS, and NEXIS, but she credits Dan Pirone, a programmer at the Lab, for teaching her how to navigate the Internet. Toni says of the Internet, "This is what the hackers like the best!" Toni scans print, online, Internet, and Usenet sources. She posts electronic information to one of her three internal bulletin boards: *hitl.knowledge*, *hitl.grants*, and *hitl.nsf*.

Another part of the Knowledge Base Project is the *sci.virtual-worlds* Usenet newsgroup. This is moderated by a HIT Lab employee, currently Mark DeLoura. (A "moderator" reviews incoming messages before sending them out to provide quality control.) The purpose of the *sci.virtual-worlds* newsgroup is to transfer advanced interface technology to industry. Frequent topics include technical discussions of virtual interface technology and its applications, virtual worlds, human-computer interaction, and human perception.

END-USERS AT THE HIT LAB

End-user education is another important part of Toni's work at the Lab. She's developed lectures which she refers to as LITL HITLs (Lunchtime Interactive Technical Lecture at the Human Interface Technology Laboratory) to teach the Lab members about online and CD-ROM sources and how to search them.

Long-range plans include building a HITL knowledge base that people outside the Lab can access. This might be a MUD (multiuser dimension) whereby users gain access to the knowledge base, select an icon, and have some type of multimedia experience. In addition, Toni feels strongly that this interaction must be a unique and significantly enhanced alternative to what is already available on the Internet.

Funding is Toni's primary obstacle at this point. With several ideas for projects that companies in the online industry might be interested in supporting—such as end-user research, multimedia knowledge bases, and living documentation, Toni thinks funds could be generated outside the Virtual Worlds Consortium for the Knowledge Base Project. Feel free to contact her at diderot@hitl.washington.edu *or* 206/543-5075 if you would like to discuss these projects or other ideas. —CM technology is immature, but it is growing at a fairly high rate. I think that probably by 1995 the technology will have gone in two directions. One is the low end, and the low end is going to be games. We're going to see the next generation Nintendo, or the next couple generations of Nintendo, have this kind of technology in it at a low end. We have already seen this with the PowerGlove, even though the PowerGlove was really before its time. There wasn't any software to really use it. Furthermore, people found that holding up their hand all the time when trying to interact with the screen was very tiring. Then there's going to be the high end. This is where we're going to have the very expensive machines used in medicine, design, and things like that.

I think there's going to be something else that happens around this time. Broadband telecommunications will come with the wiring of the country with fiber. You will have a broadband telecommunications link that will become a ubiquitous port for information flow in and out of the home. This will support the development of a technology we call the virtuphone. The virtuphone is a telephone that you wear. It takes the place of your television and your telephone, and you do everything with it.

CLM: You wear it?

TAF: You wear it. It's a telephone that you wear.

CLM: Always accessible!

TAF: Yes. Basically, it's the transportation system for your senses. Now instead of dialing a number and coupling acoustically with another person (with a voice phone call), or typing on a keyboard and having a screen come up, you dial a place and your senses go to this place. It may be a place where you are going to learn. It may be a place where you are searching databases. It may be a place where you are going to school or going to work. Or it may be a place where you are entertained. You may be standing on the set of King Lear, and you can be anywhere you want on the set. As a matter of fact, you can be inside King Lear if you want to be.

CLM: Are you suggesting that people will no longer drive to work or to the theater?

TAF: I think that there are going to be some changes. I don't think that this will take the place of some group experiences, for example, the Folklife Festival at the Seattle Center last weekend. It would be tough to do that virtually. That was a marvelous celebration, and it would be difficult to get that ambiance virtually. On the other hand, again, you can do about 90% of it virtually and get the same information content. It's that last 10% that is where humans really make the difference.

CLM: Will the virtuphone have an effect similar to that of the VCR on the movie business? Will people have the choice of staying at home or going to the theater?

TAF: Yes. So why do they go to the movie when they can watch it at home?

CLM: Because they like that big screen.

TAF: That's right. Well, you'll have the big screen with VR. I mean, you'll have the biggest screen, because you're in it, you are in the picture!

CLM: Finally, Dr. Furness, is there anything that we haven't covered that you would like to share with the participants in the online information industry?

TAF: Well, I guess to look forward to virtual interface technologies changing their business, because it's coming! The reason it's coming is that we can't hold it back, because that's the way humans are wired. The closer we can get to using fully the capabilities that we have, our innate capability in terms of our three-dimensional architecture, then the more effective these interfaces are going to be. So we are actually being driven by human capabilities, rather than by technology.

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BABY BELLS SPECIAL REPORT EUROPE THE LONGER ROAD TO UNITY PEOPLE DEAN WITTER'S PHIL PURCELL

BusinessWeek

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VIRTUAL REALITY

HOW TECHNOLOGY CAN AMPLIFY THE HUMAN MIND

BEST COPY AVAILABLE

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STRAP ON THE GEAR, FLIP A SWITCH—AND *VOILA*, VIRTUAL REALITY. FOR THE COMPUTER INDUSTRY, IT'S A UNIVERSE OF OPPORTUNITY

TOOLS TO AMPLIFY THE MIND

BRAIN

Research into the human brain and behavior is shaping the design of computer-generated worlds. The goal: Present information so it can be absorbed and manipulated more easily and quickly. For instance, scientists know that the human mind is genetically programmed to pick up certain visual cues. This is helping researchers design better computer icons

SOUND

Virtual worlds can include 3-D sound that appears to come from specific locations. Such a system could help those who monitor multiple sound sources. Pilots keeping track of nearby traffic are an example. NASA and Crystal River Engineering Inc. have developed a circuit board that can make sounds seem to originate from specific points and grow louder or fainter

VISION

Computer-generated worlds need to move with the speed of live action so that viewers perceive what they see as real. Most VR is still too slow, but increased computing power is closing the gap. Today's systems use stereoscopic displays with small screens encased in goggles or helmets. Less intrusive future displays may resemble a pair of glasses. Computer-generated visuals could help with such tasks as repairing machines

TOUCH

Today, gloves, or entire body suits, armed with sensors let a participant communicate with the computer and direct objects in virtual space through gestures. In the future, touch-sensitive joysticks and gloves with feedback mechanisms will create the sensation of picking up an object. This ability will make it easier to use such systems to direct equipment remotely

TELEPRESENCE

Adding computer-enhanced graphics to live video may make it possible to perform activities long distance. A designer in Los Angeles might make a change in a simulated dashboard prototype, while colleagues in three other cities watch and see how it would look

VIRTUAL REALITY

HOW A COMPUTER-GENERATED WORLD COULD CHANGE THE REAL WORLD

Psychologists call it "suspending disbelief." Computer jocks call it entering "virtual reality." Whatever the jargon, it doesn't begin to describe what happens in Arlington, Va., at the Institute for Defense Analyses.

You sit in a wood-paneled room as Colonel Jack Thorpe, special assistant for simulation at the Pentagon's Defense Advanced Research Projects Agency, douses the lights, flips on a computer—and sends three five-foot screens in front of you thundering into action. Instantly, you're transported inside a tank rolling across the Iraqi desert. You are performing the same maneuvers as a unit of the 2nd Armored Cavalry during "73 Easting," an actual battle in the Persian Gulf war. The graphics on the screens are only video-game quality. Yet, the illusion works: You duck as shells scream toward you and explode in ear-splitting fury.

It isn't unusual for soldiers participating in this exercise to curse or sweat as the computer-simulated fight unfolds. Something else happens as well: Their scores for battlefield acumen improve dramatically after they practice with these video tank crews. In an era of shrinking defense budgets, such training offers invaluable experience without the cost, damage, and logistical hassle of war games. "We will expect a smaller military to be masters of a wider ensemble of skills," says Thorpe. "This is an idea whose time is right."

NEW SENSATIONS. The cyberspace tank battle is primitive compared with visions of "virtual reality" trumpeted in books, movies, and the TV show *Star Trek: The Next Generation*. There, intergalactic travelers use computers to conjure up Sherlock Holmes's London or a sexy date. But as DARPA's system proves, computer-generated worlds don't have to be super-realistic to evoke real life. That fact is turning virtual reality into a red-hot technology.

There's plenty of confusion over what VR is. But to most developers, the core of every system is a data base that contains data from a brain scan, specifications for a car dashboard, the description of a fictional landscape—in short, data that can represent almost anything. A powerful computer with sophisticated graphics then renders a "world," often in 3-D, that recreates precisely what the data describe. VR displays vary widely, from images on a computer monitor to theater-style displays such as 73 Easting to projections on stereoscopic lenses mounted inside helmets that VR participants wear.

CYBERSPACE SIMULATIONS MAY ENHANCE JOB PERFORMANCE AND TRAINING, IMPROVE PRODUCT DESIGN, ASSIST SURGEONS, AND CREATE INTERACTIVE FORMS OF ENTERTAINMENT. BUT IT WILL BE YEARS, IF EVER, BEFORE ALL THAT IS A REALITY

Whatever the approach, two characteristics distinguish VR worlds from other computer graphics: Increasingly, they convey multiple sensory information—sound or touch—to make environments more realistic. And they are interactive. In some systems, a viewer wearing a sensor-laden glove manipulates objects in the computer as one would naturally. In others, images on the screen or a viewer's perspective are manipulated with a mouse or joystick.

At IBM's Watson Labs in Hawthorne, N.Y., for instance, an engineer seated in front of a projection screen, looking at a sleek, beige dashboard becomes a test driver for a 1997 Chrysler. Wearing 3-D glasses and a glove with sensors, he turns the steering wheel and reaches for buttons as though in a real car. Chrysler Corp. is developing the system with IBM in hopes that the exercise could cut months off the three-year to five-year car-design process by letting engineers spot inconveniently positioned knobs and other problems before they surface in expensive prototypes.

'PAST THE HYPE.' Intrigued by this kind of potential, dozens of government, university, and industrial labs, from NASA and the Defense Dept. to the University of Washington (UW), are embracing virtual reality. In the next four years, the military hopes to spend more than $500 million on simulations. This fall, the Army will likely award an additional $350 million, eight-year contract to create an advanced network for battlefield simulations. Industry giants—including Boeing, AT&T, Sharp, and Fujitsu—are investing millions, too. At UW's Human Interface Technology Laboratory, some 19 companies have created the Virtual Worlds Consortium to apply VR to business. "Forget the games and electronic sex," says Bryan Lewis, a researcher at IBM. "We are past the hype and pursuing real applications."

This could be a boon to computer giants such as IBM, DEC, Apple, Sun, and graphics workstation maker Silicon Graphics. VR represents a potentially big market—and a flashy selling point—for their muscle machines. Startups including Exos, Virtual Vision, and Fake Space Labs are building gear to enhance VR worlds—viewing devices, acoustical chips, and sensors. Autodesk, Sense8, VPL Research, and others see their fortunes in systems that business can use.

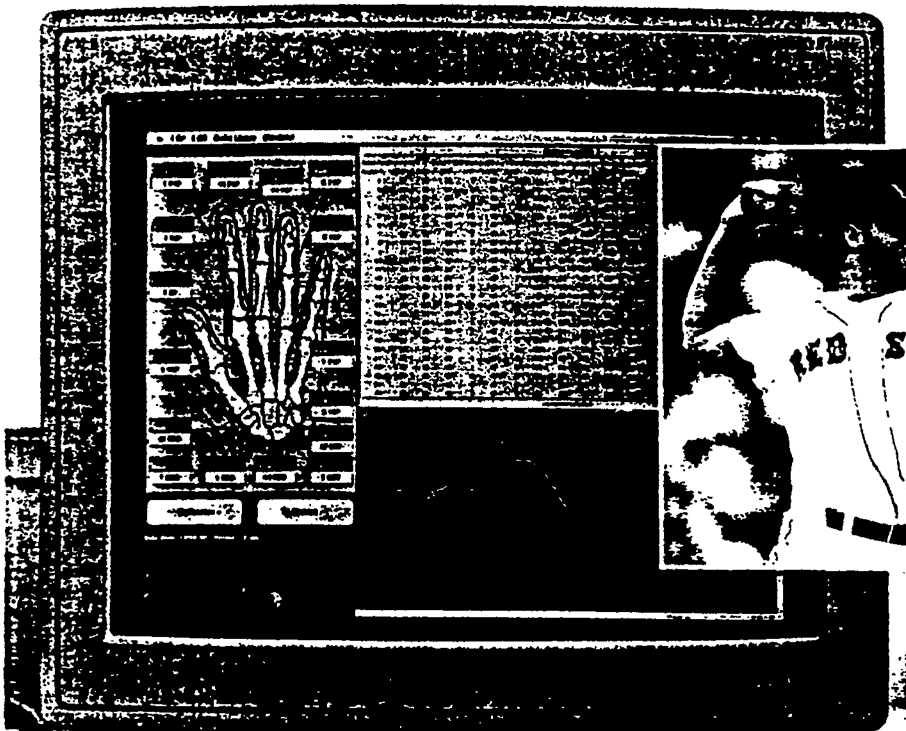
For good reason. Cyberspace worlds that exist only in the electronic ether can be a powerful tool in the hands of architects, engineers, and scientists. They can also be used to boost productivity, improve product design, and provide more cost-effective training. In medicine, VR tools are being used to create 3-D X-rays to help surgeons plan procedures or assist in surgery miles away. Psychologists want to use the technology to treat patients and to study human behavior. Artists and entertainment moguls are pioneering new attractions—interactive theater, interactive fiction, and even virtual sculpture, cyberspace works that defy the laws of physics.

Whether VR systems will ever match the sophistication they display in fiction is far from certain. The field faces huge technical hurdles: Success will depend on improvements in hardware and software, plus new insights into the human brain and behavior. And as systems become more "real," they will pose thorny ethical questions: Could VR influence people in pernicious ways that conventional media cannot?

Still, VR's social and economic potential seems clear. Democratic Vice-Presidential hopeful Al Gore considers VR so crucial to "the way we design new products, teach our children, and spend free time" that last year he chaired hearings on its value to American competitiveness. The conclusion: The U.S. is underinvesting in the technology.

To VR advocates, that's a mistake. Virtual reality represents "the manifest destiny for computers," asserts Eric Gullichsen, founder of VR software producer Sense8. By creating worlds of color, shapes, sounds, and feel, these systems should amplify the powers of the mind to see previously hidden relationships in complex sets of data and to absorb, manipulate, and interpret information more quickly and completely. The distinction between immersion in a VR world and analyzing the same information using blueprints, numbers, or text "is the difference between looking at an aquarium and putting on your scuba gear and diving in," says Thomas Furness, director of UW's Human Interface Technology Laboratory.

BUMP AND GRAB. Just ask engineers at Northrop Corp., who are using a VR system from Simgraphics Engineering Corp. to help redesign the Air Force's F-18 fighter jet. They model air-intake ducts on computers to make sure they fit through bulkheads, rather than building expensive hard models. An operator wearing wraparound goggles moves parts around with a type of mouse, making sure they fit together in virtual space. The software even simulates resistance, so engineers know when parts "bump" against each other. Project Engineer Robert E. Joy loves the flexibility: "It's like reaching into the workstation and grabbing the part," he says.



RESEARCHERS USED A 'DATAGLOVE' TO ANALYZE CLEMENS' MOTION

PHOTOGRAPHS BY ROBERT HOLMGREN, INSET: FOCUS ON SPORTS

ANATOMY OF A FASTBALL

Hurling a 100-mile-per-hour fastball down the middle is a special skill worth analyzing. But a big-league pitcher's arm, wrist, and finger movements change so rapidly that they're almost impossible to dissect. This thwarts efforts to learn from good pitchers—or figure out what's wrong when they have injuries or slumps.

Insights into these puzzles of movement could come from a new data-collection tool that's integral to virtual reality. Greenleaf Medical Systems, a four-year-old startup in Palo Alto, Calif., has licensed the "dataglove" from VPL Research Inc. for medical uses. A black Lycra glove with fiber-optic cables attached relays movement signals to a computer, which quantifies hand motion. In a recent experiment, Greenleaf put datagloves on the hands of four Boston Red Sox pitchers, including team ace Roger Clemens.

Attached to an Apple Macintosh computer, the glove recorded subtle relationships between speed, position, flex, and other variables as the four men threw a variety of pitches. For every three-second pitch, the system compiled 16,000 data points. Red Sox associate team physician William J. Morgan is building graphic images to see what he can learn. By repeating the experiment, he hopes to identify movement changes that make a pitcher less effective—and correct them.

Company founder Walter J. Greenleaf sees broader potential in the experiment: He envisions a huge market analyzing repetitive-stress injuries, an increasingly common malady of office workers, and in diagnosing other orthopedic and neurological ills. He also hopes to make patients who can't speak able to communicate through gestures the computer interprets.

VR represents the second major effort in two decades to bring about a dramatic evolution in computers. The aim of the first, artificial intelligence, originally was to build systems that could mimic human reasoning, a goal that has yet to be reached. Virtual reality is the antithesis of what AI tried to do. It aims "to extend the power of the person" says Robert Jacobson, president of Worl-Design, a Seattle VR software startup.

That's what a visualization tool designed by Maxus Systems International does for managers at TIAA-CREF, a New York pension fund with $105 billion in assets. Tracking the performance of a group of stocks against the larger market is a challenge for analysts, who must follow hundreds of ever-changing numbers. Using software from Sense8, the Maxus system converts the numbers to a 3-D schematic of colored squares that move and symbolize individual stocks within grids representing market and industry sectors. It runs on a personal computer and draws on real-time feeds from financial wires.

A specialist in bank stocks may glance at the computer and notice that a box showing banks in the Pacific Rim is active. The squares are red, a signal that the stocks are falling. The analyst uses a mouse to "fly" into the lowest tier of stocks, which have plunged the fastest, and click on the security that has dropped most. Up pops text on that bank. The process takes seconds, so portfolio managers can "identify trends, recognize exceptions, and make decisions more quickly," says Sense8 President Tom Couli. "That can translate into a tremendous amount of money."

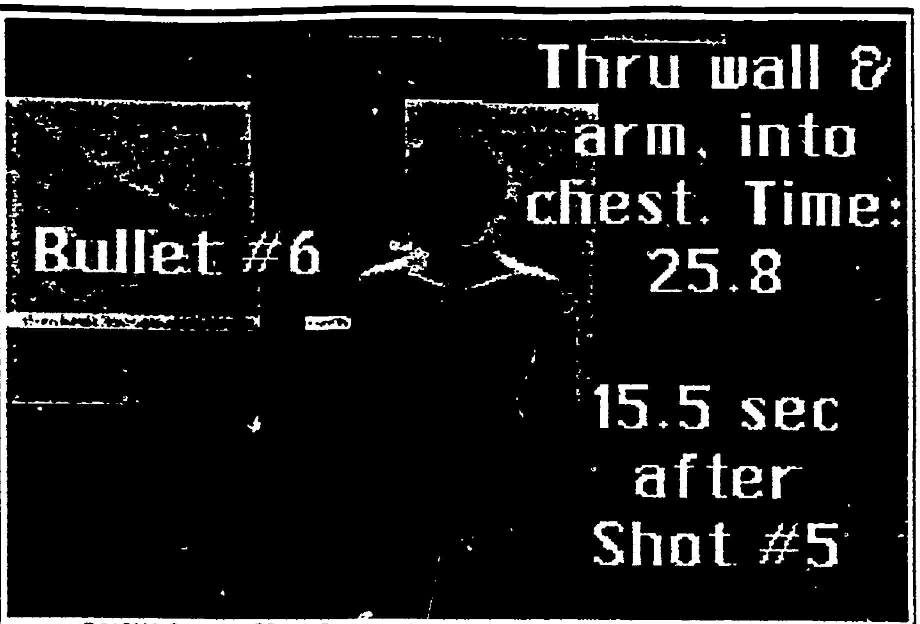
FLYING MICE. Such a system falls short for VR purists, who argue that only an immersive experience with a helmet holding two stereoscopic screens and headphones will do. That way, you see and hear only what the computer generates, interacting with the environment as in the real world. At NASA Ames Research Center in Mountain View, Calif., this approach lets you look around the surface of Mars, which has been recreated from satellite data. A motion sensor in the helmet lets you look in any direction, and the computer rerenders the scene to reflect your new perspective on the Martian landscape.

Still, theater-style simulations and two-dimensional computer displays can be just as powerful. Using a Silicon Graphics Inc. system, urban planners in Los Angeles are building an 80-block-by-80-block virtual model of renovation plans for riot-damaged areas. The value: It's hard for untrained people to read blueprints, and models are expensive. Yet, community involvement is essential. This way, residents can use a mouse to "fly" through the streets as if they were in a helicopter. And designers can pop in a park bench or delete a 7-Eleven, testing suggestions from those who live in the real Los Angeles.

The idea of using computers to render useful environments dates back to the 1960s. Back then, however, the computing power needed to generate even crude 3-D graphics was so expensive that only government agencies such as Defense or NASA, plus a few university labs, could afford it. Even today, special helmets used for military flight simulators can cost $1 million.

The field began to attract attention when onetime computer hacker Jaron Lanier coined the term virtual reality in the mid-1980s. In 1984, he founded VPL Research Inc. in Foster City, Calif.—the first company dedicated to VR worlds (page 104). VPL has developed key VR aids—head-mounted stereo screen displays, or "eyephones," plus the "dataglove" and the "datasuit," which let VR viewers convey information to computers with hand signals. Don a Dataglove, and an image of a hand appears in the virtual world, so you can point to objects, pick them up, or command the computer.

More than anything else, though, the relentless increase in performance—and decrease in price—of semiconductor chips is driving VR by allowing computer



GRISLY GRAPHICS: FROM THE VR RECREATION OF A 1991 SHOOTING

IS VR REAL ENOUGH FOR THE COURTROOM?

On the night of Feb. 27, 1991, San Francisco porn-movie king Jim Mitchell drove to the home of his younger brother and business partner, Artie, in Corte Madera, Calif. Minutes later, Artie was dead, and a dazed Jim was arrested walking away from the scene.

The district attorney didn't buy Jim's story that he shot eight times in self-defense, frightened by a beer bottle an intoxicated Artie wielded in a dim hallway. But there were no eyewitnesses. So, the prosecution persuaded the judge to let the jury watch a video of Artie's death.

This was no candid videotape, however. In the first-ever use of VR in a criminal trial, a ballistics expert recreated the event, complete with bullet trajectories, on a personal computer using computer-aided design software from Autodesk Inc. In the animation, a ghostly figure peeks from behind a door. The figure emerges and walks stiffly down a hallway. A red tube pierces, then exits, the body. The figure continues to walk until another red tube strikes its forehead.

The video, which was created after analyzing evidence found at the scene, had the desired effect. Last Feb. 19, the jury convicted Jim Mitchell of manslaughter and sentenced him to six years in prison. He's appealing, in part because of the videotape, which his attorney, Nanci Clarence, calls "wizardry that has no place in a court of law."

The Mitchell case highlights the ethical dilemmas inherent in VR. Reality is, after all, more than sophisticated software. To the defense's chagrin, for instance, the figure in the tape doesn't wield his beer bottle in a remotely threatening way. In short, VR may raise a thorny question for judges: Even in the best of simulations, can reality be manipulated unfairly?

makers to build more sophisticated graphics systems. At the high end, Silicon Graphics' new $100,000 "Reality Engine" has a computing speed 1,000 times as fast as most PCs, allowing it to provide quick rendering and real-time motion in VR worlds. On the low end, desktop VR systems based on Intel Corp.'s 486 chip cost as little as $20,000. Richard H. Dym, general manager for multimedia at Autodesk Inc., calls new programming tools and applications for these systems the leading edge of software development.

Entertainment is one of the first beneficiaries. Nintendo Co.'s $99 Powerglove, a simpler version of VPL's $8,800 Dataglove, lets video-game wizards play with hand gestures and has already helped spawn a host of VR-like video games. Virtual World Entertainment LP's VR game site in Chicago, the "Battletech Center," has sold some 300,000 tickets at $7 each since it opened in July to players who sit in an enclosed cockpit to engage in *Star Wars*-like battles. The company has two sites in Japan and plans to open 17 more over the next three years.

'TELEPRESENCE.' In business, much VR technology will evolve out of current computer systems. Computer-aided design, or CAD, systems have been around for years. Adding VR's greater resolution and interactivity can enhance their utility, as Chrysler, among others, is discovering.

"Telepresence," a VR tool that refers to the remote manipulation of equipment, shows similar potential. The Japanese construction company Fujita Corp. has hired VPL to help it build a system that lets an operator in Tokyo direct a spray-painting robot anywhere in the world. The operator views the building to be painted on a computer, then works controls that signal the robot to spray. With VR, the image is so painstakingly exact that the human operator makes no mistakes in directing the operation.

In business education and job training, VR's chief benefit would be lower costs. The Electric Power Research Institute has teamed up with MITRE Corp. to determine if an electronic mock-up of a power-plant control room using stereo projection displays can be effective in training plant operators. Today's training rooms for fossil-fuel plants cost up to $1 million. Using VR, the cost might dip under $100,000. And eventually, says Hugh W. Ryan, director of new-age systems for Arthur Andersen Consulting, VR worlds will be used to simulate business interactions—from sales negotiations to general management problems—and will replace some of today's expensive seminars and classes.

VR may also help train workers for flexible manufacturing. Boeing Co.'s project manager for human-computer interactions, Keith Butler, is developing techniques to project job instructions onto see-through goggles worn by assembly workers or onto the work space in front of them. In theory, instructions presented this way could replace hours of training in which workers learn jobs, then must be trained again when the task changes. With such displays, a worker might assemble wing flaps, then switch to nose cones on the same day with little loss of productivity.

DAVID STRICK/ONYX

VIRTUAL MODELS: Northrop Corp. engineer Robert Joy uses a VR system to design parts for the Air Force's F-18 fighter jet in virtual space, lessening the need for expensive, time-consuming physical mock-ups

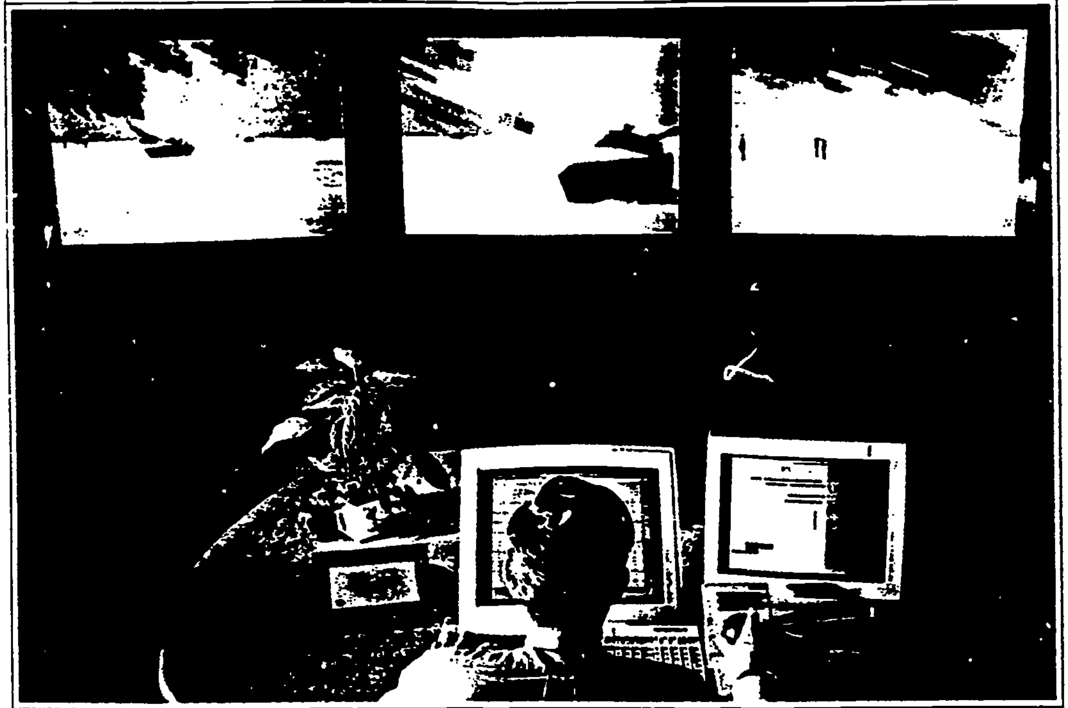
In perfecting such systems, developers must solve some novel problems. Why do some people become nauseated when navigating in cyberspace? And if you have to make a trade-off between complex, realistic graphics or live-action motion, which is more important for maintaining the illusion of reality?

The answers to such questions lie in the cognitive and behavioral sciences. Greater knowledge of the structure of the brain, how it processes information, and how people think and perceive is the key. Such research already indicates why VR worlds are so effective in training, says Roger Shank, director of the Institute for the Learning Sciences at Northwestern University. Studies show that in general, people reason or solve problems based on cases, examples, and experience, not by learning rules. "That's why the flight simulator is the best piece of educational software ever made," says Shank.

GENETIC CUES. One of the key assumptions of VR work is that the brain can process information better when it is presented through sight, sound, and touch instead of just text or numbers. Scientists also are finding that the responses to certain visual cues—including hand-eye coordination and the ability to detect the edges of objects and to recognize movement across a meadow of grass—are encoded in genes. Our cave-dwelling forebears originally developed these responses in reaction to the world around them, says Ronald M. Pickett, professor of psychology at the University of Massachusetts at Lowell.

Pickett and others are designing software icons that mimic those cues. "We want to trick the visual system to evoke quick, natural perceptual processes in the service of analyzing data," he says. To do that, he has created an icon that looks like grass. It changes length, curve, and arc to represent numeric data such as income level, age, and sex. Each icon can convey multiple characteristics that can be comprehended at a glance.

Whether people experience virtual worlds as "real" doesn't depend entirely on real-time motion, graphics, or visual cues, however. One of the most difficult challenges is to imbue computer characters with humanlike qualities. As part of that effort, Joseph Bates, a computer scientist at Carnegie Mellon University in Pittsburgh, is trying to create VR drama—interactive programs in which com-



WAR GAMES: The Pentagon is sharpening soldiers' skills with computer-generated battlefield exercises that unfold on huge screens

puter characters and people collaborate to create stories or situations. At first, it's hard to understand how an animated landscape with four bouncing blobs could be relevant. The blobs' only activity is jumping up and down, and they are supposed to take turns "leading." But when one ball starts to dominate the activity, the others react. They change color, or slow down. One even turns from red to blue, retreating to a corner, its sides heaving, to... well, sulk.

The balls appear to be exhibiting emotion and acting independently because Bates and his colleagues have programmed them based on theories of behavior. These hold that emotion—and the behavior that results from it—arise from goals that are being met, opposed, or otherwise affected. When programmed this way, the blobs begin to act as if they have "personalities," and people can identify with them.

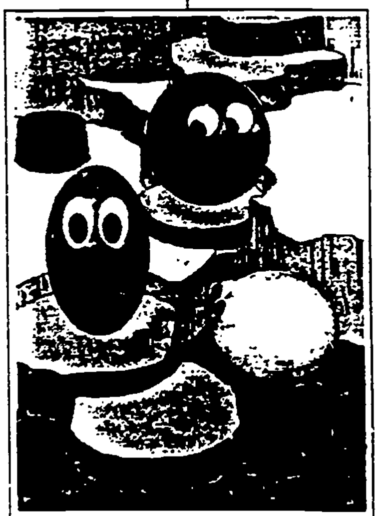
'BARFOGENIC ZONE.' Building on such work, researchers one day hope to populate virtual worlds with creatures—human-looking or not—that people interact with as they would another person. These characters might analyze a problem, monitor an experiment, or play the role of someone in a business simulation—a hot sales prospect, say. They would probably react to voice commands but would also need to convey and understand more subtle human communication such as body language. Sound fantastic? Not to Fujitsu Ltd., which has invested $250,000 in Bates's work. His work reinforces Fujitsu's research in "artificial life," computer algorithms that behave like biological entities and could become the basis of computer-generated characters in VR worlds.

Fine-tuning the sensory and psychological factors that make a VR world "real" is a further technical challenge. Experience shows that VR viewers adjust to low-resolution monitors. The brain also accepts slow, jerky frame speed and much faster live action—30 frames per second. But in between lies what Thomas P. Piantanida, principal scientist of SRI International's Virtual Perception Program, calls the "barfogenic zone"—from 4 to 12 frames per second. At that speed, the confusion between what the brain expects and what it sees can make viewers sick. Until computers can create complex worlds with live motion, Piantanida's work suggests that it's better to run crude displays faster than to run detailed displays in the barfogenic zone.

Putting sound to virtual worlds is one more key to improving people's ability to absorb information. "Our ears point our eyes," says NASA Research Psychologist Elizabeth M. Wenzel, an expert in adding 3-D sound to virtual environments. A military pilot, for instance, often monitors as many as eight conversations from air and ground sources through the same earpiece. Wenzel says that making the sound appear to come from different directions helps pilots key in on high-priority information. A new circuit board developed by NASA and Crystal River Engineering Inc. that produces 3-D sound will make it easier to put sound in virtual worlds. The chips mimic the shape of sound waves as they hit the human ear from different directions, creating the illusion of distance as sounds grow louder and softer.

VR researchers are opening another portal to the brain through so-called force feedback. The idea is to build weight, resistance, or attraction into joysticks, so that VR voyagers can "feel" simulated objects. Researchers at Digital Equipment Corp. are working with outside chemists to simulate the forces of molecular attraction and repulsion. Their goal is to develop a system within two years that will help chemists feel these forces as they experiment with 3-D images of molecules to develop drugs and other chemicals. That's important because molecules that appear to be compatible often are not. Knowing this in advance could help scientists avoid blind alleys.

The more sophisticated VR worlds become, the more controversy they may generate. Some psychologists want to use VR in psychotherapy to alter the perspective of patients, or to recreate environments that cause stress or other problems as a way to help treat phobias, depressions and schizophrenia. British psychologist Peter Ward, who plans to use VR to



THE BLOBS: Carnegie Mellon University's Joseph Bates has created animated characters that exhibit emotions based on theories of human behavior. The next step: Virtual worlds filled with creatures that can interact with humans

GOING WHERE NO MINDS HAVE GONE BEFORE

To get a feel for what is different about virtual reality, meet Jaron Lanier, chairman of VPL Research Inc. Dreadlocks crown his ample frame. His Sausalito (Calif.) studio—he's an accomplished musician—is filled with exotic instruments. On the door hangs his image emblazoned on a psychedelic poster. The poster is hot in Europe, where VR is *très trendy* and Lanier is a cult figure, reflecting VPL's preeminent role among the startups that are pushing the technology's frontiers.

THE CULT FIGURE AND THE EXEC: LANIER AND FISCHER OF VPL

Lanier, 33, started VPL in his garage eight years ago with money he made from programming an Atari Corp. video game called Moondust. Fiddling with icons and graphics he hoped would make math easier led him to a more sweeping vision. Today, VPL sells hardware devices such as the Dataglove and Datasuit for navigating in virtual space, helmets that surround you with computer-generated worlds, and programming software that even children have used to create virtual environments—kids, and a few other customers, such as Boeing, SRI International, Matsushita, and MCA.

THE 'BOOM.' VR's big winners eventually should be heavyweights such as Intel, IBM, Apple, and Silicon Graphics—the makers of graphics chips and computers. Alan Meckler, publisher of the newsletter *The Virtual Reality Report*, sees liftoff toward the end of this decade. But whoever cashes in will owe a debt to VPL and many other innovators. Crystal River Engineering in Groveland, Calif., is selling acoustical circuit boards that let programmers put 3-D sound—say, the sound of a door opening and closing—in a virtual space. Fake Space Labs has invented a stereoscopic viewing device called the "boom"—as in boom microphone—that lets a person move around a virtual space by looking through a viewfinder.

Lanier thinks medicine will be VR's "monster market," partly because of the need for better visualization of diagnostic scans. At a recent San Diego conference, surgeon-inventors mingled with science fiction writers, while Sony Corp. marketers pitched high-definition-television screens. The other products discussed ranged from systems for doing remote surgery to 3-D data bases for analyzing casualty data in a war.

The core of such markets will be software, says Robert Jacobson, founder of WorlDesign in Seattle. StereoCad in Sunnyvale, Calif., and Virtus in Cary, N.C., specialize in architectural and engineering design programs. BioCad in Mountain View, Calif., sells "virtual chemistry" software that lets scientists create 3-D, interactive models of molecules and other chemical structures. Engineering Animation Inc. in Ames, Iowa, makes 3-D graphics and animation programs that recreate accident scenes for use in court. Both Sense8 and VPL sell "tool-kit" programs for VR software programmers. But they may not rule the market for long. Autodesk Inc. in Sausalito, which has 700,000 customers for its computer-aided-design software, could have an edge when it comes out soon with its own tool-kit program.

BETTER ENTRÉE. Such competition has begun to alarm Lanier, a major VPL shareholder. In May, he named a new chief executive: ex-Hewlett-Packard Co. executive Walt Fischer. As white collar as Lanier is not, Fischer may have better entrée to corporate customers. This could be crucial for VPL's plan to become a systems integrator, selling packaged solutions—not just components. "We've sold millions of dollars' worth of hobby stuff," says Lanier. "The transition now is into a real company."

Whether VPL and the other VR upstarts will prosper is impossible to predict. But even if they do not, pioneers such as Lanier are trailblazing a technology that is likely to benefit every industry that relies on computing.

By Joan O'C. Hamilton in Sausalito, Calif.

PIONEERS IN VIRTUAL REALITY

THESE VR LEADERS ARE ALL PRIVATE COMPANIES

Company	Location	Employees	Founded
[illegible]	FOSTER CITY, CALIF.	25	1984
Makes hardware and software, including DataGlove and EyePhones			
[illegible]	SAUSALITO, CALIF.	8	1990
Creates programming packages for virtual worlds			
[illegible]	MENLO PARK, CALIF.	7	1989
Makes stereoscopic viewing device			
[illegible]	SOUTH PASADENA, CALIF.	15	1985
Develops engineering visualization programs			
[illegible]	PALO ALTO, CALIF.	12	1988
Adapting the DataGlove for use in medicine			
[illegible]	WOBURN, MASS.	25	1988
Sells a device that signals computers through gestures			

'Virtual Reality'

Sci-Fi Technology on Verge of Billion-Dollar Boom

BY PETER HOEY—THE WASHINGTON POST

By Mark Potts
Washington Post Staff Writer

It appears to be a landscape made up of paint chips—rolling hills of blue and red squares, undulating slightly as if rippling in a breeze. The lone inhabitant of this odd, computer-created vista maneuvers among the chips, as if in flight, by caressing a palm-sized ball and pointing at chips with a wand.

It sounds like science fiction. Actually, it's a profoundly new way of viewing the stock market—and a preview of one of the hottest new technologies around: virtual reality (VR), which uses the personal computer to create a world unlike anything humans have ever seen and then puts them into it.

Wearing a helmet that provides a television view and stereo sound, and guiding motion with a joystick or other device, a user can move electronically through a simulation of real life—or through something abstract that only a computer can create.

The effect is something like a computerized flight simulator, but far more detailed and realistic. "Immersion" is the word that VR experts use to describe it. Turn your head and the scene changes accordingly, just as it would in real life. Put your hand into a special electronic glove, and you can "pick up" items you see—but which actually exist only as computer graphics.

In the stock-market version, each colored square represents a stock, its price and activity determining its position and color, each changing as the market changes. The blue squares signify rising stocks, the reds losers. By wandering through this surreal, computer-generated field, a stock trader can see in an instant how individual stocks are performing, relative to others. That may allow the trader to buy and sell shares more quickly than a competitor studying a more traditional list of prices—an edge that can mean millions of dollars in profit in fast-paced financial markets. Already being tested on Wall Street, the system is one of the first commercial applications of virtual reality computing.

Predicted by sci-fi novels and the subject of experimentation in the computer community for decades, virtual reality is about to burst from illusion into, well, reality. Entrepreneurial VR companies are outgrowing the garages in which they were founded and are beginning to bring products to market. Experts are predicting that the VR industry could mushroom into billions of dollars of annual revenue well before the end of the decade.

"It is going to explode, and the fundamental questions are going to be what are you going to do with it, not how are we going to do it," said Kevin Teixeira, virtual reality project manager at Intel Corp., the Santa Clara, Calif.-based computer chipmaker.

Not everyone is so optimistic:

See VIRTUAL REALITY, H4, Col. 1

Virtual Reality: From Illusion to Market

VIRTUAL REALITY, From H1

Noting that some pioneer companies in the field already are foundering while waiting for the industry to develop, some observers caution that many leading-edge technologies like VR evolve into businesses far more slowly than their proponents envision. And the VR systems already in place are still no substitute for real life—the limited graphics and animation capabilities of today's computers leave most VR systems rather crude.

Still, the consensus among technologists is that steady improvements in computing power and graphics capabilities and steadily declining costs have put virtual reality on the cusp of something big. "Enough of the technology is here that you can get some crude sort of virtual reality, relatively cheaply, relatively soon," said Steve Ditlea, a New York journalist and consultant who has written extensively about virtual reality.

The price tag on a sophisticated virtual reality system has dropped from $200,000 a couple of years ago to about $20,000 now, and customized desktop computers based on Intel's ubiquitous 486 chip are beginning to show up as engines of virtual reality systems.

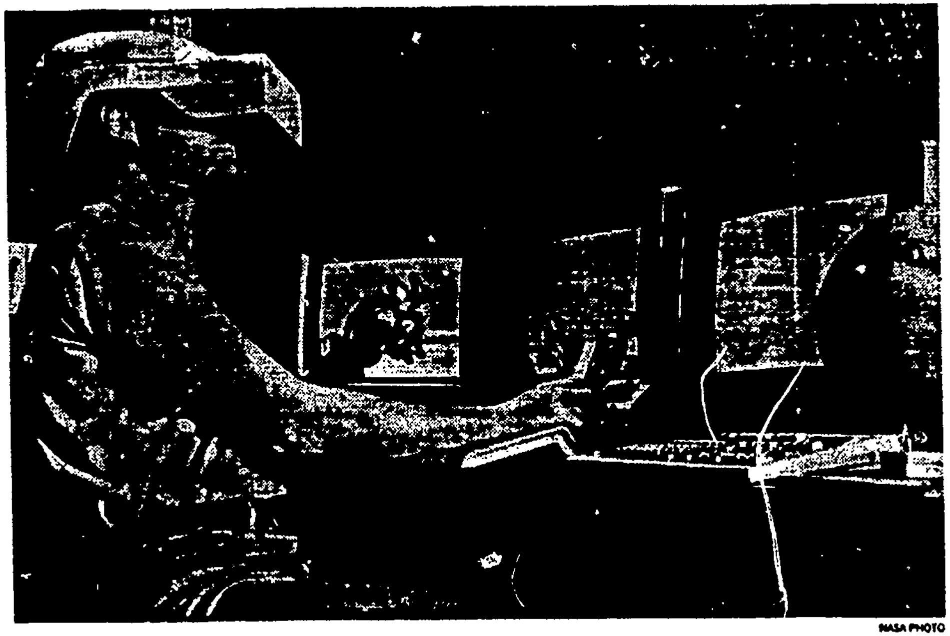
VR arcade games already are beginning to appear, and some experts predict that the hottest toy for Christmas 1993 may be a virtual reality version of Nintendo that puts kids inside their video games.

"This may be the first technology that goes directly from supercomputers to entertainment, with nothing else in between," said Mike Ramsey, senior vice president at Silicon Graphics Inc., a Mountain View, Calif.-based maker of high-power graphics computers that is active in virtual reality work.

But virtual reality's potential goes way beyond games, proponents of the technology say, and other, more sophisticated applications are expected to follow shortly after games appear on the market.

As the stock market example shows, VR is expected to provide dramatic new ways to view and manage data. The technology could allow doctors to enter computer-generated versions of patients to better visualize surgery, creating what some call "Nintendo surgeons."

The Pentagon wants virtual reality for simulations and combat planning. The technology might allow astronauts to explore areas of Mars and other planets by remote control and give firefighters visual images of the interiors of smoke-filled buildings. Educators are expected to use VR to create "virtual textbooks" in which students could inhabit computerized recreations of the things they are studying. An offshoot, "televirtuality," could allow business associates to hold meetings thousands of miles apart, yet appear to be at



NASA PHOTO

NASA researcher wears helmet and "power glove" to maneuver around a computer-generated planetary surface.

the same desk—with the ability even to hand electronic documents back and forth. Some visionaries even predict the advent of highly realistic computerized sex.

Fantastic stuff, and it already is raising questions about whether virtual reality can be abused, like a drug, to create alternate psychedelic environments in which users could disappear from the real world. "Electronic LSD," some call it. There even are fears among some in the VR field that the government will seek to regulate virtual reality.

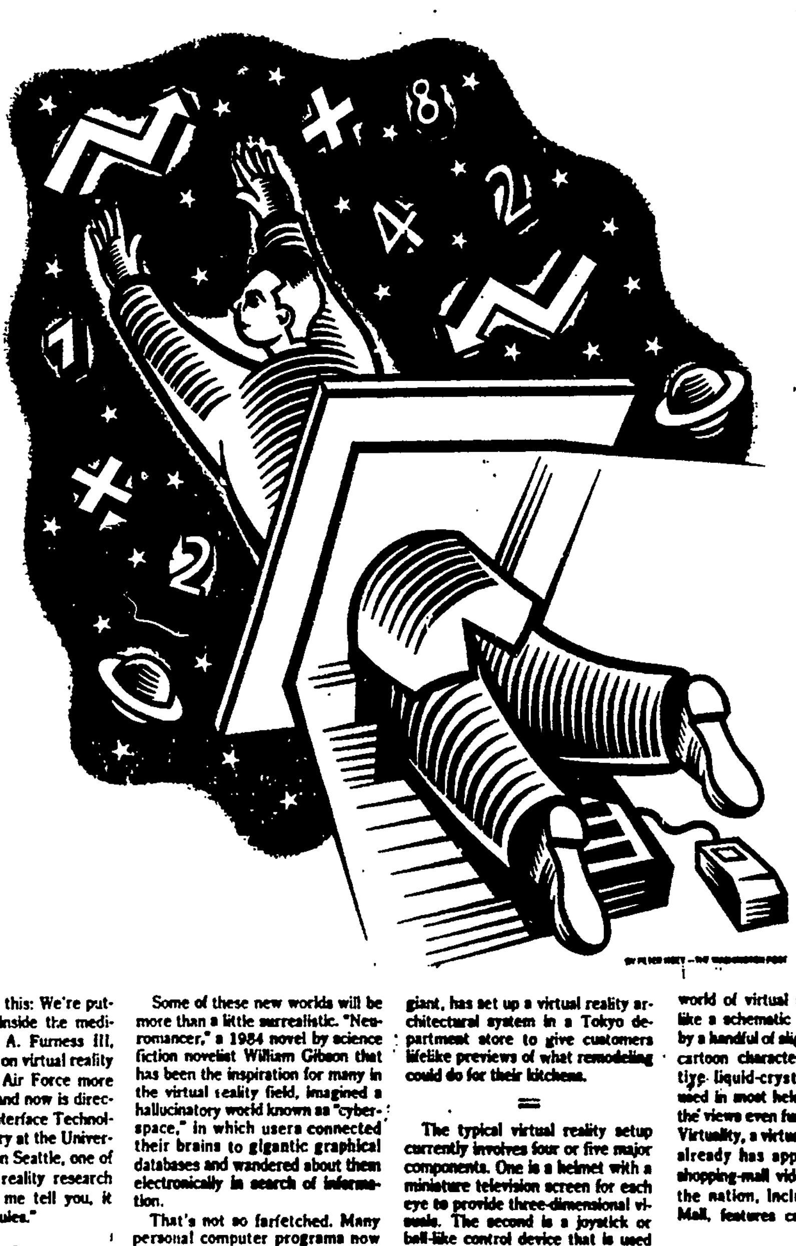
"The problem with virtual reality is that it's a door to another world," said Michael McGreevy, head of NASA's virtual reality research effort and a pioneer in the field. "People might walk through it and choose not to come back."

Even in its more conservative forms, virtual reality can produce a disorienting and nauseating feeling known as "simulator sickness," in which the eyes tell the brain the body is moving, based on the images from the VR system—contrary to the signals from the inner ear, which thinks the body is stationary.

But experts say the positive attributes of VR far outweigh any potential negatives. Virtual reality, they say, is the best example yet of how powerful computers will change life—quite literally, in this case.

"In virtual reality, what happens is this: We're putting the observer inside the medium," said Thomas A. Furness III, who began working on virtual reality technology for the Air Force more than 25 years ago and now is director of the Human Interface Technology (HIT) Laboratory at the University of Washington in Seattle, one of the leading virtual reality research facilities. "Boy, let me tell you, it changes the whole rules."

In a way, virtual reality is the ultimate optical illusion. Ideally, the user has the feeling of being in an alternate world, one whose attributes can be anything its designer wants them to be. "We can change gravity, we can change the speed of light, we can change the speed of sound," Furness said. "We are all-powerful."



Some of these new worlds will be more than a little surrealistic. "Neuromancer," a 1984 novel by science fiction novelist William Gibson that has been the inspiration for many in the virtual reality field, imagined a hallucinatory world known as "cyberspace," in which users connected their brains to gigantic graphical databases and wandered about them electronically in search of information.

That's not so farfetched. Many personal computer programs now can convert numbers from spreadsheets into sophisticated three-dimensional charts. Virtual reality puts the user into the middle of those graphs and animates them.

"You might see ebbing and flowing of the tide [of data], oceans rising and falling, trees growing, some sort of organic model" of data, McGreevy said. Applied to the analysis of financial markets, a virtual reality-based system could be a powerful tool. "If you liked program trading, you'll love virtual reality trading," McGreevy said.

Other virtual reality examples are a little more like real life. There already are several products that allow architects to convert computerized plans into three-dimensional computer-generated models of buildings and then use virtual reality to "walk" through them. Unlike a blueprint or even a computer-generated design, virtual reality allows architects to experience what a building will be like once it is built—and to decide on design changes that might otherwise not be obvious until construction started.

One experimental system allows an architect to move through the design of a veteran's hospital in a virtual wheelchair to test access to doors, hallways, light switches and other design elements. And Matsushita Electric Industrial Co., the Japanese giant, has set up a virtual reality architectural system in a Tokyo department store to give customers lifelike previews of what remodeling could do for their kitchens.

The typical virtual reality setup currently involves four or five major components. One is a helmet with a miniature television screen for each eye to provide three-dimensional visuals. The second is a joystick or ball-like control device that is used to direct movement. The third is a "Polhemus" sensor, suspended above the user, that constantly senses the locations of the helmet and control device and transmits this information back to the fourth and perhaps most important component, a computer, which generates the sound and graphics piped into the helmet and keeps track of the user's position in this artificially generated world.

Some systems add a fifth component, an electronic wand or a "power glove"—an elaborate array of hand-mounted electrical sensors—that can be used to point at, grasp or move objects in the virtual world. The user can see the electronically generated hand or wand extending before him in the TV display of the virtual world.

It is, for now, a cumbersome setup—especially when the thick cables used to connect it all together are taken into account. Researchers are working on lighter, more comfortable devices, most notably replacements for the bulky helmet. "Helmets are Stone Age," declared Ken Pimental, product manager at Sense8, a Sausalito, Calif.-based company that writes computer software used in VR systems, including the stock-trading system, which is viewed on a regular television screen rather than from a helmet.

The goal is to come up with a virtual reality interface that is as easy to wear as a pair of glasses. "If the consumer market comes out with some effective, lightweight glasses, it could drive the market, even if it's low quality," said John Latta, president of Fourth Wave Inc., an Alexandria consulting firm active in virtual reality work.

The University of Washington's HIT lab is testing a visual device known as a "virtual retina display," in which a filtered laser draws images on the user's retina—a scarifying and currently crude technology that experts nonetheless believe holds great promise. Another alternative does away with head-mounted displays entirely by constructing virtual reality viewing rooms with large-projection TV screens as the walls, ceilings and floors.

Also crude, for the moment, are the images projected of the virtual world. Because of limitations of even the most powerful computer graphics systems, the world of virtual reality often looks like a schematic drawing populated by a handful of slightly more realistic cartoon characters; the still-primitive liquid-crystal video displays used in most helmet systems make the views even fuzzier. For instance, Virtuality, a virtual reality game that already has appeared in several shopping-mall video arcades around the nation, including Springfield Mall, features cartoon-like characters that chase the user around what looks like the framework of a building. The effect is three-dimensional, but hardly realistic.

Other VR applications, however, bear a closer resemblance to reality. Some of the building walkthroughs being developed as a tool for architects are striking in their verisimilitude. Lifelike furniture, window views, lighting and shadows appear; some systems even provide detailed renditions of artwork, brick walls or items on desk tops. The scenes are a bit blurry and move in a herky-jerky fashion, but are nonetheless convincing.

The expense of virtual reality systems so far has limited the market for them—some experts estimate that there are fewer than 1,000 true virtual reality systems in existence, almost all of them in academic, corporate or government laboratories.

The low volume has made it slow going for the fledgling virtual reality industry. Most of the handful of companies that are leaders in the field are entrepreneurial start-ups, some of which have struggled financially as they wait for the industry to develop.

Larger corporations, while watching the field with interest, are involved mostly in funding research into applications that will benefit them. Many industrial firms are looking at VR as a possible design and testing tool, financial services companies are interested in its use in analyzing data, and movie and amusement parks are fascinated by its potential as an entertainment medium—just imagine being able to watch "Batman Returns" from Batman's perspective, inside the movie.

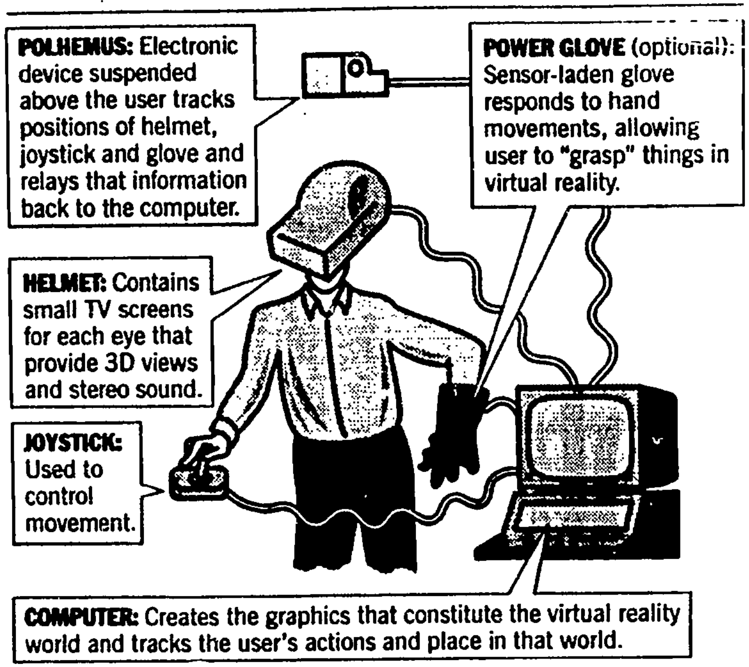
American companies and researchers seem to be defining the field of virtual reality, but many VR experts are worried that the United States could lose its leadership in the field to Japan and other Asian nations, which are said to be quietly working on myriad virtual reality projects.

Nonetheless, with costs dropping and technology improving, participants in the field are almost uniformly optimistic that a major breakthrough is near that will turn VR into a commercial bonanza. Many liken the state of VR to the personal computer business in the late 1970s.

"It's exactly where PCs were about 15 years ago, and I think it's got the potential to be way bigger than PCs," said Ben Delaney, publisher of CyberEdge Journal, a newsletter that covers the virtual reality field. "It's all crude now, but we're at, I sincerely believe, the birth of an industry."

"It's like the first days of the Wright Brothers' airplane. It's crude, but we can get off the ground and have a hell of a thrilling ride," Intel's Teixeira said. "And like the Wright Brothers, people can jump in and get involved. It's the barnstorming days of virtual reality."

THE VIRTUAL REALITY SETUP



BUSINESS

Snaring Sharks in an Unreal World

By Mark Potts
Washington Post Staff Writer

SEATTLE—I am standing in a tankful of sharks, armed only with a flimsy fishing net.

Turning slowly, I can see four of the beasts moving around the darkened tank, mingling with other fish and underwater plants. In the background, there is a steady "glub-glub" sound, like the soundtrack to a World War II submarine movie.

I reach out with the net to grab one of the sharks, but miss. Another glides past my shoulder. I pirouette, reach up with the net, and snare the shark.

The incongruous sound of breaking glass signals success. A miscalculation could leave me staring into the gaping jaws of a hungry great white.

Fortunately, none of this is real. The shark tank exists only in the mind of a computer that feeds cartoonish images of the scene to what looks like a heavy, elongated bicycle helmet on my head. The net is actually a joystick in my right hand.

And instead of feeling water rushing by, I am entangled by my movements in the thick cables that attach the helmet and joystick to the computer—a sort of occupational hazard for anybody dabbling in the new world of virtual reality.

Still, Shark World, developed by Division Ltd., a British company, and demonstrated at the Human Interface Technology Laboratory at the University of Washington, is an impressive example of fledgling virtual reality technology.

It's one of the reasons that many industry insiders and observers believe that a huge market for virtual reality as an entertainment, scientific or business medium is just around the corner.

Another is a building-simulation system, developed by Straylight Corp. of New Jersey and shown at several computer trade shows in recent months.

See SHARKS, H4, Col. 5

Demonstration Suggests Commercial Possibilities

SHARKS, From H1

Using a similar helmet-and-joystick setup, Straylight's system allows the user to "walk" through a virtual building—a potential boon to architects or building owners who want to test a design.

Some versions in laboratories around the nation provide users with the ability to move walls around and experiment with different configurations, or to test different lighting with amazing realism.

The images seen through the Straylight helmet are fuzzy, but convincing.

Look down and you see desk tops. Look up and you see the ceiling.

Turn around and you can see a 360-degree view of your computer-generated surroundings, replete with furniture and potted plants. Move through a door and you enter another room, or an outdoor scene.

Throw yourself through a window and . . . you find yourself floating past the Jefferson Memorial.

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LOOKING AT REALITY, VIRTUALLY

COMPUTER HEADWARE: University of North Carolina computer scientist Walter Robinett dons head-mounted display to experience a "virtual reality." It's the latest fashion. See Research, page 14.

Researchers See A Wealth Of Applications For Virtual Reality

BY ROBIN EISNER

X-ray crystallographer Vivian Cody has found a way to sit—virtually—in the midst of enzyme drug binding sites. She especially likes to experience the feel of it all—the pushes and pulls that a drug goes through as it finds the coziest place to rest on a protein. Although this kind of molecular space exploration sounds like fun and games, some scientists in academia, industry, and government see it as a most serious and advanced application of "virtual reality," an emerging computer technology that its most enthusiastic advocates suggest could change the entire complexion of research.

While virtual reality has been used by the military and by space scientists for the last decade, pharmacologists, molecular biologists, and theoretical physicists are beginning to venture into its domain. Simply speaking, the technology provides heightened representation of the real, physical attributes of scientific models. It is a tool that takes visualization and interpretation of data to a new dimension—to the point at which a researcher, in a sense, touches, interacts with, or is engulfed by the model that he or she has created.

Unlike the usual interfaces between humans and computers, such as the mouse or the keyboard, virtual reality hardware—head-mounted displays and gloves—allows people to feel as if they are entering the world inside a computer display, flying around and manipulating the objects they encounter (see accompanying story). Indeed, it promises to accelerate scientific understanding by enabling researchers to refine their hypothesized models of the mysteries of nature.

"Science moves by its ability to see and model," says Myron Krueger, one of the innovators of the technology. "Although we downplay our intuitive grasp of things and think mathematical equations are more correct, our intuition is more highly developed than our symbolic sense of the world. New perceptions and perspectives create radical sources for discovery and insight in science."

Other scientists agree. Crystallographer Cody, head of drug design at the Medical Research Foundation of Buffalo, is one of the small but growing number of academic, basic science researchers—from biologists to physicists—who have begun to use or investigate the use of VR in their work. Cody and other noncomputer, nonspace, and nonmilitary scientists are being introduced to VR through collaborations with private and public facilities specializing in the technology.

Cody felt the power of VR technology last year at one of the centers doing research on it in the United States, the department of computer science at the University of North Carolina, Chapel Hill. As editor of the Journal of Molecular Graphics, Cody says, "I often get to be the first kid on the block to play with new toys like [these]." And because the facility is considered a special resource center, funded by the National Institutes of Health, part of the $300,000 a year it gets must go toward collaborative work.

Cody went to the center to see if the university's prototypic VR force-feedback, drug-docking program could reproduce results she gets with the current standard computer software and hardware. She left with a lot more. She found new binding orientations for one of the drugs she works with—the enzyme dihydrofolate reductase (DHFR), a major chemotherapy target of anti-cancer agents in cells. Now she intends to determine if what she saw in the virtual world can exist in the real world by crystallizing the drugs and the enzymes in these new configurations.

A FEELING FOR THE MOLECULE: Computer scientist Fred Brooks uses a robotic arm to feel the forces between a drug and its target.

Photo: Peter Muntzel

Although the center has energy data available only for DHFR, the technology represents a major advance over what is currently available, Cody and others say. "The fastest way to do all the energy measurements between a drug and a substrate is to use a supercomputer," says Cody. But since the supercomputer calculates every energy possibility between the atoms, it takes a long time to do the analysis and is costly. VR puts a human being into the loop to both visualize and feel the interaction between the molecules. "The mind is still the best pattern recognition system available," says Cody. What the supercomputer wastes time on doing by rote, a person can quickly do by using sight and touch, she says.

Although the technology promises to be revolutionary, "there is still a trade-off between resolution and speed of transmission of images," says Michael McGreevy, head of the National Aeronautics and Space Administration's Virtual Environment Research Laboratory at Ames Research Center in South San Francisco, Calif. At the current level of commercially available virtual reality, for example, a biologist could develop a highly stylized model of a cell and poke around inside. But the technology at the centers and on the market has not been refined to the point at which a biologist can enter into an image of a living cell and watch the chromosomes divide.

Not yet, that is. The virtual landscape is expected to become more refined in five years. There are some 50 VR startups, a number of major corporations, about five centers in the U.S., and more in Japan doing research on VR, according to William Bricken, a scientist at the Human Interface Technology Laboratory in Seattle, one such center. But these firms and institutions aren't focusing on refining the technology for bench researchers. Most of the recent applications of virtual reality have been in rendering 3-D architectural drawings, landing astronauts on Venusian landscapes, medical imaging, and telecommunications. Academic scientists make up a small percentage of VR's potential user market and therefore don't provide a substantial economic incentive for product development.

But according to NIH computer specialist Richard Feldmann and others, designing affordable, mass-market consumer products, such as virtual video games or virtual telecommunication systems, are driving the VR marketplace. In such applications, people would be able to "walk" into a computer game, or two people separated by distance could "occupy" a computer-generated space and interact in it.

Spin-offs from these consumer products and advances in supercomputers should eventually decrease the cost of VR software and hardware, say computer experts. And then scientists can benefit. "Scientists are parasites in that sense," says Feldmann, of NIH's Division of Computer Research and Technology. In five to 10 years, say the experts, virtual experimentation on a wider scale could become a reality.

The computer graphics and virtual reality center at North Carolina, under principal investigator Fred Brooks, has been evolving since the early 1970s. Years of support from NIH, the Office of Naval Research, the university, and Burroughs Wellcome Co. of Research Triangle Park, N.C., have finally begun to pay off. "The [force-feedback] drug docking project allows a researcher to feel in his or her hands the electrostatic forces that exist between a drug and its substrate—in real time. No small task," says Richard DuBois, director of the computer technology section of biomedical research in NIH's National Center for Research Resources in Bethesda, Md.

To dock drugs at the North Carolina center, the researcher stands in front of a 4' x 3' screen, upon which is displayed a model of a drug molecule and its target protein. By using a robotic arm that acts as a joystick, he or she can move the drug up and down, left and right, and backward and forward. An energy histogram displayed on the screen allows the investigator to eyeball whether the fit between the drug and its substrate is energetically stable. At the same time, the robotic arm responds to repulsive forces between the molecules depicted on the screen.

Other projects at the center, including the drug-docking program without force feedback, involve one of the more popular interfaces of VR technology, called the head-mounted display. Force-feedback drug docking using head-mounted displays is not possible yet. "The technology is just not here," says Walter Robinett, chief of the head-mounted display project. But he and others are working on it.

Head-mounted displays are the window into the virtual world. They create a stereoscopic, wide-angle view of the virtual world that the wearer can seemingly enter. Inside the displays are two small televisions, one for each eye. The view comes from a computer that generates images 15 to 30 times per second. The picture changes depending on the wearer's movements.

An input device allows a person to be transported inside the virtual world. These devices enable a person to make commands that the computer interprets. The computer then changes the image that it sends to the television screens in the head-mounted display. The input device is a joystick that has been transformed into a glove that a person wears on the hand or a joyball with buttons.

The glove was originally made by computer scientist Tom Zimmerman because he wanted to play "air guitar"—actually producing the sound of strings with a flick of the wrist. He licensed the glove to Jaron Lanier, CEO of VPL Research Inc.

(Continued on Page 16)

WINDOWS ON THE VIRTUAL WORLD: HEAD-MOUNTED DISPLAYS

If *Alice Through the Looking Glass* were written today, the heroine might have used a head-mounted display to go through to the other side, instead of a mirror. Inside head-mounted displays, explains Walter Robinett, director of the head-mounted display project at the University of North Carolina, "are two 3-inch-square liquid crystal display television screens. In front of them are some lenses so that the image portrayed on the television screen doesn't seem two inches in front of the viewer, but 10 feet off. It creates the illusion that you are in a life-size, 3-D world. Each screen has a different view so you see a stereoscopic, wide-angle view of this computer-simulated place."

"On the head-mounted display," Robinett goes on, "is a device called a Polhemus that measures your head position and can detect where your eyes are looking in space. This tells the computer database what coordinates the vertices of polygons creating the virtual world should occupy. It generates an image for each of your eyes 30 times per second, so when your head moves, what you are seeing continually changes, just like what happens when you turn your head from side to side.

"The net effect is that you open your eyes and look through this head-mounted display, and you see this 3-D scene. You can push your head forward and walk into the scene. The stuff in front of you gets closer. If you turn your head, the stuff that was in front goes off to the side."

Such head-mounted displays were conceived in 1965 and created by Ivan Sutherland at the University of Utah in 1968. Researchers are working on developing software and hardware so a user can see images from the real world while operating in the virtual world.

—R.E.

Scientists Explore Uses Of Virtual Reality

(Continued from Page 14)

in Redwood City, Calif., one of the 50 or so VR startups.

Wide acceptance and application of VR technology isn't going to happen overnight. While there are some commercial VR software and hardware products on the market, the machines are costly, and only the centers today have enough computing power and expertise to create a believable, three-dimensional visual reality in which a researcher can interact. Before VR can be used more widely, observers agree, a considerable number of technical and financial hurdles must be overcome.

One criticism of virtual reality as it exists today is that the essential equipment is uncomfortable and unreliable. The head-mounted displays, for instance, are said to nauseate people.

"The problem with the glove is that it is made of stretchy material, and it is hard to get it to work from day to day with different sized hands," says Robinett, who uses the ball device. "But from the point of view of seeing a live hand in an environment and seeing the scale of things inside a virtual world in proportion to your own body, the glove is wonderful."

An alternative to virtual reality, called artificial reality, overcomes some of the equipment unfriendliness. Invented by Myron Krueger in 1969, it is a system that allows a human being to interact in computer events unencumbered by gloves and head-mounted displays. In Krueger's artificial reality, video cameras send images of a person to a computer, which translates his or her movements and responds to them.

VPL Research Inc.'s Lasko: "Many people underestimate the power of the technology that does exist."

One of the fastest-growing manufacturers in the U.S. of gloves and other virtual reality hardware and software is Redwood City's VPL Research. The firm was founded in 1985 by its president, Jean-Jacques Grimaud, and CEO Lanier, who has become a media celebrity of sorts, having been profiled in *Playboy*, *Rolling Stone*, and *Smithsonian*. In June 1989, VPL performed a tour de force—the first commercial demonstration of two people in separate locations sharing a virtual reality experience.

Today VPL's customers include telecommunications firms, engineering designers, and forestry researchers. And while VPL employees acknowledge that the technology is still in its early stages, customers say that it is worth getting in on the ground floor to gain an edge on what they predict will become a widely used technology in business.

"... e we started selling our products, the only people who could work in this field had to have all of the skills and resources to build the system from the ground up," says Anne Lasko, director of product design at VPL. "They needed an optical engineer to develop the eye phones and an electrical engineer to figure out the tracking. The system we sell is ready to go, so someone can make their own virtual reality.

"But there are misconceptions about virtual reality. On the one hand, people have greater expectations of the technology than is currently available. On the other hand, many people underestimate the power of the technology that does exist. It is a very creative software. It is up to the user to see its application to their system."

VPL sells a virtual reality system for one person that includes a head-mounted display, the glove, the two advanced graphic workstations, and accessories for about $200,000. The two workstations account for $150,000 of the price. The glove alone goes for $8,800.

Most academic researchers would be hard-pressed to find money from their university or from a federal agency to use VR in their lab, some observers say. "If a lone researcher, independent of the groups doing this sort of thing, put in a grant to the government even to do collaborative VR, it would be impossible to get it peer-reviewed," says NIH computer specialist Feldmann. "There just isn't enough of a base of scientists with expertise in applications of this technology to new areas.

"Peer review is a control mechanism that is somewhat repressive and reactionary. But once you get some brave souls who show the technology isn't just whiz-bang, but can produce new and interesting results, you might get some funding. This has happened before with other technologies that people originally thought were just toys."

Right now, in fact, the 18-month-old Human Interface Technology (HIT) Laboratory in Seattle is in the process of convincing the National Science Foundation to help fund its program. With Tom Furness at its helm, getting money should be no problem, say colleagues. Furness used to head the Dayton, Ohio-based Wright Paterson Air Force Base VR flight simulation project, a VR application used to train pilots.

"HIT is a state-funded institution whose purpose is to transfer technology from the states' universities to the private sector," says Bob Jacobson, associate director of the center, based at the University of Washington. HIT is also soliciting $50,000-a-year memberships in a consortium program from industry investors. The pooled money from the members of the consortium supports general research in the lab. In return, industry members gain an advantage over competitors, since they have access to the initial stages of the VR technology. Current members of the consortium include Digital Equipment Corp. of Maynard, Mass., Sun Microsystems of Mountain View, Calif., and VPL Research.

For those academic researchers who want to ride the VR train but cannot afford it, collaboration with industry may be the ticket. John Joannopoulus, a theoretical physicist at the Massachusetts Institute of Technology in Cambridge, has such an arrangement with IBM's Veridical Laboratory in Yorktown Heights, N.Y. Hoping eventually to use VR as a visualization tool, Joannopoulus and colleagues are in the process of developing a machine that could simulate the structure of solids. This machine would create three-dimensional, electron-density maps of solids upon being provided only with the atomic number of an element.

NIH's Feldmann: "If a lone researcher put in a grant [to use VR], it would be impossible to get it peer-reviewed."

"Now I do the calculations on the supercomputers at MIT and Carnegie Mellon University," he says. "Office of Naval Research money pays for them. The visualizations of the solid structures I do at IBM." In the near future, he wants to be able to enter into the structure of a solid and see what an electron sees with VR. By disturbing the structure of a pure solid with a contaminant, he wants to see the effect from inside the solid.

But with all the money in the world, Joshua Zimmerberg still couldn't do what he wants to in virtual reality. Zimmerberg, chief of the Laboratory of Theoretical and Physical Biology at the National Institute of Child Health and Human Development, wanted to take his two-dimensional fluorescent microscope images, translate them into a three-dimensional volume, and look at a cell as a whole, instead of sectionally. "We would need a supercomputer that doesn't exist yet to allow me to see the cell in 3-D through a head-mounted display," says Zimmerberg, who studies the biophysics of membrane fusion. "At the current time, VR is only good for people who work with computer-generated images. But to do the kind of work I and others want to do is a good reason to push supercomputer development."

Maintaining U.S. competitiveness in supercomputers and virtual reality prompted Sen. Albert Gore (D-Tenn.) to visit North Carolina this past January. Gore is concerned that the Japanese will exploit the VR market before the U.S. His concern may be warranted. According to HIT's Jacobson, the Japanese have 10 times as many facilities researching VR as the U.S. NIH's DuBois is concerned as well. He says, "If we want to stay at the forefront of this field, we must be committed to keeping our technical base so we aren't scooped by the Japanese." ❐

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EXPERIENCING SCIENCE WITH COMPUTER-CREATED 'VIRTUAL REALITIES'

U. of North Carolina's Russ Taylor uses a robot arm to sense simulated molecular force fields around computer-generated images of proteins. Story on Page A6.

Computer-Created World of 'Virtual Reality' Opening New Vistas to Scientists

By DAVID L. WHEELER

Computer-generated environments that create the illusion of three-dimensional worlds are giving scientists the ability to work surrounded by images of molecules and other objects that they once had to use an electron microscope to study.

"You can take a stroll on an insect's eye or take a tour of an integrated circuit," says Thomas A. Furness, director of the Human Interface Technology Laboratory at the University of Washington. His laboratory hopes to bring "virtual realities," as the computer-created worlds are often called, into broad public and scientific use.

In the simplest version of the virtual worlds, computers generate images on goggles worn by the users, creating the sensation they are in a different place. Those developing the virtual realities hope they will open up new intellectual vistas in education, entertainment, art, and architecture, as well as in science.

William Bricken, the chief scientist at the University of Washington laboratory, says that the primary purpose of virtual realities should be to go to "places that are absolutely unreal."

Mr. Bricken believes virtual realities could let people experience mathematical equations, for instance. People could act as a variable in an equation and watch forms, colors, or curves shift around them in response to changes in the variable's value.

Used in Cancer Therapy

At the University of North Carolina at Chapel Hill, variations on virtual-worlds technology have been used to help physicians position the beams of radiation used in cancer therapy and to aid biochemists searching for targets on protein molecules where they can attach drugs.

Virtual worlds may also inform the research of psychologists who study perception. Psychology, says Mr. Bricken "is the physics of virtual reality."

Computer scientists see virtual-worlds technology as a natural extension of their work. "For 25 years," says Henry Fuchs, a professor of computer science at the University of North Carolina, "the major thrust in computer graphics has been to convey a sense of reality so the user cannot distinguish computer-simulated objects from real objects."

Rich Holloway of the U. of North Carolina shows how virtual realities might be applied in the future to help doctors "see" inside a patient.

Researchers at the University of Washington want to find more natural ways than keyboards for people to communicate with computers. "In the past, human talent and flexibility has been subservient to a narrow capability of computing," says Mr. Bricken. "We need to reverse this. Now that we have very sophisticated computational abilities, we need to adapt them to the needs of the human."

He adds that people also need to begin to get used to the idea of "wearing" computers.

In one currently available version of virtual-reality technology, a user puts on goggles that create images with liquid crystal displays—the same technology used in laptop computer screens.

The picture in front of each eye of the goggle wearer is slightly different, creating the illusion of three dimensions. An electromagnetic field is generated around the user, and wires running from a magnet on the top of a helmet that the user wears lets the computer generating the virtual reality know where the person's head is in the electromagnetic field.

Gloves With Fiber-Optic Cables

As the user's head moves, the computer adjusts the view being projected in the goggles to what the user would be seeing from the new stance inside the virtual reality. A person viewing a "virtual tree" would see its other side if he or she walked in a semicircle and looked back.

For help in steering themselves through virtual realities, users usually wear a glove with fiber-optic cables along the fingers and thumb. The glove relays commands to the computer. A pointing gesture, for example, lets a user fly through the virtual reality and indicates the direction desired.

Those who have experienced virtual reality say the illusions are successful, but they sometimes find that the motion of images are jerky and the computer-generated objects look more like cartoons than the real thing. Experts in computer graphics who have seen the photo-realism possible on the screens of high-resolution, color monitors are generally disappointed when they don virtual-reality goggles.

"The resolution is terrible" says Mr. Fuchs.

Researchers are experimenting with adding three-dimensional sound and a sense of touch to the virtual worlds. Biochemists who use a "GROPE" system at the University of North Carolina can see molecules ahead of them in three-dimensional space and, through a hand grip, can get a crude sense of the physical forces that would be generated if the molecules were real.

The chemists say that feeling the atomic attractions and repulsions while they are manipulating the illusionary molecules helps them find the best way to attach one molecule to the other.

Along with trying to plunge users into complete virtual worlds, scientists are using the virtual-reality technology to augment the normal senses. Researchers are, for example, developing systems that let

Continued on Page A12

U. of Washington's William Bricken: "The primary purpose of virtual ...es should be to go to ...s that are absolutely unreal."

Scientists Use Computers to Create 'Virtual Realities'

Continued From Page A6

physicians see and touch a patient normally but also let them see, superimposed on the patient, information from medical imaging equipment that shows what is under the skin.

An Obscure Domain

Virtual-reality research, once the domain of a few laboratories that labored in relative obscurity, has suddenly come into more widespread use. Two virtual-reality newsletters and the discipline's first scientific journal are starting up this year, and scientists say corporations are expressing interest in paying for the research.

The corporate financing, combined with commercially available hardware—goggles and gloves—has made it easier for more scientists to start experiments.

At least one computer scientist—Ivan E. Sutherland—envisioned what he called "the Ultimate Display" almost 25 years ago. In 1968, Mr. Sutherland, then at the University of Utah, published a paper describing the first helmet that could project images in front of the viewer's eyes.

Since then, researchers in the Air Force, at the University of North Carolina, at the Massachusetts Institute of Technology, and at the National Aeronautics and Space Administration's Ames Research Center in Mountain View, Cal., have worked to perfect the technologies that have resulted in the first virtual worlds.

Young and Chaotic

Virtual-reality research as a distinct discipline is young and chaotic, scientists say. Terms and their definitions have yet to be agreed on, and even the name of the field is in dispute.

"The term 'virtual environments' better fits a field of scientific research," says David Zeltzer, an associate professor of computer graphics at the Massachusetts Institute of Technology's Media Laboratory. "Virtual reality is an unattainable goal, like artificial intelligence."

Those interested in virtual worlds say they have not been hindered by the lack of a journal. Using electronic mail and specialized branches of computer networks intended for the builders of virtual worlds, researchers have been energetically conversing and exchanging bibliographies, philosophy, references, and relevant computer programs. One scientist printed out the virtual-reality discussions from one computer network and found he had 800 pages of reading ahead of him.

Although some companies are marketing hardware for creating virtual realities, the conversations on the computer networks are chiefly related to research. "Anyone who gets into too much of a sales pitch is chastised," says one software engineer.

Research on "virtual realities" has three chief components, says Mr. Bricken. One part consists of the effort to develop and improve technologies that make the computer-generated worlds look, sound, and feel more real.

In another part, researchers are writing computer programs to organize the vast amounts of data that stream back and forth between the people and the computers creating virtual worlds.

In the third, scientists are trying to improve their understanding of human perception so they can do a better job of tricking the senses.

"We're trying to tie these three

parts together as tightly as possible," Mr. Bricken says.

The Birth of 'Cyberspace'

As the concept of virtual worlds spreads, Mr. Bricken and others believe it will be accompanied by a new view of electronically stored and communicated information.

"In the space around me, there are a dozen or so television channels and hundreds of radio channels and telephone conversations on cellular phones," Mr. Bricken says.

"Perceptually they're invisible," he adds, "yet given an instrument, I'm able to make them apparent. What's the word for that place?"

That place has come to be called "cyberspace," a term lifted from a science-fiction novel that described a common hallucination sustained electronically.

The concept of cyberspace—an electronic dimension separate from the physical world—has enthralled anthropologists, sociologists, philosophers, and artists. Michael Benedikt, a professor of architecture at the University of Texas at Austin, organized the First Annual Conference on Cyberspace last spring. It drew hardware builders and software writers as well as social scientists. Mr. Benedikt says he came to appreciate the concept of cyberspace after a long period of ambivalence about the influence of electronic communication on architecture. But as he learned about cyberspace and virtual realities, Mr. Benedikt says he became convinced that they would open up an important new frontier for design.

"I became intrigued by the idea that architecture could exist in an unreal space," says Mr. Benedikt, who is editing a book called *Cyberspace: First Steps* that will be published later this year by MIT Press.

This year's cyberspace conference is being organized by Allucquere Rosanne Stone, a lecturer in sociology at the University of California at San Diego. Ms. Stone sees virtual worlds as a more elaborate version of other electronic media that are used socially, such as computer bulletin boards and telephone sex services.

Ms. Stone says that virtual reality, like the other electronic media before it, carries the danger that people will become too engrossed in the cyberspace image they project. "No matter how beautiful a body you code for yourself in high resolution, 3-D color—no matter how seductive a space you enter," Ms. Stone says, "it will not slow down by one second how quickly you will die of AIDS if you have it."

Limited and Expensive

For now, access to virtual reality is limited and very expensive. The cost of start-up equipment alone is about $300,000 to $400,000, and serious researchers will need to spend more.

Virtual-reality researchers eventually hope to use telephone lines to allow users to enter virtual worlds even when they are away from the powerful computers needed to generate the worlds. Mr. Furness envisions a "virtual commons"—a three-dimensional illusionary place where participants, in their "virtual bodies," could mingle, converse, and listen to lectures or view entertainment. Mr. Furness, who spent 23 years in the Air Force building "virtual cockpits," has managed to interest at least one telephone company—U.S. West Communications—in related research.

Difficult to Focus

Nine other companies, including AT&T Network Systems, Digital Equipment Corporation, and Sun Microsystems, are charter members of a consortium that Mr. Furness has set up to further virtual-reality research. The corporations' chief concern seems to be that the technology has so many applications that it will be difficult for researchers to focus their efforts.

Many obstacles block realizing the potential of virtual worlds. Massive electronic "pipelines" and fast switches will be needed to carry an enlarged flow of data between people and computers. The University of Washington researchers estimate that the equivalent of 15,625 circuits capable of carrying the human voice will be needed to carry information about the position of a person's entire body to the computer and to bring information back to that person's senses of sight, touch, and sound.

> "In the past, human talent and flexibility has been subservient to a narrow capability of computing. We need to reverse this."

At the University of North Carolina, Mr. Fuchs says generating the three-dimensional images for virtual worlds eats up so much computer power that the researchers have to search for ways to economize. One way to cut down is to lower the quality of the image a person sees when his or her head is moving rapidly, but to increase the image quality when the head is still.

Another developmental barrier, says Mr. Fuchs, is the current method of tracking head position. In electromagnetic tracking, users have to stay within the confines of a small electromagnetic field.

Scientists at the University of North Carolina would like to try applications that would give users more freedom of movement. They would like architects, for example, to be able to walk around an outdoor site wearing a helmet free of any wired connection to the computer. The architects would be able to see an image of the building they are planning and the site's features, such as trees, at the same time.

Mr. Fuchs and his colleagues are beginning to create an optical tracking system that would allow that kind of freedom.

As virtual-reality equipment becomes smaller, lighter, and cheaper, its uses will spread, scientists say.

"I hope to live long enough to see the Walkman version of this," says Mr. Fuchs. ■