DOCUMENT RESUME

ED 363 278 IR 016 265

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TITLE Televirtuality: "Being There" in the 21st Century.
INSTITUTION Washington Univ., Seattle. Human Interface Technology Lab.
REPORT NO TR-HITL-M-90-1
PUB DATE Apr 91
NOTE 20p.; Paper presented at the Silicon Valley Networking Conference (Santa Clara, CA, April 23-25, 1991).
PUB TYPE Reports - Evaluative/Feasibility (142) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Computer Assisted Instruction; *Computer Simulation; Economic Factors; Educational Technology; Electronic Equipment; Futures (of Society); *Information Networks; Learner Controlled Instruction; *Man Machine Systems; Models; Public Policy; Standards; *Technological Advancement; *Telecommunications; User Needs (Information)
IDENTIFIERS Interface Devices; *Virtual Reality

ABSTRACT

Virtual worlds technology (VWT) uses special computer hardware and software to link humans with computers in natural ways. A data model, or virtual world, is created and presented as a three-dimensional world of sights and sounds. The participant manipulates apparent objects in the world, and in so doing, alters the data model. VWT will become commonplace for work and play in the future. Televirtuality and how it is accomplished are described, and some of the associated business and policy questions are explored. Televirtuality is the sharing of virtual worlds via the public telecommunications network and private communication networks. How potential systems could work and applications in teleconferencing are reviewed. Several economic issues exist, since there is at present no assured source of funding for VWT. Policy issues that will have to be resolved include how technology investments are made by corporations and how standards and protocols are selected and met. National and international policies regarding the public telecommunications network must be examined to take a long-range view. Within the decade, the telephone and the computer terminal will begin to disappear. The networking community has the largest possible stake in how the new technology is implemented. Two figures illustrate the discussion. (SLD)

Technical Report No. HITL-M-90-1

Televirtuality: "Being There" in the 21st Century

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Silicon Valley Networking Conference
Santa Clara, CA
April 23-25, 1991

INTRODUCTION

Virtual worlds technology uses special computer hardware and software to link humans with computers in natural ways. Simply put, a data model, or "virtual world," is created in a computer and presented to the user, or "participant," as an inclusive three-dimensional world of sights and sounds. The participant, who has the impression of being inside this world, is equipped with locational sensors that change the world to match the participants' movements in space. The participant, in turn, uses various input/output (I/O) devices to manipulate apparent objects in the world. In so doing, the participant alters the data model contained in the computer.

The maturation of virtual worlds technology (VWT) will dramatically alter the way in which human beings communicate with computers and with each other. With the disappearance of the the computer terminal -- the small CRT "window" and the devilish keyboard -- new realms of computer-generated experience and knowledge acquisition will become available. Today, users savor the novelty of three-dimensional, inclusive "worlds" created in the laboratory; tomorrow, they will enter virtual environments to augment work and play.

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Network technology, combined with VWT, makes possible a new phenomenon: *televirtuality.* Televirtuality is the sharing of one or more virtual worlds between two users or among many users. Televirtuality enhances the scope of other virtual-worlds applications. The distribution of processing power throughout a network permits individuals to enjoy a virtual world experience without extensive personal investments in machinery. Televirtuality as a medium of communication will subsume other media, including the telephone, broadcast media (including high-definition television), and computer graphics.

The continued development of VWT and televirtual systems requires substantial public and private support. This support eventually will come. When it does, televirtual systems will expand the role of computing and telecommunications in all types of organizations. This paper briefly describes televirtuality, how it is accomplished, and some of the business and policy questions that are associated with it.

THE TECHNOLOGY BEHIND VIRTUAL WORLDS

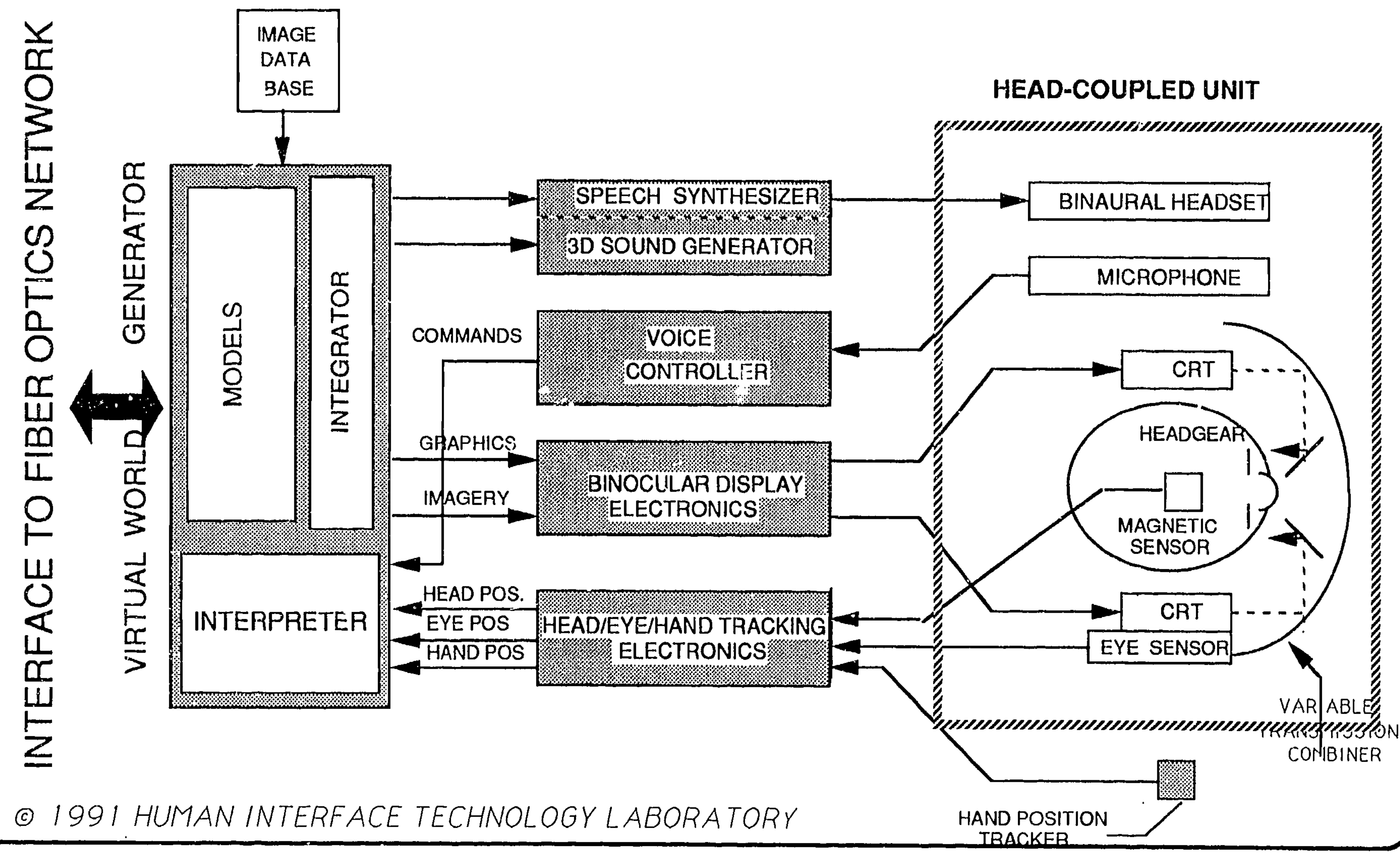
To understand televirtuality, one must first understand virtual worlds technology. A virtual world system is conceptually a simple affair. One or more computers are programmed with the model of a place -- or *virtual world* -- and the objects that inhabit it. These places can be as expansive as the known universe or as specific as the space within a subnuclear particle. The virtual world need not replicate a place or thing. In the case of a database, for example, where there are no physical characteristics to represent, one might use various metaphorical icons to stand in for data's properties (hierarchies, intensities, directional relations, and so forth).

These models are presented to the participant through special output devices that mimic normal channels of information: stereoscopic, wide-angle LCD or CRT headsets that create a 120-degree field of vision; 3-D sound headphones; and even tactile feedback devices to simulate the feel of surfaces. (This last is still in the experimental stage.) Currently, the visual input to each eye is supplied by a separate computer. However, "video splitter" boards may make it possible to multiplex two separate points of view on one machine. The sound can be run on a simple Mac II computer using the inexpensive Focal Point system marketed by Gehring Research; or on the more complex Convolatron developed by Crystal River Technology and NASA. The state-of-the-art for these devices is advancing at a reasonable rate, so that within the next five years we may expect to see much lighter and higher-resolution presentation gear. At the Human Interface Technology Laboratory (HIT Lab), plans are underway to begin building a prototype "virtual retinal scanner" to create a Maxwellian image of exceptionally high resolution (16×10^6 pixels) within the eye itself, eliminating all optics.

Positional sensors -- currently, Polhemus magnetic resonators are the typical choice -- adjust the computer's presentation of the world so that it always responds to the movements of the participant within the world. These may eventually be replaced with headset-mounted inertial positioning devices, untethering the participant from today's positioning gear, with its limited range. Using sensor-equipped tools like the Dataglove and the Wand, the participant can scale up or scale down the world; add, subtract, and modify objects; and call up other media (like a pull-down HDTV image or a video backdrop) as required.

As the participant uses natural body movements and voice commands to alter the virtual world and the things within it, the computers maintaining and rendering the world read these actions and make corresponding adjust: nts to their data models and databases. (These computers are joined by Ethernet, in typical configurations.) Ultimately, the virtual world replaces the computer terminal as an I/O system -- the *preferred* I/O system. Not only is the virtual world a faster and more accessible interface (for both novice and expert computer users), but it permits the participant to do things with the computer that were difficult or impossible before, when only the user's sense of sight -- and not the

1. A Virtual World Generator



equally important sense of space, or "virtuality" -- was able to be used. With the participant's spatial sense now involved in data perception and manipulation, the constraints imposed by visual-only data presentation are removed. Old but forgotten haptic skills can brought to bear on real-world problems which are inherently spatial.

Virtual worlds technology is also advancing on the software front. Virtual worlds built for the U.S. Air Force's SuperCockpit program in the 1980s were created with proprietary software operating on Digital PDP-10 machines. NASA virtual worlds were also built with proprietary software. Autodesk, Inc., in Sausalito, California, has been working for several years on a 3-D version of its best-selling CAD software, AutoCAD. Recently, VPL Research, Inc., in Redwood City, California, has been marketing a "Virtual Reality" software package including the Swivel 3-D CAD program, the ISAAC renderer (running on Silicon Graphics Powerstations), and Body Electric. Other commercial software is now available. W Industries, Ltd., in England, markets a world-building software called Espality. At the HIT Lab, we are now completing development of what is to be the first public-domain Virtual World Operating Shell (VEOS), comparable to Unix in the scope of its applications.

Today's virtual world systems range in price from $40,000 to $250,000 or more, because these systems are largely custom-built and the workstations running them are fairly pricey. However, as the cost of computer chips and components continues to drop, virtual world systems will decline in price, also. Moreover, the availability of networking technology will drop the price of individual investments in the technology. As it become possible to locate processing power wherever it can be provided most efficiently, individual participants will require only minimal local equipment to jack into virtual worlds being maintained by large machines elsewhere.

The main sites of current research and development in the area of virtual worlds are: University of North Carolina, Computer Science

Department; VPL Research, Inc.; Autodesk, Inc.; NASA Ames Research Center; and the HIT Lab. Digital Equipment, Sun Microsystems, IBM, and Hewlett Packard are all building laboratories to explore the technology's application in their respective markets; as are several of the RBOC. Bechtel Corporation is one of the first of the ultimate end users to begin working with VWT.

Overseas, the European interest in the field is typified by such small-scale endeavors as W Industries and the Advanced Robotics Laboratory in Britain; and LIFIA, in Grenoble, France. By far the most intensive work in this field is taking place in Japan, where Fujitsu, ATR Laboratories, NTT, Matsushita, and NHK (the national broadcasting network) have ongoing work in the field. In the last part of 1990, MITI (the national industrial policy agency) and the Japan Technology Transfer Association (JTTAS) convened a "study commission on virtual reality and telepresence" joining the intellectual resources of Japan's most prestigious academic and industrial laboratories with the economic resources of 25 of the nation's largest firms.

A February 1991 industry symposium sponsored by the HIT Lab in Seattle brought many of these parties together for the first time, to discuss how the new industry might be catalyzed. In July 1991, the JTTAS study commission will hold a similar symposium in Tokyo, to further stimulate interest in VWT.

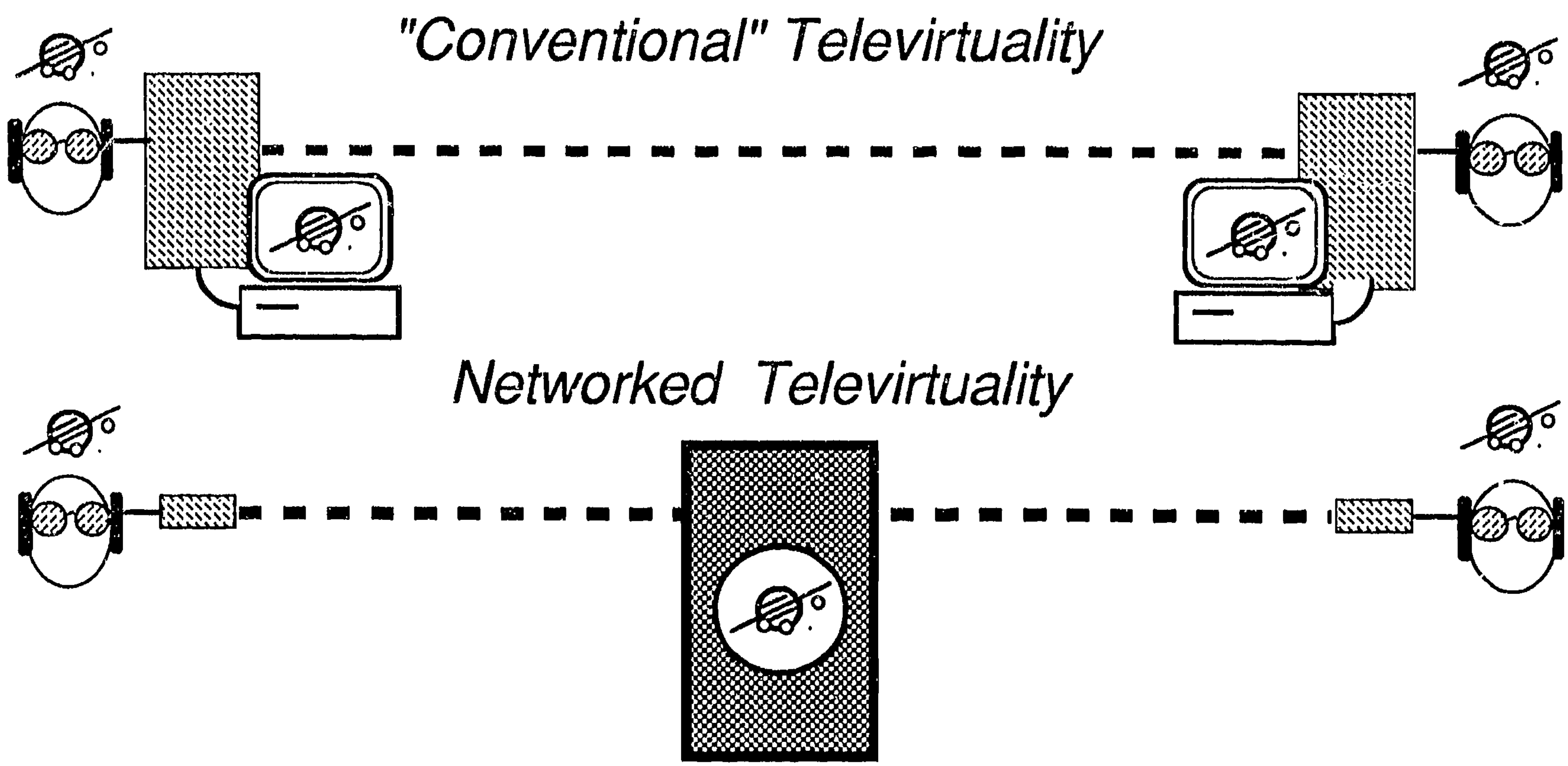
TELEVIRTUALITY

Televirtuality is the sharing of virtual worlds via the public telecommunications network and private communication networks. Still more a concept than an application, televirtuality in theory would make possible the distribution of computing requirements throughout a network. In the same way that networked computers completely transformed the tasking of jobs formerly run on stand-alone computers, televirtuality will transform the virtual worlds experience. For example, concurrent engineering conducted in "three-space" (three-dimensional space) will be much more efficient and effective if each engineer can tap into a shared model from a remote site. The same is true of other applications in the fields of medicine, education, the creative arts, industry, and science. Televirtuality is the key to making virtual worlds a useful technology in practical situations.

Proponents of televirtuality express two distinct visions of tomorrow's televirtual network. These exist at the extremes of a possible client-server continuum. At one extreme, the individual participants are responsible for nearly all of the processing requirements to create and maintain their respective virtual worlds. Each local site has a fairly massive system to do the processing of transmissions that include only the limited information necessary for each local machine to transform its virtual world in accordance with the others. The network only has to provide coordinating information, and thus can be rather simple in construction and of low capacity. VPL Research has proposed establishing a "Reality Net" along these lines. Each node on the net would require a full computing ensemble (costing approximately $100,000), but the bandwidth provided by the network itself could be as low as 9.6K baud.

At the other extreme of the client-server continuum, the local participant would require only a video-aural headset, some virtual-worlds tools, and a small computer to receive virtual-worlds transmissions from the network. The network would carry the full load of computation, including creating, maintaining, and storing the virtual worlds in use, as well as managing their distribution and the coordination of presentations at the individual sites. In this case, both the central computing machinery and the network would be high capacity (to say the least!). The data streams generated by the central computers would be immense and complex, on the order of many gigabits of data, and would have to be coordinated and

Figure 2. Conventional vs. Networked Televirtuality



distributed among thousands or even millions of simultaneous televirtual "conversations."

The actual implementation of televirtual systems will probably fall somewhere between these two extremes, with the network contributing a good deal but not all of the required computational power; and the local site doing the rest. This means that local technology, for its part, must also be capable of noteworthy computational feats. Fortunately, the descending price/performance ratio for computer and I/O equipment suggests that eventually even a modest local investment in technology will produce adequate virtual worlds. At a slightly higher level of investment, local area televirtual networks (LATNs) spanning an office, an industrial park, or a metropolitan area (a MATN?) would support the internal virtual-communication needs of private and public enterprises.

How might such a system work? In the central office (CO) of a telephone company or another telecommunications provider (a cable television or cellular phone company), large computer systems (COCs) would maintain libraries of virtual worlds on CD-ROM or other storage media. These worlds could be as mundane as your or my office or living room (or wherever we like to chat with business acquaintances and friends), or as elaborate as an urban scene in another place or time; a complex physical process interpreted in multimedia form; or a fantasy world constructed to enhance metaphysical insights. These large computers would also be capable of storing customized worlds built as a consequence of communications for specific purposes (like that of an individual patient's heart muscle, constructed from EKG readings, computer tomographs, and surgical procedures). In a variant of this scenario, the CO switch accesses third-party computers linked to the network but not operated by the telecommunications vendor. These scenarios are not mutually exclusive.

On receiving a call signal from the party desirous of entering a virtual world, the CO computer (COC) (for convenience we use the telephone model) activates a high bandwidth channel between it and the calling party. Coordinating signals are transmitted between the calling party's virtual worlds set and the COC. Various channels are used to conduct communications between the COC and the local site equipment, to maintain order among the various components of the virtual world: the basic model and its objects, the I/O actions by the participants at the site, and the participants' in-world representations as they move about in the virtual world. The COC (or third-party surrogates) does not actually render virtual worlds; this is done by the calling parties' local technology or intermediate computing machinery that is distributed throughout the network.

(The ability of currently available telephone technology to set up and maintain virtual circuits suggests that the problems that might be associated with running high bandwidth communications via packet switching technology can be avoided to a large degree and perhaps entirely.)

A party at one site might also call up a party at another site, to share or construct a virtual world together The COC would then assist in the coordination not only of the participants at one site, but multiple participants at multiple sites. The computational load for this sort of magic is very high and will require thoughtful solutions for distributing the burden among hierarchies of sites. In theory, this is no different from today's network management; in practice, it could be quite tricky. But the value of communications networks would be greatly enhanced -- even, one might say, revolutionized -- by televirtual capabilities -- and thus worth the investment.

At the local level, these procedures might be mirrored (in more immediate fashion) by a genuine client-server system. However, given the likelihood of that virtual worlds to be called upon within a single organization will be many fewer than those required by a universal population of participants, local storage requirements may be limited. Also, local equipment may be customized to optimize for certain types of televirtuality-aided activities (surgery, librarianship, teleconferences, and so forth). Nevertheless, even the reduced requirements of these localized activities may put a considerable load on site-specific equipment. However, as there are no operating sites where these empirical questions might be tested, they remain unanswered.

APPLICATIONS OF TELEVIRTUALITY

When we think of teleconferencing, we commonly envision two groups awkwardly posed before television cameras, each seeing a two-dimensional raster version of the other. Televirtual systems, on the other hand, will permit real teleconferences, with the "look and feel" of a physical conference. This remarkable qualitative difference between conventional media of communication and the televirtual medium will be consistent across all application domains.

Devising applications for VWT and televirtuality is one of the most pleasant pastimes among today's adherents to the technology, and one of the easiest. Nearly everyone who enters a virtual world exits with applications on his or her mind. But we can briefly mention some applications in passing:

- The virtual classroom
- Database navigation and access
- Virtual travel/entertainment
- Marketing presentations
- Enterprisewide visualization
- Medical care and consultation
- Virtual design and prototyping
- Cross-cultural communication
- Virtual mobility (for disabled)
- Virtual museum/art gallery

These applications will develop over time as VWT becomes more widely diffused, beyond the computer and telecommunications sectors. The industry is now only in its infancy. For the moment, those researching and developing VWT are also responsible for inventing and marketing applications. This situation will change rapidly as VWT matures and cheapens and larger organizations begin to sell OEM equipment and services. Already, Alias Research, Inc., of Toronto, Canada, a maker of world-class CAD software, is abetting diverse applications of this technology by building alliances with the Banff Art Center and similar non-industrial development sites.

Evangelism on the part of VWT developers is gradually winning converts to the virtual worlds paradigm: *that human intelligence (not artificial intelligence) should be enhanced by computers that communicate the way we communicate.* Personal exposure to VWT subjectively reinforces the power of this paradigm. As more executives in both the private and public sectors gain such exposure, calls for the implementation of VWT will grow in number and strength.

ECONOMIC ISSUES

Despite an anticipated call for more and better VWT applications, presaged by widespread press interest in VWT, presently there is no assured source of funding for the development of this technology. The U.S. federal government has invested heavily in "conventional" HDTV technology and apparently has few funds available for development of novel communications media like VWT. Even the slight military VWT R&D that began in the 1970s and continued into the 1980s has been curtailed in favor of other projects.

The private sector, too, is strapped for capital in the face of a recession whose full dimensions are not yet known. The "boom" years of the 1980s, which resulted in incredible debt loads throughout the American economy, were unkind to basic scientific and engineering research. Not only is there little capital available for new research, but the R&D infrastructure is riddled and broken down. New VWT laboratories have to be built literally from scratch, while financial support is very sparse. All told, the few VWT research laboratories in North America might have a combined annual budget of $1-5 million.

Overseas, particularly in Japan, the situation is not yet so bleak. Japanese VWT is exceptionally well-developed; several laboratories are working in this area, more or less collaboratively. The largest Japanese firms have joined in this effort under the auspices of the Japanese Technology Transfer Association (JTTAS), described above. There are some variants on traditional VWT that are peculiarly Japanese: for example, the substitution as a positional technology of three video cameras, viewing the participant in three axes, for the Polhemus sensors more commonly used in North America. While the Japanese have not yet made outstanding VWT breakthroughs, their work is competent and state-of-the-art -- and funded to the tune of at least $40 million per year. Nevertheless, while this support is considerably greater than that enjoyed by their North American colleagues, the Japanese researchers are hardly central to their organizations' research efforts. In at least one case, a major Japanese project was almost shut down when it did not meet the firm's executives' premature expectations for its performance.

Building a global industry is thus a major challenge for those who want VWT to advance. The synergy of simultaneous economic investments by many buyers and sellers, in several sectors, can contribute to the extensive spread of VWT. The future of the research laboratories may still be precarious, at least for awhile. But while a proliferation of R&D activities is probably unavoidable ("reinventing the wheel" being a popular preoccupation in some corporate circles), once the technology's promise is more widely recognized, more funds will flow to the research labs. This will be important for the intensive development of the technology, to push it to new levels of performance. Also, the R&D labs can assist in coordinating, more or less, the joint efforts of different players in the field who might otherwise duel to a competitive standoff.

Televirtuality will require substantial investments in high capacity fiber, switches, rendering computers embedded in the telecommunications network, and large computers for the storage of virtual worlds. Presumably, telecommunications vendors will pay for these enhancements to the network and roll their costs into the rates they charge customers for televirtuality service. The speed with wnich these investments will be made is the great unknown plaguing prognostications regarding all new telecommunications services, not just televirtuality. But alone among these new services, televirtuality offers applications useful to all categories of customers. A televirtuality-capable network could radically reduce the cost of individual televirtual uses. Televirtuality is the integrative technology that could tie together national and international telecommunications networks with a common standard applicable across the board to voice, video, and data transmissions.

POLICY ISSUES

Several policy issues must be resolved to hasten the development and availability of televirtuality via the network.

The first of these policy issues is how technology investments are made by corporations, and under what conditions. It is a matter of faith among large corporations that more liberal treatment of capital gains tax together with incentives for financial adventurism will promote investment in new technologies like VWT and televirtuality. This may be the case, but a more profound deterrent to corporate investment in these technologies may be the corporate culture of fear and second-opinionism that plagues managers in the post-1980s. Our experience at the HIT Lab has been that managers are very open to the idea of investing in VWT once others have braved the path and shown that there is competitive value here. Of course, by that time, the opportunity for competitive advantage has been lost to the late investors; but at least no one can call them down for unbecoming fiscal bravado. Nevertheless, a good case can be made for some government-supplied financial incentives *if* those who benefit by this public largesse can amply demonstrate that they are willing to take necessary chances. At the very least, providing these incentives would deprive sheepish executives of a convenient excuse behind which they have hidden for too long.

A second policy issue requiring resolution is how standards and protocols are to be selected and adhered to. Perhaps it is too early to expect today's turbulent technological waters to calm themselves and become and conducive to collaboration. On *sci.virtual-worlds,* the USENET newsgroup that I moderate, there are regular reports of new VWT systems devised using everything from proprietary minicomputer-engines to Amiga PCs. The separate VWT laboratories established by

Digital Equipment, Sun, and Hewlett-Packard in the U.S.; and by Fujitsu, Matsushita, and NTT in Japan do not widely share information about their respective projects, nationally or internationally. For awhile at least, there will be constant change. But this tendency undermines the long-term goal of a stable technological base on which new applications (including televirtuality) can be built. For now, there are no standard-setting bodies in this field; there isn't even a dedicated professional organization where VWT researchers and developers can productively schmooze. (Most do so, when they can, under the auspices of SIGCHI and SIGGRAPH in the ACM.) The first professional journal in the field, *Presence: The Journal of Teleoperators and Virtual Environments,* published by the MIT Press, will first appear in Summer 1991. The HIT Lab, through its Virtual Worlds Consortium support group and through the sci.virtual-worlds online newsgroup, is attempting to create a "safe haven" where coordinative discussions can take place. But the outcome of these efforts is far from certain; and uncertainty is a damper on planning for televirtual applications.

Finally, we must consider our national and international policies regarding the public telecommunications network. Many have applauded this "information highway" as the blacktop to national prosperity. In Japan, construction of a national fiber-optic network is already underway, for precisely the purposes advocated by proponents of televirtuality and other new information services. In Europe, a similar network has been proposed, although it must first survive The Torture of a Dozen PTTs as it races the gauntlet of wildly different national telecommunications policies. In the U.S., no such grand plan is in evidence. IBM and its affiliates are busily rebuilding the NSFnet according to their own image (i.e., large users get served first, smaller users may have to find their own way). AT&T and MCI, in a deadly competition that could mean the survival or demise of the smaller challenger, are stringing very high capacity fiber on prime traffic routes. But the notion of universal broadband service seems alien to U.S. policymakers, an ironic comment on a nation that prides itself as the home of economic and cultural opportunity for all. Until this selfproclaimed mandate is taken seriously, it is difficult to predict just how and where televirtuality will eventually unwind -- and whom it will serve.

Short-sighted policies, within and among organizations, and in the domestic and global communities, do not match the vision of universally available televirtuality or the televirtual promise of improved human-computer and human-human communications. Perhaps, if enough policymaker are exposed to the medium, they may come away with an appreciation for the communicative commonweal that restrictive policies deny.

CONCLUSION

Within the decade, the telephone and the computer terminal, two inventions which have seen better days, will begin to disappear. The network technology that today supports these primitive communication devices may instead offer a new medium, televirtuality, that will alter forever the ways that humans communicate among themselves and with computers.

Still, many questions about this new technology -- technical, economic, and political -- remain to be answered. The networking community has the largest possible stake in how these questions are framed and answered.

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