Pushing the Envelope

Push engineering, science, or mathematics far enough and you get art. At its edges, physics is indistinguishable from poetry. Chaos and fractals have given artists new eyes, and graphical computer simulations can induce a kind of reverence normally reserved for the natural world.

At a conference called "Inner Reality and Outer Space" sponsored by the Jung Institute in San Francisco several years ago, former astronaut Rusty Schweickart told a wonderful story. He was outside the spacecraft, the first astronaut in space without a tether—nothing but a backpack to supply air. His goal was to determine whether a person could move hand-over-hand over the surface of the capsule to reenter it, and astronaut Dave Scott was to take pictures of him from inside. The camera jammed, and commander Jim McDivott gave Scott five minutes to try to fix it. For that interval, Schweickart says, he became "the world's first unemployed astronaut." He swung out on one arm and regarded the Earth, and at that moment he realized that he had a choice. He asked himself, "Am I going to let it in?" He did, and his life changed.

Virtual reality (VR) is an extreme idea—human computer interaction taken beyond familiar limits. By positing that one may treat a computer-generated world as if it were real, VR contradicts the notion that one needs a special-purpose language to interact with computers. "Direct manipulation" becomes direct sensory encounter, and the pane is blown out of the interface window to reveal an open portal to the imagination. As one gazes through it, one may ask Rusty Schweickart's question.

From its strange childhood in military and government labs, VR has emerged as a Major Concept in the pop-culture scene. It has been hailed as the techno-wave of the future, with potential to transform every thing from movies to medical imaging. It has also been demonized as the latest in mind-control drugs and the world's baddest war machine. Philosophers have adopted it as a platform for renewed debates about the nature of reality, the evolution of global culture, and the relationship of technology to the body and the physical world. Nearly everyone agrees that a head-mounted display will give you a look inside Pandora's black box. The mythos of VR seems to be a key ingredient in the popculture view of how the world is changing—a many faceted icon for the coming weird times. Why?

In the book *Through the Vanishing Point,* Marshall McLuhan mused about how new technologies change our consciousness:

> Anything that raises the environment to high intensity, whether it be a storm in nature or violent change resulting from new technology, turns the environment into an object of attention. When it becomes an object of attention, it assumes the character of an antienvironment or an art object. [MCLUHAN AND PARKER, 1968]

Such antienvironments, McLuhan believes, "open the door of perception to people otherwise numbed in a non-perceivable situation." Shakespeare was barking up the same tree when he said that drama "holds the mirror up to nature." Media represent us to ourselves in a multidimensional way—beyond the content of any particular representation, the characteristics of the medium itself give us insight into the invisible cultural context. Whoever discovered the ocean, as the saying goes, it certainly wasn't a fish.

If McLuhan was right about antienvironments, the media-making impulse may be a built in species-level survival mechanism. It this sense, VR manifests humanity's need to encounter and transform the notion of control. No matter how you look at VR, the control issue is center stage. The public and the press are worried about mind control: Is VR addictive? Can it be used for brainwashing ? Can special interests, from secret police to commercial advertisers, alter our beliefs and desires with hypnotic potency? Will it be used as a way to deny and circumvent the blood-and-guts realities of war? Will it replace condoms, cosmetic surgery, and real, live lovers with electronic sex?

What we fear is the loss of control—over our minds, our society, our government, our bodies, and our sexuality. And with good reason. VR functions as an antienvironment that boosts our awareness of conditions that already exist in our culture, but to which we have become, if not completely numb, at least resigned and mute. VR may ultimately function to demonstrate that Control is a toxic philosophy in the contemporary world, not only in terms of culture and art, but also in terms of our relationships with individuals, societies,

and environments—and especially in terms of how we define and measure our own freedom and self esteem [LAUREL, 1992]

VR is also about control in the way that it challenges traditional views of human-computer interaction. Since the inception of the idea of intelligent machines in fiction and fantasy, the hope has been that computers would be the servants of humanity; the fear has been that they would be our masters. In the last decade, empowerment has become a leading buzzword—computers empower people to do things, make things, learn things, find information, and play games.

VR questions whether explicit choice-making through a formal interface language is empowering enough. In general terms, a traditional interface only allows people to do what a programmer has decided to let them do. Out of all the millions of things we might want to do in a representational world, interfaces only empower us to do a tiny subset. Our channel of communication with computers is a drop from the fire hose of human bandwidth. In the philosophy of VR, empowerment means enabling people to do whatever they think of. VR aspires to respond to our choices and actions with the robustness of the real world; it aims to let the whole body in where only bits have gone before.

Similarly, VR confronts the issue of control in the paradigm of authorship. Without predetermined sets of choices for users, it is impossible to preconstruct a "story," or even a set of alternative stories, that a user can experience. Some designers of interactive environments are beginning to work with a notion that replaces "user" with participant" and the author/consumer dichotomy with a model of collaborative co-creation. The collaborative model suggests that what is designed is a dynamic environment with predispositions and potentialities, and an essential element in the authorship of experience is a dynamic participant who changes the world by being in it.

Pushing the envelope" in VR involves both gineering expertise and artistic sensibili- While engineering provides the means accomplishing dazzling photorealism graphics and animation, art recognizes that ambiguity evokes imaginative participation. While engineering gives us the capability to create both visual and auditory representations with great fidelity and resolution, art examines how the senses combine to affect our experience. Engineers are often disgruntled by the inevitable invasion of artists as their technologies mature, and artists are often strident in their criticisms of the arcane tools at their disposal.

But forced marriages sometimes turn out well. As Paul Heckel observed about the history of film, "Movies did not flourish until the engineers lost control to artists—or more precisely, to the communications craftsmen" [HECKEL, 1982]. It is important to remember that engineering and art are different sensibilities which may exist in the same person. You will note that I have cleverly avoided providing definitions for either one. You might say that engineering focuses on functionality while art focuses on experience, and beauty is the common ground. The rest of this article describes some of the ways that workers in VR have arrived at a "fusion" approach, with examples of people and works that demonstrate the power of art and engineering in partnership.

VR functions as an antienvironment that boosts our awareness of conditions that already exist in our culture, but to which we have become, if not completely numb, at least resigned and mute.

Crossover People

Many prominent VR innovators share the characteristic of a multidisciplinary background. In some cases, people have consciously constructed educational programs for themselves that combine art, technology, and humanities. Others have backed into a fusion approach through discoveries and conversion experiences as they pursued their work in art or engineering.

Michael Naimark is a self-styled crossover person. Long before the hype, long before people started claiming they invented the term "virtual reality," Mike was working on virtual world-making in ways that the VR incrowd today would call unconventional. He earned his B.S. in Cybernetic Systems (a home-brewed major) at the University of Michigan in 1974, rubbed elbows with folks like Marshall McLuhan, then went on to get an M.S. in Visual Studies and Environmental Art at M.I.T. in 1979. This makes him an old-timer by anybody's standards (except, perhaps, Ted Nelson's). In fact, he's one of the few people who says he or she worked on the famous Aspen disc who actually did.

Beginning with Aspen, Mike has been a principal designer of literally every significant work in a field called moviemapping (sometimes referred to as surrogate travel). The idea is to use film or video to create a three-dimensional representation of a real place that can be explored in a relatively unconstrained way. Going out of the studio to record with the intention of interactive end-use is what Mike describes as a "lateral approach" to 3D modeling. Mike has moviemapped San Francisco from the air, Paris from the sidewalk, and Karlsruhe, Germany, from the tram. One of his next projects, on which I am lucky enough to be a collaborator, will let people "walk" through natural environments and see them in 3D.

Similarly, Naimark has investigated spatial correspondence between representations and real-world objects, the concept behind both head-tracking and texture-mapping in VR, through the vehicle of novel projection environments. For example, in "Displacements," an installation at the San Francisco Museum of Modern Art in 1984, he assembled a typical American living room (complete with bric-a-brac) and filmed it with a camera mounted on a turntable. Then he sprayed the entire room white, mounted the projector on the same turntable, and re-projected the room onto itself using the actual objects as projection surfaces. Mike and his students from the San Francisco Art Institute combined relief projection with live performance in an installation called EAT, shown at the Tomorrow's Realities Gallery at SIGGRAPH '91 and at various venues in Europe.

Michael Naimark has been "straddling the fence" in a conscious way throughout his career. "I've always been spinning two plates on two poles —one is art the other is media tech-—and the intention has always been to do a 50/50 number. When I find myself going toward one I consciously head back toward the other." Mike is also making technical contributions in capturing and employing camera-originated imagery to build 3D computer models. His Field Recording Study for Virtual Environments has been funded by the Banff Center for the Arts for the summer of 1993. When "hybrid VR" arrives, Michael Naimark will know exactly what to do with it.

Mark Bolas, founder and president of Fake Space Labs, also designed a multi-disciplinary education for himself. With an undergraduate degree in Physics, Mark learned to program in the Computer Music program at the University of California at San Diego. He earned his Master's degree in the Stanford Design Program, a joint program between art and engineering formed in the Sixties with an emphasis on product design. In addition to running his own company, Mark is currently a lecturer in the Stanford Design Program.

Bolas has designed some of the earliest examples of crossover work in VR, great engineering driven by artistic motivations. Several works in 1988, produced under the auspices of the Stanford Design Program in collaboration with the NASA Virtual Environment Workstation (VIEW) Lab, investigated what one might describe as artistic issues. "During my master's year," Bolas says, "I tried to implement an idea or design in a virtual environment every week. My goal was to experientially find out what works, what pulls a person further into the illusion, and what doesn't. Once I found phenomena and techniques that worked, I exploited them in more complex scenarios."

"Flatlands" and "Enter" are works that explore tricks of perspective. In "Flatlands," you find yourself standing in front of a simplified version of a Mondrian painting. You discover when you move toward this apparent painting that it is actually a three-dimensional array of lines that recedes behind the frame. When you fly above the painting, you can see the lines like a swarm of elongated bees. Bolas has somewhat perversely transformed Mondrian's "flatland" into a 3D composition. "Enter" employs the same trick, this time surrounding you with doors labeled "ENTER." When you approach, the doors deconstruct themselves in the same way. From this work came the VR notion of a "G-spot": a point in 3-space where some Graphic becomes recognizable.

With Phil Stone, Bolas also built a virtual theremin (itself a pretty virtual instrument). Gestures and contacts with the theremin produce different frequencies and series of tones and simulate various musical instruments via a sound synthesizer. Also in 1988, Bolas built "Touchface," an exercise in synesthesia intended to help participants transition from "here" (the real world) to "there" (the virtual environment). Bolas describes it this way: "The scenario requires a user to reach out and touch a person's face a real person standing still in front of the user. The user cannot, of course, see the person standing there. When the user touches the person's face, a drum beat is heard, and a small shaded polygon is placed at the fingertip of the user. After touching the person's face for a while, a virtual representation of that face begins to form in front of the user. This is a Tactile to Sound to Sight transformation experience.

Creon Levit is an example of a designer who "backed into" an artistic approach through an engineering project. (Named after a character in the earliest Greek tragedy, Creon may have been destined to do artistic work whether he intended to or not.) At the Numerical Aerodynamic Simulation Facility at the NASA Ames Research Center, he was a principal designer of the "Virtual Windtunnel" exhibited at the SIGGRAPH '91 Tomorrow's Realities Gallery. In 1991 he was trying to make a benchmark program that would create an exact number of polygons, lines, and points in order to measure the performance of graphics systems. Specifically, he was exploring the rendering throughput of Silicon Graphics machines in different configurations. "Tapeworld," also shown at SIGGRAPH '91, was originally displayed on a workstation screen. "You'd say, 'give me 50,000 polygons,'" Levit explains, "and it would distribute them in these weird curly ribbons in a quasi-random way." The results were "so beautiful to look at" that he moved them into a VR environment.

William Bricken's Ph.D. is in Education. He also has an extensive background in philosophy, psychology, computer science, and mathematics. His work in boundary mathematics is playing a key role in the development of VEOS, the Virtual Environment Authoring System, at the Human Interface Technology Laboratory (HITL) associated with the University of Washington in Seattle. I met William when we worked together at the Atari Systems Research Laboratory in 1982-83. In those days, his talk about boundary math—always delivered with a cosmic glint in his eye—seemed like visionary ravings. Now, William has the beatific look of someone whose dreams are coming perpetually true.

When I asked him to tell me about VR art projects at HITL, William responded with some questions: "So, what is art in VR? Is it a world built by an artist? Is it specifically non-functional worlds? Is art narrowly defined as painting-like (so no inclusive work is art), or has art graduated to experiential (so whatever you do is art)? Is art an attitude?" Yes, William. "The 3D sound stuff at NASA is art. Myron [Krueger's] work is art. The code in the VEOS is art—that is, some coding style considerations are motivated by aesthetics."

William believes that art in VR is inexorably bound up with a capacity for achieving beauty that is embedded in the tools. He cites the example of VSX, a virtual airplane model demonstrated by HITL at the Tomorrow's Realities Gallery. In the original implementation language, Bricken says, the model was "colorful, enticing, comprehensible." Then they ported the same model to a different implementation environment. The ported version was "a green blob, frustrating, nondescript, meshy." He concludes, "The difference between the two models is art." William's

many-faceted contributions to VR—philosophical, mathematical, and aesthetic—will, I believe, have a profound influence on the field for a long time.

Ann Lasko-Harvill works at VPL Research, the world's first VR company. Her work provides more strong examples of the value of a multidisciplinary background. After receiving her undergraduate degree in fine arts from the University of California at Santa Cruz, she ran a print studio and taught art for eight years at Evergreen State College in Washington state. She also worked as a rehabilitation engineer, designing things like seating for wheelchairs and new, improved skis for her boss, a paraplegic who was a world champion mono-skier. Ann moved to California when her husband came to get his MFA at Stanford, and after getting bored out of her mind "hanging around married student housing," she decided to get a Master's degree in the Stanford Design Program. Because of her anthropometric background, VPL hired her to design the DataSuit in 1987. Ann isn't a programmer by trade; she took some programming classes at Stanford but ended up working exclusively in Body Electric, a high-level VR programming language from VPL, which she learned as the language was being written.

One of the things that Ann has found herself doing at VPL is designing characters—both autonomous entities and virtual bodies that can be inhabited by real participants. Her first "electronic puppet" was the infamous VPL lobster. People seemed drawn to it, and seemed to have fun exploring "what a lobster is, or what they think lobsterness might be." She also designed an angel, but discovered that few people were interested in putting it on. Her background in art has led her to make some interesting connections between virtual identities and the world of masks and costumes. "The self we design for pleasure, play, and social interaction" she writes, "can be very different from the ghly constrained one determined by role r task... Everyone could invent a whole ast of characters, representing the range from the utterly private to various forms of the public self." She adds that "Self-disclosure is not always synonymous with authenticity" [LASKO-HARVILL, 1992].

Ann's most complex autonomous character arose from a collaboration with film and television director Alex Singer. The Sprite is a trickster character with an ambivalent personality, a mischief maker who leads you into trouble and then helps you get out of it. Singer designed the character's inner traits and behavior, and Ann focused on the character's visual appearance and movement characteristics. For Ann, the ability to support such collaborations is a key criterion that must be met by any VR authoring environment. She proclaims: "Virtual reality is an art form. It is and should be a creative medium... In order for the virtual reality artist to function as an agent for change, the technology must be accessible." Ann should know since she's devoted much of her life to providing access for people with differing abilities.

> ...in the absence of tools for non-programmers, the best solution may be what we call "strapping an artist to a programmer..."

Access to Tools

I asked Mark Bolas how the evolution of VR compared to the histories of other relat ed fields that utilized computers. He was struck by similarities with computer music. Many of the pioneers in computer music took it upon themselves to learn the language of computing and construct their own tools. But as Mark points out, many of the musicians who began grappling with signal processing found (to their chagrin) that the process had blown a decade-wide hole in their lives as composers and performers.

There are two lessons here. The first is that, in the absence of tools for non-programmers, the best solution may be what we call "strapping an artist to a programmer"—that is, forming art/engineering partnerships where both people can learn, produce interesting works together, and evolve the medium. The second is that first and second-generation tools will necessarily differ. In the first, the emphasis must be on facilitating skills transfer from the existing medium (in the case of VR, animation, theatrical improvisation, puppetry, or architectural design are examples) to the new. As with computer music, second-generation artists are much more like those kids in Marin who know how to swim because Mom threw them in the pool when they were babies. They are so intimately conversant with the new medium that they have absorbed the original contradictions.

Acting in Virtual Worlds

SimGraphics, a VR company in South Pasadena, California, can boast of significant technological innovations that have been developed through collaboration with artists. The company has transformed itself from a provider of engineering and defense applications to a major player in the Hollywood scene. Through the efforts of a number of people, including Steve Tice and Mike Fusco, SimGraphics began developing virtual-world design tools and capabilities more than four years ago. A collaboration with Chris Walker of Mr. Film led to the implementation of dramatic new tools for real-time character animation. The Performance Animation System, introduced in 1991, was showcased in the Tomorrow's Realities Gallery with "Susie Surfer," a user-controlled gleaming silver female body riding a surfboard.

In response to actors' requests for a hands-free interface, the Performance Animation System has been augmented with Waldo, a "facial armature" that consists of an array of pads that are medically glued to different parts of an actor's face. Through Waldo and a combination of joystick and foot pedals, actors can control eyes, mustaches, sound effects, gross physical movement, whatever they want. SimGraphics is developing applications for their system in live stage shows, film, and

television. It is likely that their techniques will revolutionize the production of animation by making it cheaper, faster, and more expressive. The system will be demonstrated in a live multimedia stage show at SIGGRAPH '93.

Both Lasko-Harvill and the designers at SimGraphics are making use of a fundamental truth about dramatic character: traits can be few and sparsely drawn because human enactment and human perception are so good at filling in the gaps. The trick to good characterization, as playwrights know, is to do a good job of matching semiotic traits (the traits we perceive) with actionable traits (the traits we infer from observing a character's behavior). The right match produces a wealth of information and hypotheses in the minds of an audience for two reasons: one, we have a few millennia of experience with theatrical representations; and two, because it's a skill we use every day in getting acquainted with new people [LAUREL, 1991]

VR Down Under

At the Royal Melbourne Institute of Technology (RMIT) in Australia, Michael Gigante's Advanced Computer Graphics Centre supports an amazing collection of artistic endeavors. There are some fairly normal collaborations—a virtual sculpting environment that's been worked up by a sculptor strapped to a programmer, for instance. There are projects that are breathtaking in scope and concept for example, an 8,000 cubic meter white-light hologram. Holographic artist Paula Dawson explains that the work, entitled "You Are Here," will depict sea-level changes over the past 2.5 million years, and will be illuminated by the light of the full moon on a beach in Northern Queensland, Australia [JEPSEN AND DAWSON, 1991]

Then there is the downright bizarre—performance artist Stelarc's Virtual Arm project, which adds a third arm and one or more additional hands or fingers to the body of the performer. Stelarc is interested in "how normal performance parameters can be extended by a Virtual Arm and how the body can be visually augmented by such images and choreographed by biosensors." This is not strange to a man whose performances have included suspending his body from the ceiling of a gallery on hooks through his skin, and it is also not bizarre to Michael Gigante, the director of the lab, who both appreciates the work as art and sees enormous practical potential in it. Gigante believes that the Virtual Arm could be useful for teleoperations on manipulators in remote locations, and that it can be seen as sophisticated human-like extended manipulators for handling objects in a virtual task environment. He and his technically oriented colleagues have filled several complex technical papers with new information and theories derived from this project.

Gigante founded the lab in 1988. Of his motivations, he says:

> I was a regular SIGGRAPH attendee, and like many others, I dreamed of producing wonderful animations or beautiful pieces of computer graphics art. Unfortunately for me, this desire was not accompanied by much in the way of artistic talent. I had some ideas I would love to explore and knew that I could provide technical skills to complement someone with artistic talent, but that I could not do it on my own. It was clear that there was a real synergy possible, that many of the artists I spoke to needed someone with technical skills, and just as important technical facilities to make their ideas possible.

Gigante managed to convince RMIT to create a multi-disciplinary computer graphics center by garnering the support of the Associate Director of RMIT, who in turn persuaded the faculties of Art, Science, and Engineering to throw their computer budgets into the kitty. With the help of computer graphics artist Paul Brown, Gigante managed to keep the center alive through an extremely lean year until a large government grant came through. Holographer Paula Dawson helped him design an art program in which each artist had a "buddy" from the research staff. Initially, Gigante had difficulty gaining the trust of some of the artists, but in the end, he says, a key group of artists "were so enthusiastic that it propelled the program faster than I would have believed possible." Indisputably the leading lab of its kind in Australia and one of the best in the world, the Advanced Computer Graphics Centre will not be complete, Gigante says, until artists can be supported by in-residence programs or generous fellowships.

Australia seems to have more than its share of artists working in new media, including VR. Jon McCormack of Melbourne produced a work entitled "Four Imaginary Walls" which was exhibited in 1991 in Australia's largest show of contemporary art, *Perspecta*. McCormack's virtual world is animated by data supplied from a digital meteorology station outside the gallery space. Wind speed and direction, temperature, and light conditions are monitored and transformed into sound and image. Tim Gruchy in Brisbane is working on a third person, video-based system (similar to Vivid Effects) for interactive sculpture and performance events. I am waiting eagerly for the day that aboriginal artists bring the notion of Dreaming to a medium that seems to have been made for it.

Mecca in the Mountains

The Banff Centre for the Arts in Alberta, Canada, has sustained a reputation for supporting excellent experimental work in the arts for many years. Under the direction of Douglas MacLeod, the Art and Virtual Environments Project supports artists working in the VR medium with access to an impressive array of equipment, a staff of technical experts, and a chance to reside in one of Canada's most breathtaking landscapes. MacLeod's fundamental goal is access for artists:

> Virtual technologies represent a new and hotly contested site for artistic exploration. Just as it is important for artists to open themselves up to technology, it is also paramount for artists to have access to equipment. More than any other group, their explorations, investigations, and debates have the potential to expand our relationship to both technology and the world.

The program was inaugurated in 1991 with the Bioapparatus project, directed by Catherine Richards and Nell Tenhaaf, focusing on explorations of "the technologized body and the new biology." Among the works produced was a piece by Ottawa-based artist Robert McFadden entitled "Picture Yourself in Fiction," combining scanned imagery of the artist's body with digitized samples of his poetry. Another piece, entitled "Inherent Vision, Inherent Rights," was developed by Lawrence Pau a native Canadian of the Salish tribe. Pau created a spirit lodge environment inhabited by figures derived from his paintings

and incorporating smoke, fire, and environmental sounds. This fall, Paul's piece will be part of an exhibition entitled "Land, Spirit, and Power" at the National Gallery of Canada in Ottawa—the first VR art work to be exhibited at the Gallery.

Outreach at the HIT-Lab

Similarly, the Human Interface Technology Laboratory in Seattle has been providing access to VR for young people. Until spring of 1992, Meredith Bricken served as director of the education program at HITL. In the summer of 1991 she arranged a collaboration with the Technology Academy, a technology oriented summer day camp for students from ages five through eighteen. In cooperation with HITL researchers and sponsors, students were given the option to explore VR for the first time in 1991. A total of fifty nine students, aged ten through fifteen, participated, in weekly groups of ten, over the course of the summer. VPL provided a costfree site license for the Macintosh modelling software package Swivel 3-D, the Technology Academy supplied Mac IIs, and HITL furnished a "protoworld" implemented in Swivel for the students to explore and customize. Seven new worlds were created by the students, ranging from a moon colony to a neighborhood with houses to a medieval space station" [BRICKEN AND BYRNE, 1992].

n the course of their work, the students mastered a variety of computer graphics concepts and techniques, VR concepts ike the idea of "presence"), 3D modeling techniques, and methods of data organization. The students filled out opinion surveys that predictably revealed an extremely high level of enthusiasm for VR. Not so predictable was their preference [76%] for experiencing worlds that they ad built themselves as opposed to worlds that had already been built. Meredith concudes, "Most important was the demonstration of the students' desire and ability o use VR constructively to build expresons of their knowledge and imagination. s our preliminary conclusion from this udy that VR is a significantly compelling reative environment in which to teach and learn."

Another project supported by HITL was a VR piece called Angels, designed by Nicole Stenger. HITL provided technical support and access to tools. Stenger refers to the outcome as "my first real-time movie," the culmination of a ten-year quest. Her work was driven by an interest in textures: "I started my journey through tactility using textured glass in the late Seventies, then maintained this artistic necessity throughout my computer work. In VR I hope to eventually bring the pleasure of touch to users, and when tactile systems.. are integrated, have the participants feel the folds of the Angels' sleeves." In supporting work like Stenger's and the Technology Academy project, HITL demonstrates the insight that the creative impulse is an excellent guide in the development of technology and tools.

Moving into the Future

The people mentioned in this article are certainly not VR's only artistic pioneers. The works of Myron Krueger, Vincent John Vincent, and Ed Tannenbaum in the domain of immersive second-person environments, to name some examples, have contributed enormously to our understanding of how people experience and express themselves in virtual worlds. Their works have been guided by the belief, shared by Michael Naimark, that an immersive environment need not be worn on one's head.

Today, thanks to the pioneering efforts of many engineers and artists and aggressively enlightened programs like those at RMIT, HITL, and Banff, more artists—and more renowned artists, like Jenny Holzer and Shalom Gorewitz—are exploring VR as a medium. Several new works have been funded at Banff in the summers of 1992 and 1993. Doug Macleod describes the new crop of projects:

Each of these works is uniquely different. Will Bauer's "Objects of Ritual" will use his gesture and media system to create multidimensional "hyper-objects" through human gestures. "Virtual Coyote" by Rachel Strickland and myself will explore new means of narrative action in interactive virtual environments. Michael Naimark's "Field Recording Studies" proposes to study the notion of "place" by creating three-dimensional computer models of the physical world... And in Michael Scroggins' "Topological Slide" viewers will be invited to slide over four-dimensional objects. [MACLEOD, 1992]

Other upcoming Banff projects include Perry Hoberman's "Virtual Hat;" "Dancing with the Virtual Dervish" by Diane Gromala, Marcos Novak, and Yacov Sharir; "Virtual Reality on Five Dollars a Day" by Ron Kuivila; and, a piece by Toni Dove and Michael Mackenzie.

"Breaking the Art Barrier" took the better part of a decade in computer graphics. Thanks in part to the persistence and success of CG pioneers, the transition seems to be happening much more quickly in VR. My hopes for VR, as well as for the future of human-computer interaction, are founded on the quick and strong response of artists and of the artistic impulse in engineers. Whatever else the world may make of VR, the work on the artistic frontier assures that it can be used to empower the imagination and to nourish the spirit.

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