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VEY

The serious artist
is the only person
able to encounter
technology with
impunity, just
because he is an
expert aware of
the changes in
sense perception.

The Industrial Revolution that began in the late 1700s was fuelled primarily by steam engines physically connected to the machine being powered. This was practical only for large devices with adequate ventilation, such as locomotives and mills. Although battery-powered telegraphy emerged in the 1830s, another fifty years passed before the first local telephone exchange was established. As municipal utilities emerged in the 1880s to generate and deliver AC power, the stage was set for the proliferation and use of electrical appliances by the general public.

Following the popularity of electric lighting and telephony in urban centres in the late nineteenth century, the first electronic household items, such as vacuum cleaners,

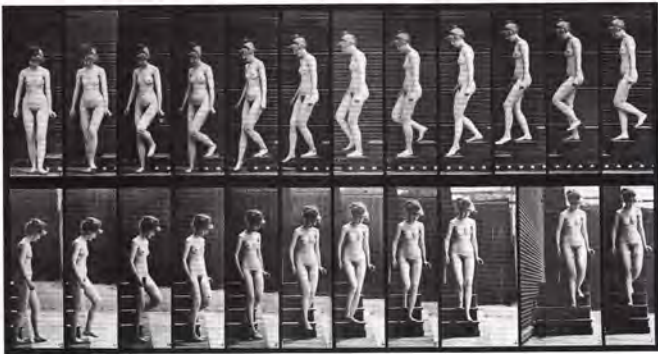
washing machines and refrigerators, came to market in the 1910s. The market for radios exploded in the 1920s together with the growth of commercial broadcasting. Technologies that were developed during the lean years of the Second World War precipitated another outpour of electronic consumer goods during the prosperity of peacetime. Television became wildly successful in the 1950s, while the 1960s and 1970s brought hi-fi stereo sound-systems, video cameras, remote controls, cable television and satellite telecasts. In the 1980s and 1990s, the advent of personal computing, public access to the Internet and the multimedia capabilities of the World Wide Web, along with broadband Internet and cellular mobile phones, sparked the E-commerce boom and fuelled globalization, flooding world markets with an unprecedented deluge of consumer electronics.

This nutshell history only begins to scratch the surface of the wondrous and ingenious devices that have inspired artists to expand the ability to see the present and to envision and create the future. Indeed, artists use, re-purpose and invent electronic media in ways that delight the senses, baffle the mind and offer profound insights into the implications – both positive and negative – of techno culture. Although electricity has become so ubiquitous as to be mundane,

artists continue to discover its poetic significance, if not magic. In doing so, they simultaneously humanize and mythologize electronic media, transforming it through artistic alchemy to stretch the imagination, expand consciousness and inspire others to new levels of creativity and invention.

Motion, Duration, Illumination

Traditional visual art is static: it captures or represents a moment in time. Moreover, it typically depends on a light source for illumination. Electronic media facilitate the liberation of art from conventional stasis and provide a means for it to consist of light itself. Since the early twentieth century, artists have used neon, fluorescent, laser and other forms of electric light as bona fide artistic media, often in ways that incorporate motion and time. Paralleling the intrinsic temporality of music and cinema, artists increasingly have set art in motion in such a way that the work can only properly be perceived as a



durational experience. Indeed, the traditions of experimental music and film, along with the use of sound and moving images, have become increasingly incorporated into contemporary art practices,

particularly those involving electronic media.

Since the paleolithic cave paintings of deer hunts at Lascaux (c. 15,000 BC), artists have used static media to suggest and represent the vitality of entities in motion. Drawing on the physiological phenomenon known as persistence of vision, eighteenth and nineteenth century inventions such as zoetropes and kinetoscopes animated a sequence of drawings, enabling the viewer to perceive motion smoothly unfolding over time. Photographer Eadweard Muybridge, who experimented with such stroboscopic devices, accomplished the reverse in the 1870s through high-speed chronophotography. His stop-action techniques – like those of contemporaries, Etienne Jules Marey and Thomas Eakins – captured motion as a sequence of still images, metaphorically freezing time and enabling perception of micro-temporal instants beyond the capacity of the naked eye.

The Cinematographe, an integrated recording and projection device invented by Louis Lumière in the mid-1890s, enabled the registration and playback of moving images for

large audiences, laying the foundations for cinema. In the 1930s, Harold 'Doc' Edgerton synchronized a camera's shutter with a high-intensity electronic flash unit, which enabled significantly faster shutter speeds as in *Milk Drop Coronet* (1936). These technological developments, occurring in a broad range of artistic, scientific and commercial contexts, have widely influenced art in the twentieth and twenty-first centuries, including cubist and futurist painting and sculpture, kinetic art, performance, video and more contemporary time based media.

Metaphors from chronophotography and cinema were employed by philosophers Henri Bergson and Henry James to theorize vitality and duration with respect to human perception and consciousness. In particular, Bergson's *Matter and Memory* (1896) and *Creative Evolution* (1907) have been singularly influential philosophical texts among artists, specially many associated with Cubism and Futurism. Given dramatic increases in the speed of production, transportation



and the general flux of daily life, questions pertaining to the nature and perception of time, space, motion and light form a nexus at which the inquiries of art, science and philosophy have become increasingly interwound.

Rapid advances in computing, telecommunications, nanotechnology and genomic science hint at further conceptual shifts at this complex interdisciplinary crossroads.

Alongside the visual exploration of motion and time, artists have studied the way light falls on objects creating shadows, as well as the way light illuminates artworks in the particular settings where they are installed. The chiaroscuro technique of light and dark shading that reached maturity during the Renaissance emulates three-dimensionality on a two-dimensional plane by mimicking how light falls on solid objects. In *The Conversion of St. Paul on the Way to Damascus* (1601), Caravaggio depicts the instant of the saint's epiphany upon falling from his horse as if illuminated by a sudden burst of divine light. His technique, a high-contrast form of chiaroscuro known as *tenebroso*, achieves effects that bear an uncanny resemblance to Edgerton's high-speed flash photography. Bernini designed the *Ecstasy of St. Theresa* (1647–52) so that gilded bronze rays would shimmer in natural light that shines through a small window above the altar in the

Cornaro Chapel in Rome. Actual light thus becomes an integral part of the work, functioning as a protagonist in the dramatic scene.

A combination of technological and scientific developments in the nineteenth century resulted in new understandings of light and visual perception, provoking significant changes in art. Amidst the popularization of photography, many artists shifted focus from rendering likenesses of objects and the effects of light on them to capturing and giving visual form to the sensate experience of how light affects the human eye. Impressionist painting, for example, was bound up in contemporary views on the physiology and phenomenology of perception that emphasized the mediation of vision through the eyes and brain, suggesting an element of subjectivity. Combined with the faddish success of stereo-photography in the 1870s and 1880s, the popular understanding of vision shifted from a simple 1:1 correspondence between an object and its perception by the viewer to a conception of vision as the result of light reflecting off an object, entering each of the viewers' eyes from slightly different angles and being processed by their brains into a single, composite image that offered a sense of depth.¹ In this way, Impressionism, and later, Pointillism, demanded that viewers play an active role in the perception of art, a prevailing ethos of contemporary interactive art. Similarly, contemporary artists including Olafur Eliasson, Robert Irwin, Ulf Langheinrich and James Turrell have created work that examines the perceptual limits of the human visual system.

Despite this preoccupation with light and motion, it was not until around 1920 that artists made works that moved or that were sources of light. Such kinetic artworks extended the frame of art by breaking with two forms of stasis: spatial and temporal. Art no longer stood still in space or time. Freed of frame and pedestal, animated by electricity, it could move about in the space of the viewer or the environment, modulate between various states or take on a new identity that required four dimensions to envision and experience. Artists who seized upon electric light as an artistic medium similarly liberated art from its dependency on external light sources and made it the source of its own illumination.

Whereas cubist and futurist art theories sought to draw the viewer into an aesthetic experience that implied movement and time, around 1920 Thomas Wilfred, Marcel Duchamp,

Naum Gabo and László Moholy-Nagy began using electronic elements to make motion and duration explicit and essential characteristics of their work. Building on an enduring fascination with synaesthesia and light-organs, notably those of precursor Louis-Bertrand Castel in the eighteenth century, the first public demonstration of Wilfred's Clavilux in 1922 was performed using a keyboard that controlled six projectors and an array of reflectors, enabling the artist to modulate the movement, hue and intensity of light on the screen. Wilfred later created and sold individual Lumia cabinets, the visual equivalent of player-pianos, that displayed predetermined arrangements of coloured light that he composed, such as *Aspiration*, comprised of 397 variations with a total duration of 42 hours, 14 minutes and 11 seconds.² These devices anticipated the kinetic paintings of Abraham Palatnik and Frank Malina in the 1950s, light shows at rock concerts beginning in the 1960s and visualization software that transforms MP3 files into undulating patterns on PCs in the



2000s.
Gabo's
*Kinetic
Construction*
(1920)
produced a
virtual volume
only when

activated, thereby making motion a necessary feature of the art object and further emphasizing temporality. Indeed, the term 'kinetic' was first used in connection with visual art by Gabo and his brother Anton Pevsner in their *Realistic Manifesto* dating from the same year (Documents, 193). Duchamp's *Nude Descending a Staircase* (1912) and *Bicycle Wheel* (1913) anticipated subsequent research on the perception of actual motion in the 1920s. Powered by an electric motor, his *Rotary Glass Plates (Precision Optics)* (1920) incorporated a series of five painted glass plates mounted on a motorized shaft. Spinning at high speeds, it created the appearance of concentric circles on a single plane when viewed at a distance of one metre. The work thus required motion and time to produce this perceptual effect in the viewer. Electric motors in Moholy-Nagy's *Light-Space Modulator* (1923–30; Works, 55) set the shiny steel sculpture in motion while electrical illumination in the gallery reflected light off it and into its surroundings. The *Light Prop*, as it also is known, not only pushes the

temporal dimensions of art but expands its spatial dimensions into the entire environment, including the viewer, who becomes a surface onto which light is reflected. In *The New Vision* (1928), Moholy-Nagy advocated pushing art beyond static forms and introducing kinetic elements, 'in which the volume relationships are virtual ones, i.e., resulting mainly from the actual movement of the contours, rings, rods, and other objects.... To the three dimensions of volume, a fourth – movement – (in other words, *time* is added).'³ With respect to light, he noted that 'light – as time-spatial energy and its projection – is an outstanding aid in propelling kinetic sculpture and in attaining virtual volume.' He continued: *Ever since the introduction of the means of producing high-powered, intense artificial light, it has been one of the elemental factors in art creation, though it has not yet been elevated to its legitimate place... The reflectors and neon tubes of advertisements, the blinking letters of store fronts, the rotating colored electric bulbs, the broad strip of the electric news bulletin are elements of a new field of expression, which will probably not have to wait much longer for its creative artists.*⁴

Vladimir Tatlin's design for the *Monument to the Third International* (1919–1920) proposed a 400 metre spiral structure comprised of three levels revolving at different speeds: a cube-shaped conference centre turning at the rate of one revolution a year; a pyramid for administrative offices revolving once a month; and an information centre cylinder completing one revolution per day. This durational aspect of kinetic art has been taken to an extreme in the work of Tatsuo Miyajima, whose *Clock for 300 Thousand Years* (1987; Works, 72) will continuously count off a seeming eternity.

The idea of putting art in motion began to spread in the early 1930s, when Alexander Calder's mobiles were first exhibited in Paris and New York. By the 1950s and 1960s artists throughout North and South America and Eastern and Western Europe began experimenting with duration, light and motion.⁵ 1955 bore two important exhibitions: 'Man, Machine, and Motion', curated by artist Richard Hamilton at the Institute of Contemporary Arts (ICA) in London; and 'Le Mouvement', curated by K.G. Pontus Hultén at the Galerie Denise René in Paris and including work by a highly diverse group of artists from around the world, such as Duchamp, Calder, Victor Vasarely, Agam, Pol Bury, Jesús Rafael Soto, Jean Tinguely, Gyorgy Kepes and Robert Breer. The latter exhibition was also the occasion for the publication by Vasarely and

Hultén of the *Yellow Manifesto*, which played an important role in popularizing the term, 'Kinetic Art', to refer to this growing international movement.

'Le Mouvement' exemplifies the considerable global exchange between artists, curators and institutions engaged in the creation and presentation of works that examined the artistic frontiers of motion, duration and light in the 1940s, 1950s and 1960s. Originally from Hungary, Moholy-Nagy, a Bauhaus master from 1923–28, emigrated from Germany to Chicago to direct the New Bauhaus in 1937. Kepes, also Hungarian, assisted Moholy in Berlin and London between 1930–37 and joined the New Bauhaus as head of the Light and Color Department. In 1946, Kepes became Professor of Visual Design at MIT and in 1967 founded the Center for Advanced Visual Studies, subsequently directed by German artist and ZERO co-founder Otto Piene from 1974–93. Working in Czechoslovakia, Zdenek Pesánek made perhaps the first work of art employing neon in 1936 and Gyula Kosice began working

where as fire is uncontrollable and naked. Light is a comprehensible representation of the human mind, whereas flame is incomprehensible and hence difficult to represent. So the decision to use neon represents the possibility of mental control.⁶

Artists have energized public spaces with light and sound, as in PULSA's *Boston Gardens Demonstration* (1968; Works, 100), and also employed lasers to connect vast urban areas, as in Rockne Krebs' *Walker Night Passage* (1971; Works, 68) in downtown Minneapolis and Horst Baumann's *Laser-Environment* (1977) for Documenta 6 in Kassel. More recently, light has been used as an artistic medium to illuminate a metaphorical passage between the earth and the heavens, as in Jaume Plensa's *Blake in Gateshead* (1996) at the BALTIC Centre for Contemporary Art in England and in Julian LaVerdiere and Paul Myoda's memorial to the victims of 11 September, 2001, at the former site of the World Trade Center, *Tribute in Light* (2002). Exploring the perceptual relationship between light and sound by eliminating the former, Yolande

Harris's *A Collection of Circles (or Pharology)* (2005), translates the rotating field of illumination that emanates from lighthouse looms into a 3-D sound installation in which the viewer triggers and experiences only the sonic spectre of light, as its audible apparition

revolves around a central axis, changing in response to its environment.

Developments in science and engineering deeply influenced the work of artists exploring the potential of motion and light. The interdisciplinary science of cybernetics, which conceived of both animals and machines as systems of interconnected feedback loops, became a model for kinetic art that was responsive to its environment. Nicolas Schöffer's *CYSP I* (1956; Works, 62) was developed in collaboration with Dutch electronics corporation Philips. An 'electronic brain', sensors, controls and motors enabled the work to interact with its environment by physically responding to sound and movement. The viewer thus became an active participator in the experience of the work. Schöffer later incorporated these concepts into monumental architectural structures, including the *Spatiodynamic Tower* in Liège (1961), a fifty-two-metre tower that incorporated sixty-four revolving mirrors, seventy projectors, 120 coloured spotlights, five half-hour music



with neon in Argentina in 1948. In Brazil, Abraham Palatnik, who had begun working with light and motion in 1949, exhibited a 'cinechromatic' artwork at the First International Biennial in Sao Paulo in 1951.

The growing acceptance of electric light as an artistic medium can be observed through an exploration of recent art history. From Neo-Constructivism and New Tendency to Arte Povera, Postminimalism and Conceptual Art, artists have used the vernacular of neon to wield the eye-catching brilliance of the Las Vegas strip, as in Kepes' commissions for Radio Shack (1950) and KLM (1959; Works, 58), Fontana's ceiling installation at the Ninth Milan Triennale in 1959 (Works, 58), Joseph Kosuth's *Five Words in Blue Neon* (1965), Bruce Nauman's *The True Artist Helps the World by Revealing Mystic Truths* (1967) and Mario Merz's *Giap's Igloo* (1969; Works, 65). On the symbolic significance of neon as an artistic medium, Merz wrote: *Light is nevertheless technological energy in the making, if it is to be controlled by electric light, it is dressed up,*

recordings, along with a variety of sensors that enabled the computer-controlled structure to respond to its environment. These early interactive works were important precursors to a broad range of contemporary practices involving robotics, responsive environments and intelligent architecture.

Artists have used kinetics and light to explore parallels between electronic technology and natural energetic phenomena and to consider the relationship between creation and destruction. Greek artist Takis first exhibited his un-electrified kinetic 'Signals' series at the Hanover Gallery in London in 1958 (Works, 63). He employed electromagnetism in his 'Telesculptures' of 1959 and added blinking lights to his 'Signals Multiples' of 1966. Filipino artist David Medalla, who created his first bio-kinetic sculptures in 1963, opened the Signals Gallery in London in 1964 and edited the *Signals Newsbulletin* from 1964–6, both of which were inspired by Takis and dedicated to kinetic and light art. In 1959, German-born artist Gustav Metzger published *Auto-Destructive Art*, the



first of several related manifestos, including proposals for integrating art with science and technology and using cybernetics and computers to create self-destructing civic monuments that would exist 'from a few minutes to twenty years.' In 1960, German-born art historian Peter Selz, then chief curator at The Museum of Modern Art, New York, invited Swiss artist Jean Tinguely to construct *Homage to New York*, a mechanical work of art that self-destructed in the museum's sculpture garden on 17 March, 1960. Dr. Billy Klüver, a laser researcher at Bell Labs in nearby Murray Hill, New Jersey, collaborated with Tinguely on the technical aspects of the work, and American artist Robert Rauschenberg added a component that literally threw money from the sculpture.

Several important exhibitions took place in the early and mid-1960s, exposing popular audiences in Europe and the US to electronic art employing motion and light. 'Bewogen Beweging' (*Moving Movement*), was organized by Hultén, Tinguely and Romanian/Swiss artist Daniel Spoerri at the

Stedelijk Museum in Amsterdam in 1961. The show's Stockholm incarnation, 'Rörelse I Konsten' (*Art in Motion*), at the Moderna Museet, where Hultén was director, included several additional works by American artists selected by Klüver, a fellow Swede. Also in 1961, the Gallery of Contemporary Art in Zagreb organized the first of seven *New Tendencies* exhibitions, including kinetic and light works by Otto Piene and Heinz Mack of ZERO, the Italian Gruppo N and Julio Le Parc representing the Groupe de Recherche d'Art Visuel (GRAV). American artist Dan Flavin had his first solo exhibition of exclusively fluorescent work in 1964 at the Green Gallery in New York. In 1965, the Jewish Museum in New York organized the exhibition 'Two Kinetic Sculptors: Nicolas Schöffer and Jean Tinguely'. The Stedelijk Van Abbe-Museum in Eindhoven, Netherlands, organized the first major international exhibition of light art, 'Kunst Licht Kunst' (*Art Light Art*) in 1966, with a catalogue essay by French art historian Frank Popper, whose comprehensive book, *Origins and Development of Kinetic Art*,

was published in French in 1967 and translated into English in 1968. Kinetic Art and light art not only became identified as movements, but motion and light transcended stylistic categories and were employed by artists around the world.

Sharing an affinity with Wilfred's Clavilux and eighteenth and nineteenth century experiments with light organs, the desire to combine sound and image to create the experience of synaesthesia reached a culminating point in the mid-1960s, when it became popular fare at rock concerts. Scottish artist Mark Boyle produced his first public *Liquid Light* shows in 1964 (Works, 142). In 1967, he and Joan Hills formed the Sensual Laboratory and began collaborating with The Soft Machine, Pink Floyd and Jimi Hendrix. In 1965, Metzger began producing his *Liquid Crystal Light Projections*, which were used as light-shows for rock bands Cream and The Who in London. Light shows in connection with concerts and Happenings were also taking place in the US, including the Trips Festival in San Francisco in 1966 (produced by Stewart Brand and featuring the Grateful Dead), Andy Warhol's *Exploding Plastic Inevitable*, which toured with the Velvet Underground in 1966–7, and the mind-expanding, communal multimedia environments created by USCO. These psychedelic experiments laid the

foundation for early video performances and laser-light shows in the 1970s and 1980s and were reincarnated in the rise of VJs (the video equivalent of DJs, or disk-jockeys) in rave-culture in the 1990s. In this lineage, the American Museum of Natural History teamed with MTV2 to produce *SonicVision* (2003), which joins popular music and digital animation in an immersive multimedia spectacle for domed theatres.

Of 1960s events, '9 evenings: theatre & engineering' generated the most excitement about the use of electronic media in art and has exerted the most enduring influence. Spearheaded by Klüver and Rauschenberg in October, 1966, this legendary series of technologically enhanced performances in New York City included work by ten artists, composers and choreographers associated with a variety of avant-garde practices ranging from Pop to Fluxus. Bell Labs engineers assisted the artists in realizing their performances.⁷ '9 evenings' was the maiden voyage of the organization Experiments in Art and Technology (E.A.T.), which played



Andy WARHOL Exploding Plastic Inevitable, 1967
USCO Installation at Riverside Museum, 1966



a central role in promoting collaboration between artists and engineers.

1968 was a watershed year for electronic art involving motion, light and time, especially with respect to publications and exhibitions. Jack Burnham published his seminal *Beyond Modern Sculpture: The Effects of Science and Technology on the Sculpture of Our Time*, which included chapters on automata, kineticism, light and robotics. Artist/scientist Frank Malina launched international publication of *Leonardo*, which remains the premier peer-reviewed journal for scholarship on the creative intersections of art and science. Hultén curated 'The Machine: As Seen at the End of the Mechanical Age' at The Museum of Modern Art in New York, which included ten artist-engineer collaborations, such as Jean Dupuy's *Heart Beats Dust*, part of a competition overseen by E.A.T. At the Brooklyn Museum of Art, E.A.T. organized 'Some More Beginnings', an exhibition of over one hundred of the collaborative projects from the competition that could not be included in 'The

Machine'. The Nelson Gallery in Kansas City organized 'Magic Theater', an exhibition that supported collaborations between artists and engineers.⁸ Jasia Reichardt curated 'Cybernetic Serendipity', an internationally influential exhibition at the ICA in London, and the exhibition subsequently traveled to the Corcoran Gallery in Washington, DC and the Exploratorium in San Francisco. On the façade of the NAMA department store in Zagreb, Vladimir Bonačić installed his computerized light-installation, *DIN*.²¹ and the Gallery of Contemporary Art in Zagreb published the first issue of the journal *Bit International*.

By the 1970s, motion, light and time had become increasingly mainstream elements of artistic expression. Artists, drawing on a range of stylistic influences, have continued to explore their potential as the means and subject of their work. One of the most interesting developments over the last four decades has been the use of electronic media by artists to transform or translate between various forms of energy – what Robert Mallary referred to in 1969 as

'transductive art' (Documents, p 203). Dupuy's *Heart Beat Dust* (1968) translates one's pulse into kinetic energy that vibrates a membrane, causing fine red dust to dance. In Gary Hill's video *Soundings* (1979; Works, 70), a loudspeaker is subjected to the effects of fire, earth, air and water, revealing transformations of its sonic and visual presence in relation to a

spoken text. In the tradition of physicist Ernst Chladni's late-eighteenth century experiments in visualizing harmonic vibrations and physician Hans Jenny's studies of wave phenomena or 'cymatics' from the 1960s, Carsten Nicolai's *Milk* (2000) reveals how various frequencies of sound energy alter patterns of disturbances they caused in a vat of milk. Similarly, in *Protrude/Flow* (2001) by Sachiko Kodama and Minako Takeno, sounds in the exhibition space, including those of the audience, interactively transform three-dimensional patterns in black magnetic fluid, which appears to be choreographed to its sonic environment.

Light has been the primary force in several intriguing transductive works. By focusing ultra high-intensity light in a vacuum chamber, Shawn Brixey and Laura Knott's *Photon Voice* (1986; Works, 71) made graphite particles levitate and form kinetic sculptures, altered by a dancer, whose movement broke the light. In Paul DeMarinis's *Edison Effect* (1989–93; Works, 73), a laserbeam shone through a fishbowl and onto an Edison

cylinder, a nineteenth century recording device. The beam of light relayed the sound encoded in the cylinder to a computer, which translated the information from analogue to digital, then reproduced the analogue sound, interrupted sporadically by the fish, which occasionally crossed the beam.

Exploring the entropic effects of light, Mary Lucier's *Dawn Burn* (1975) pushed the physical limits of video equipment. Videotapes of seven successive sunrises, each played on a separate monitor, revealed how the sun's intensity slowly overwhelmed the recording apparatus, causing a progressively expanding burn over time in the series of tapes. Jochen Gerz's video performance *Prometheus* (1975) echoed the myth of the Titan who stole fire from Zeus and gave it to humankind. Gerz used a handheld mirror to reflect sunlight into the camera's lens, slowly overloading the camera's sensor and causing its demise. Using electronic media in innovative ways that invoke the luminous, kinetic and temporal dimensions of art, artists explore the potential of these qualities to expand aesthetic



experience and to enhance human perception.

Coded Form and Electronic Production

An important precursor to digital computing debuted in France in 1801 – the Jacquard Loom, invented by Joseph-Marie Jacquard. It employed wooden slats, encoded with instructions like computer punch-cards, to automate weaving of complex patterns. Although workers rioted against the loom's introduction, which threatened to replace humans with machines, the mechanical production of goods through encoded information offered great financial opportunities for industry and resulted in lower cost items, which benefited consumers as well. Reflecting on this technological history, artist Eve Andrée Laramée's installation, *Permutational Unfolding* (1999), included an antique Jacquard loom, woven textiles and other period and non-periodic elements to demonstrate parallels between this early programmable machine and digital computers, both of which operate on

binary code.

Not to be outdone by the French, British Industrialists supported by Prince Albert organized the Great Exhibition of 1851 in London at the Crystal Palace, an architectural and technological marvel designed by Joseph Paxton. Symbolizing the superior economic and technological strength of Great Britain, the displays intended to demonstrate to a rapidly growing urban middle class that mechanically manufactured goods met or exceeded the quality of handmade products, at a fraction of the price. For many visitors, these mass-produced items were satisfactory and affordable; indeed, the exhibition was a great financial success. However, some accounts of the merchandise suggest that not only was the quality mediocre but the designs lacked taste. One such detractor, William Morris, sought to retain the virtues of handcrafting established by medieval guilds but to update them with contemporary design principles. Although Morris was an exceptionally talented designer and a major force in the Arts and Crafts

movement, his products were outside the financial reach of the masses. In contrast, Bauhaus designers in the 1920s, following the spirit of architect Walter Gropius's maxim ('Art and technology: a new unity!'), attempted to join the highest contemporary aesthetic values with industrial production in order to create stylish goods that were affordable to a wider public. The tension between handcrafted finery and machine-produced objects that are finely designed persists with respect to electronic art.

The long and diverse history of the mechanical production and reproduction of artworks includes using technological media, such as the camera obscura and photography to render convincing likenesses, various printing methods from wood-blocks to rapid-prototyping machines to output two- and three-dimensional multiples, and a range of algorithmic techniques to generate form from mathematical formulae, genetic algorithms and other coded relationships. These approaches to image production have affected the working processes of artists and transformed the end result and impact of their work on visual culture.

Images were relatively scarce in private homes prior to the invention of the printing press. The advent of photography and the medium's popularity in the late nineteenth century provided the masses with convincing likenesses of loved ones, exotic destinations and other subjects that were far more affordable than portraits or scenes drawn or painted by hand.

Images became daily fodder for mass audiences after the development of the rotary press around 1850 and improvements in the half-tone process in the 1890s, which enabled the cheap and rapid reproduction of photographs and drawings in newspapers. The flooding of daily life with objects and images is, therefore, a relatively recent occurrence in which technologies of production and reproduction have played a major role.

In 'The Work of Art in the Age of Mechanical Reproduction' (1936), Walter Benjamin argued that technologically reproduced images lacked the 'aura' of an individually handcrafted original. At the same time, he recognized the potential of technological reproduction to enable the democratization of imagery, a condition that he hoped would offer a means of resisting Fascism and promoting democratic values.⁹ In the wake of the individualistic bravura of Abstract Expressionism, by the late 1950s artists began to critically examine the distinctive, gestural signature that implied a



symbolic connection between the hand of the artist and the surface of a canvas. Taking the ideological cluster of gesture, authenticity and originality as his foil, in the mid-1960s artist Roy Lichtenstein caricatured the abstract expressionistic brush-stroke in a cartoon style with a background comprised of Ben-Day dots – a printing technique used by newspapers to reproduce cartoons. Paradoxically, he initially mocked this eviscerated but iconic signifier in a series of unique paintings, only later reproducing them as serigraphs. Pushing this lineage further, Roman Verostko made the first robotic brush-strokes in 1987, using custom software and sumi brush mounted on a plotter to achieve remarkable gestural spontaneity from a series of algorithms.

Using closed-loop video to reflect on Benjamin's critique of mechanical reproduction, in Richard Kriesche's video performance *Twins* (1977) two identical twins in separate rooms read 'The Work of Art...' Adjacent to each performer was a monitor displaying live video of the other and a slightly

modified quotation from the text, 'The reproduced art-work (person) becomes to an ever increasing degree the reproduction of an art-work (person) that is designed to be reproduced.' Parallel assaults on originality and reproduction were mounted by artists such as Sherrie Levine, whose re-photographed images of Walker Evans' photographs for the US Works Progress Administration (WPA), to which she signed her name, spurred much debate when exhibited in New York in 1981. By the early 1980s art critics proclaimed that the ideal of originality associated with avant-garde art was a myth.¹⁰

Upping the ante, in 2001 artist Michael Mandiberg created the twin Websites, *AfterWalkerEvans.com* and *AfterSherrieLevine.com* (2001), offering free downloads of high-resolution digital files of the twenty-five Evans images that Levine re-photographed. Each site contains the same image files, distinguished only by their titles, which correspond to the images' Website address or Uniform Resource Locator (URL). After downloading the desired image and printing and framing

it according to instructions on the Website, one may sign a downloadable certificate of authenticity that declares it to be an authentic work of art by Mandiberg. Although it may not have the cache of an 'original' work by Evans or



Levine, neither does it carry the price-tag. While Levine's work and the artworld discourses surrounding it intended to ring the death knell of originality, with few exceptions, the critics who chanted this characteristic mantra of post-modern art and theory failed to address how concurrent developments in electronic art, such as Kriesche's, offered equally potent critiques of originality, authenticity, institutions and cultural hegemony. As Margot Lovejoy has pointed out, 'Electronic media challenge older [modernist] modes of representation. New media have created postmodern conditions and have changed the way art itself is viewed.'¹¹

Indeed, artists utilizing electronic tools to produce form by duplication, or by using algorithmic and other generative approaches, have challenged conventional notions of originality, creativity and art itself. Such artists recognized and exploited the potentials of electronic signal processing, computer graphics and electronic photocopying in the 1950s and 1960s and high-resolution digital photography, printing,

video and rapid-prototyping since the 1980s.

Important parallels and advances took place in music. Following the introduction of the electronic musical instruments, such as the theremin and the ondes Martenot in the 1920s, Pierre Schaeffer's *Cinq Études de Bruits* (1948) expanded the sonic palette and compositional strategies of music by employing multiple turntables, tape loops, a four-channel mixer and an echo chamber. The term 'electronic music' was coined at the Cologne radio station Northwest German Broadcasting (NWDR) in the early 1950s, where composers including Karlheinz Stockhausen synthesized music using purely electronic means. In 1956, Lejaren Hiller and Leonard Isaacson wrote the *Iliac Suite*, so-named for the computer that was used to algorithmically generate the composition for string quartet. Louis and Bebe Barron relied exclusively on custom-built electronic circuits to compose the score for the film *Forbidden Planet* (1956), spreading electronic music to broad, popular audiences. Electronic synthesizers and sequences made their debut in the late 1950s, vastly expanding the possibilities of music composition and performance. There was, moreover, significant cross-fertilization between electronic music and art, exemplified by the collaborations at Bell Labs in the 1960s. These early experiments demonstrated the flexibility of electronic technologies to produce hybrid forms of multimedia.

Electronic techniques for producing and reproducing sounds and images have affected the ways artists reflect on traditional aesthetic concerns and have expanded the creation and distribution of art, including its manifestations as code, as an image on a monitor and as an object. It remains to be seen whether or not the potential of digital production and distribution technologies will result in a the democratization and appreciation of fine art suggested by Benjamin. Attempts by artists to sell inexpensive limited licenses for works of software art via the Internet have not been commercially successful. What constitutes 'the work' is enigmatic: digital files might be simultaneously the original and the copy, a work of art and the code that generates it. Just as photography was not recognized as a bona fide artistic medium until the mid-twentieth century, so the acceptance of digital forms of production and reproduction may not occur immediately. At the same time, Apple's iTunes Music Store has succeeded in selling digital music files for under a dollar each, and brisk cottage industries have grown up around the production and

sale of mobile phone ring-tones and of avatars, fashion and accessories for Sims and Second Life enthusiasts. As digital devices increasingly saturate the cultural landscape and as technologies advance, perhaps there will be greater interest in software art. Indeed, paralleling the economic and social shifts from industrial production to service industries, meaning and value have become less embedded in goods and more dispersed in the flow and exchange of signs. Similarly, in experimental art since the 1960s, particularly that involving electronic media, the conventional aesthetic privileging of precious objects has been increasingly supplanted by a more ephemeral aesthetics of information.¹²

Given the long tradition of artists' use of technologies to mechanically reproduce works of art, from wood-cut to off-set printing, it is not surprising that artists eagerly embraced electrostatic photocopying techniques (i.e. xerography) when the first commercial machine, the Haliod Xerox 914, was released in 1960. As early as 1962, Ray Johnson, who founded the New York School of Correspondence Art in 1968, used photocopiers as a tool for propagating images. Photocopiers were used as well by artists associated with Fluxus and Conceptual Art. One of the first artists to exploit the formal potential of photocopying machines was Italian futurist Bruno Munari, whose 'Machine Art Manifesto' of 1938 anticipated his series 'Xerografie Originali' begun in 1964. Munari's work concentrated on the artist's gestural act of moving objects over the glass during the copying cycle, collaborating or performing with the machine in order to capture motion and time on a two dimensional surface. Taking a more conceptual approach, German artist Timm Ulrichs' *Die Photokopie der Photokopie der Photokopie* (1967) pushed the limits of these new machines while questioning conventional notions of the original versus the copy. Ulrichs photocopied an encyclopedia entry about photocopying, then copied the copy through ninety-nine successive generations, revealing the intrinsic qualities of the process. Was the original image degraded? Or was the whole process an original work of art, a parallel conversation or metadiscourse on electronic reproduction that embodied both a description and a demonstration of it? In any case, such work could not have been conceived or produced without electronic media, which were both the inspiration and means for the creation of innovative forms of expression.

For artist Sonia Sheridan, photocopiers made it possible to generate copious amounts of visual information, the process

of which became her primary goal. As an artist in residence at 3M Corporation in 1969 and again in 1976, she was given carte blanche to explore the creative possibilities of the company's Color-in-Color photocopying machine (Works, 86). Compared to colour photocopiers made available to the public decades later at printing shops, the original 3M machine had adjustable focus and depth of field, as well as variable voltage to regulate the electrostatic process by which the toner was fused onto the surface of the copy. With control over the quantity and quality of pigment applied to the surface, she created thick and velvety textures and richly saturated colours. Although innumerable prints could be made of any given image, each has the presence or aura of an original and in Sheridan's case nearly all were monotypes. Indeed, because the process took only sixty-seconds, Sheridan used the capacity of the machine to rapidly generate images in order to free her creativity from the temporal burden of drawing or painting by hand. She chose to assemble variations of elements directly on the glass platen,



which enabled the production of hundreds of images and variations in the time it would have taken to complete one traditionally crafted work.

Drawing on this experience, Sheridan developed her concept of generative art and founded the Generative Arts programme at the School of the Art Institute of Chicago in 1970. Some of the experiments she and her students undertook involved the use of early facsimile machines, which carried information encoded in audible signals. They would record the fax tones and then manipulate these sonic codes in order to alter the corresponding images and vice-versa. A particularly precocious student, John Dunn, developed the EASEL computer-graphics system, which Sheridan used to advance her generative art practice in the 1980s.

Some of the earliest electronically generated images include Ben Laposky's 'Oscillons', high-speed photographs of abstract patterns the American artist/mathematician first produced on an oscilloscope in 1950 by using a range of

manually controlled, analogue devices. In the early 1950s, German artist/theorist Herbert Franke independently created electronic images using oscilloscopes as well. In 1953–4, fifty of Laposky's Oscillons were the subject of the exhibition 'Electronic Abstractions', another term Laposky used for his work, which opened at the Sanford Museum in Cherokee, Iowa and travelled to thirteen other venues across the US. In 1959, the exhibition 'Experimentale Asthetik', at the Museum of Applied Art in Vienna, displayed Oscillons and other early electronically generated images. Although Laposky and Franke did not employ digital computers in these early works, their use of algorithmic signals to programme and control imagery on an oscilloscope's cathode ray tube – an electronic screen similar to a TV monitor – was an important precursor to computer art.

Much of the early development of computer graphics was undertaken by engineers and mathematicians. In 1961, electrical engineer Ivan Sutherland began doctoral research

at MIT on the first interactive computer graphics system. In the process of creating the Sketchpad system, Sutherland also developed object-oriented programming, which revolutionized not only the field of computer graphics but the discipline of computer science in general. Bell Laboratories, in the suburbs of New York City, was a hotbed of computer graphics and electronic music development in the early 1960s, driven by staff researchers, often in collaboration with artists.¹³ Stuttgart, Germany was the European centre of cutting-edge activity. At the University of Stuttgart, then called the Technische Hochschule, Ph.D. students Frieder Nake (Probability Theory, 1967; Works, 80) and Georg Nees (Philosophy, 1969) were deeply influenced by philosopher Max Bense, a co-founder with Abraham Moles of information aesthetics. Bense developed an influential theory of generative aesthetics that was the galvanizing force behind the so-called Stuttgart or Bense school of computer art and he coined the term 'artificial art' to refer to this new field.

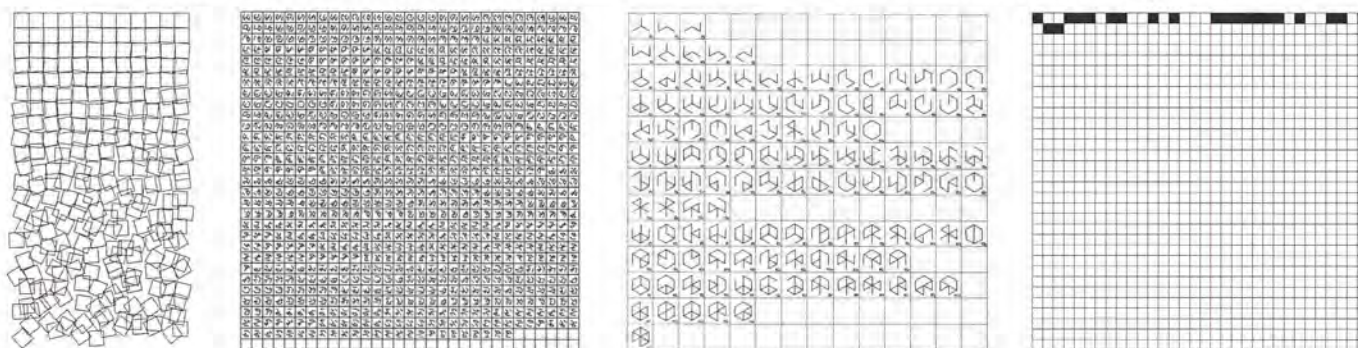
Ray JOHNSON May Wilson with Andy Warhol, 1976
Timm ULRICHs Die Photokopie der Photokopie, 1967
Sonja Landy SHERIDAN 3M Color in Color electrostatic monotype print, 1970 (detail)

The first exhibitions of computer art took place in 1965: 'Generative Computergrafik', consisting of work by Nees at the Studiengalerie in Stuttgart (February 5–19); 'Computer Generated Pictures', featuring work by Noll and Bela Julesz at Howard Wise Gallery, New York (April 6–24); and 'Computergrafik', including work by Noll and Nees at the Galerie Wendelin Niedlich in Stuttgart (November 5–26).¹⁴ German art students antagonized Nees's work, just as art critics dismissed the work shown in New York as 'cold and soulless' and having about as much appeal as the 'notch patterns found on IBM cards.'¹⁵ Nonetheless, one work at Howard Wise Gallery, Noll's *Gaussian Quadratic* (1963), won the first computer art competition, sponsored by the journal *Computers and Automation*, in 1965, and Noll won in 1966 for his work employing random-number generators, *13/9/65 Nr. 5, Distributions of Elementary Signs* (1965).

Although early computer graphics may have failed to enchant some art audiences, the philosophical, aesthetic and

possible permutations of black and white squares in a 32×32 grid, a task that will take hundreds of trillions of years to complete at a rate of 100 icons per second on a typical desktop computer from that era.

Artists also used computers in order to create images that could not have been imagined or produced using traditional media. Working in France, Hungarian artist Vera Molnar, one of the founders of GRAV, envisioned computers as a way to 'produce combinations of forms never seen before, either in nature or in museums, to create *unimaginable images*.'¹⁶ Even before she had access to computers, Molnar created a 'machine imaginaire' – essentially, a set of programmed behaviours – and followed them, in a machine-like manner, in order to generate randomness in her art.¹⁷ In 1979, polymath Benoit Mandelbrot, working at the IBM Research Laboratory, produced a complex computer generated image that could not have been imagined from its simple constituent parts. Known as the Mandelbrot Set, this algorithmic visualization spurred



mathematical underpinnings of this work often were highly complex and shared much in common with other tendencies in contemporary art. Noll considered the computer a 'Universal Picture Generator', capable of producing all possible variations of a given combination of elements. Fellow German artist, Manfred Mohr, employed the mathematics of combinatorics programmed on a computer to derive and plot variations on a cube in his 'Cubic Limit' series (1972–76). A similarly systematic approach to art-making characterizes conceptual artist Sol LeWitt's manually produced *Incomplete Open Cubes* (1974), wherein variations on a cube are translated into a variety of media and scales, exemplifying the deployment of a single idea to become, in LeWitt's words, 'a machine that makes the art.' Such an algorithmic approach to image production was a catalyst for Casey Reas's *Software Structures* (2004) and John F. Simon Jr.'s *Every Icon* (1997). The latter consists of a personalized Java applet, available for purchase from Amazon.com for \$20, that explores all 1.8×10^{308}

tremendous interest in fractal geometry and complexity theory and inspired a wide range of artistic exploration. In Scott Draves's *Electric Sheep* (2001), for example, when a computer goes to sleep, an open-source, peer-to-peer, screen-saver connects it with other silicon somnambulists via the Internet, sharing the work of generating fractal animations known as 'sheep'. Titled in homage to Philip K. Dick's novel, *Do Androids Dream of Electric Sheep?*, users design their own digital livestock and vote on their favorites, thus enabling the most popular electric sheep to live longer and reproduce – an artificial form of evolution resulting in what the artist describes as 'a collective "android dream"'.¹⁸

In addition to these algorithmic abstractions, computers have been employed to generate likenesses or emulate traditional works of art. In the mid-1960s, Noll developed algorithms that produced images very similar in appearance to the work of DeStijl artist Piet Mondrian and Op artist Bridget Riley and Noll did the same with the work of Paul Klee.

Working together at Ohio State University, Charles Csuri and James Schaffer produced *Sine Wave Man* (1967) by coding selected coordinates from a line drawing of a portrait and subjecting them to mathematical modifications known as Fourier transforms. This work won the *Computers and Automation* annual competition in 1967 and was included in the exhibition 'Cybernetic Serendipity' (1968). Kenneth Knowlton and Leon Harmon's 'Studies in Perception' series, begun in 1966, includes images of a reclining female nude (Works, 81), a gargoyle, a telephone and seagulls in flight, generated from photographs that were digitized. This series, which shares similarities with ancient mosaic techniques, also has inspired more recent work, including Andy Deck's *Glyphiti* (2001), an interactive, Web-based telematic artwork that allows participants around the world to collaborate in the endless process of creating and recreating images.

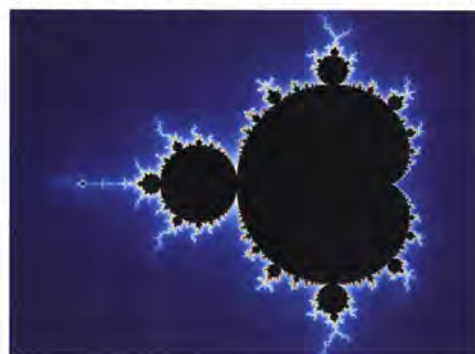
In the lineage of early twentieth century experimental animators including Viking Eggeling, Hans Richter, Oskar

(1993) slows down Alfred Hitchcock's 109-minute masterpiece of 1960 to a creeping pace that lasts twenty-four hours.

Michael Joaquin Grey's *Rereentry* (2005), dimensionalizes, syncopates and interweaves two videos displayed side by side, each comprised of hundreds of miniature videos of the other, a process the artist refers to as 'cellular cinema.'¹⁹

In the 1990s, advances in computer-aided 3D design software (CAD-3D) and rapid-prototyping technology (RP) have provided artists with tools to digitally encode and produce three-dimensional objects. RP can be thought of as three-dimensional printing. Although currently the process is neither as rapid nor as affordable as making a photocopy or printing out a page of computer-generated text, as art schools increasingly train students to use CAD-3D and as RP becomes cheaper and faster, one can anticipate greater artistic experimentation with this medium. Some of the first works of art to use this technology were *Gametes* by Michael Joaquin Grey and Randolph Huff and *Forbidden Fruits* by Masaki

Vera MOLNAR Hypertransformations, 1976
Benoit MANDELBROT Mandelbrot Set, 1979
Scott DRAVES Electric Sheep, 2001



Fischinger and Len Lye, the advent of computers led to the development of new methods for animation and filmmaking beginning in the 1960s. Although produced without a computer, James Whitney's *Yantra* (1950–7; Works, 80), embodies a complex symmetry that anticipates digital animation. In 1958, his brother John Whitney Sr. cobbled together salvaged military components to create an analogue computer that produced the animations in *Catalog* (1961). As an artist-in-residence at IBM from 1966–9, Whitney Sr. gained access to digital computers, which he used to produce films such as *Permutations* (1968). Csuri and Knowlton were also deeply engaged in developing computer animation. Csuri's *Hummingbird* (1966; Works, 80), incorporated morphing techniques similar to those used today, while Knowlton collaborated with artists including Stan VanDerBeek and Lillian Schwartz doing award-winning work at Bell Labs in the 1960s and 1970s. More recently, artists have joined computers and film or video in myriad ways. Douglas Gordon's *24-Hour Psycho*

Fujihata, both produced in 1990 using stereolithography. Since the early 1990s, artists have expanded the potential of this medium. Robert Lazzarini's 'Skull' series (2001) and *Payphone* (2002; Works, 95) used CAD and RP to evolve distortions of recognizable objects. The 3-D RP models were then used as templates to fabricate the final artworks, which could not have been executed otherwise. Michael Rees has used the CAD environment to develop infinite variations of virtual 3-D forms, much as Sheridan used photocopiers to rapidly explore variations of 2-D designs. The CAD environment, moreover, enables the creation of works that can be output as still images, animations and 3-D objects and to be produced at various scales, from the minuscule to the monumental, as in the case of Rees's *Putto 2 x 2 x 4* (2005; Works, 93), which is nearly five metres (sixteen feet) tall.

Charged Environments

Art has always been implicitly interactive, in the sense that it

demands acts of perception and cognition on the part of the viewer. By emphasizing the durational aspect of perception and thereby making explicit the process of encountering works of art, artists began to challenge and alter traditional conceptions regarding the relationship between viewer and artwork. In *Art as Experience* (1934), philosopher John Dewey stressed the viewer's role in the production of meaning in art. Similarly, Marcel Duchamp stated in 1957 that, 'The creative act is not performed by the artist alone; the spectator brings the work in contact with the external world...and thus adds his contribution to the creative act.'²⁰

As artists increasingly created kinetic works that reconfigured themselves or could be modified in response to the viewer's behaviour, traditional distinctions between viewing subject and art object, and between artist, artwork and audience, began to erode. No longer could the artist be considered the enigmatic creator of coded messages to be decoded by clever viewers. Semiotician Umberto Eco's



theorization of the 'open work' in 1962 parallels the explorations of artists working with interactive media and audience participation, who increasingly came

to think of themselves as offering audiences open-ended possibilities for the production of unpredictable meanings. Roy Ascott drew a striking parallel between participatory art and quantum physics, citing physicist J.A. Wheeler's contention that, 'To describe what has happened one has to cross out that old word "observer" and put in its place "participator"'. In some strange sense the universe is a participatory universe.'²¹ Electronic media have made possible an extraordinary range of interactive potentials for observers to become active participators who navigate charged environments along a variety of possible trajectories.

This mid-century aesthetic shift took place internationally and involved artists associated with kinetic art, new tendency, Pop Art, Happenings, performance and other genres. In addition to participating in '9 evenings' and co-founding E.A.T., pop artist Robert Rauschenberg collaborated with Billy Klüver on several artworks, including *Soundings* (1967), an interactive electronic environment that responds to sound by

activating spotlights that become increasingly luminous as the audience grows louder (see pages 2–3). Carolee Schneemann, one of the pioneers of performance art and experimental cinema, created an interactive electronic environment for her multimedia performance, *Snows*, which premiered in 1967 (Works, 98). Engineered by E.A.T., the seats of the theatre were wired so that the audience's response triggered various light and sound effects. The work of another artist known primarily for feminist performance in the 1960s, Barbara Smith's *Field Piece* (1968–71) was activated by the movement of viewers amidst 180 tinted translucent resin columns, each three metres tall, which generated changing patterns of light and sound in the immersive environment. German artist Wolf Vostell, a co-founder of Fluxus and a primary progenitor of Happenings in Europe, proposed using television as an artistic medium as early as 1958. He joined electronic media with happenings in his 1963 installation, *Television Dé-coll/age*, in New York and in his renowned spectacle, *Electronic Dé-coll/age Happening Room (Homage to Dürer)*, at the Venice Biennale in 1968. Hans Haacke, associated with ZERO in Germany before he came to the US in 1965, created *Photo-Electric Viewer-Programmed Coordinate System* (1968), which he described as a responsive, real-time system that 'merges with the environment in a relationship that is better understood as a "system" of interdependent processes.'²² In *Cybernetic Sculpture* (1968), a collaboration between kinetic artist Wen-Ying Tsai and engineer Frank T. Turner, the rate of the stroboscopic lighting responds to sound, giving the viewer the sense that the trembling of the rods translates his/her voice.

Some of the earliest electronic environments emerged from or overlapped with music, sound art and architecture. Perhaps the most spectacular of these was the *Poème Électronique*, created by architect Le Corbusier in collaboration with polymath Iannis Xenakis and composer Edgard Varèse for the Philips Pavilion at the 1958 World Fair in Brussels. This *gesamtkunstwerk*, or 'total work of art', integrated architecture, light, film and sound.²³ For Expo 67 in Montreal, the Czech pavilion featured the Kinautomat, a form of interactive cinema invented by Raduz Cincera. Told from two opposing points of view that were projected side by side, at certain moments of dramatic tension the audience was invited to decide in which direction the narrative path would unfold. The Pepsi Pavilion, engineered by E.A.T. for the 1970 World Fair in Osaka, incorporated a mirrored dome ceiling, fog-machines,

electronic music, a programmable, four-colour krypton laser that generated patterns in response to sound, and a complex sound system that enabled one to regulate the movement of live sound throughout the space. The same year, Russian collective Dvizheniye ('Movement'), drawing on roots in Constructivism and performance, created their *Kinetic Artificial Environment* for an industrial exhibition in Moscow. Building on prior experiments with 'cybertheatre' theorized by founding member Lev Nusberg, this massive interactive installation filled 660 square metres (over 7000 square feet) with multimedia elements including light, sound and film that could be triggered by various sensors.²⁴

The 1970 exhibition, 'Software – Information Technology: Its New Meaning for Art', also incorporated architectural and sonic elements in electronic environments. Curated by art historian Jack Burnham for the Jewish Museum, it included 'SEEK', created by Nicholas Negroponte and the MIT Architecture Machine Group (1969–70; Works, 185) and Ted



Victoria's *Solar Audio Window Installation* (1969–70; Works, 102). The former, a computer-controlled robotic environment, could, at least in theory, reconfigure itself in response to the behaviour of the gerbils that inhabited it. In Victoria's installation, solar panels powered ten radios, which were connected to contact speakers placed on the windows of the building, turning the Jewish Museum into a giant, faintly audible sound system and information outlet. Because the volume was no louder than a whisper and could be heard only by placing one's ear very close to or against a window, the audience was drawn to actively interact with the architectural body of the museum.

The radio waves transmitting content to Victoria's installation are a form of electromagnetic radiation that, like television, satellite and microwave transmissions, were a driving force for artist Tom Sherman's *Faraday Cage* (1972) and Catherine Richard's *Curiosity Cabinet for the End of the Millennium* (1995; Works, 112). These habitats, like the

original described by British physicist Michael Faraday in 1836, shield their inhabitants from the invisible assault of electromagnetic radiation, a growing concern given the proliferation of wireless devices. Conversely, the work of Joyce Hinterding (Works, 113) and of Radioqualia has employed VLF (Very Low Frequency) receivers to capture and sonify cosmic energy, allowing us to hear sounds generated billions of years ago in distant galaxies.

Such work builds on the ideas of American composer John Cage, who emphasized the importance of focused listening to the ambient sounds of one's environment. Indeed, it is hard to overestimate Cage's contribution to electronic art. Not only did he employ electronics for composition and in performance, but his aesthetic theories advocated their use to support aleatory (chance) methods, indeterminacy and mutability and to emphasize the unique sonic features of found objects and environments. In the tradition of Italian futurist Luigi Russolo's 1913 manifesto 'Art of Noises', Cage



wrote in 1937 that, 'the use of noise to make music will continue and increase until we reach a music produced through the aid of electrical instruments which will make available for musical purposes any and all sounds that can

be heard'.²⁵

In 1939, Cage composed his first work to use electronic media, *Imaginary Landscape No. 1* (Works, 99), one of five 'imaginary landscapes' composed between 1939–52. In this piece, dampened piano and cymbal were performed along with multiple phonographs that played Radio Corporation of America (RCA) pure electronic test-tones. *Imaginary Landscape No. 4* (1951) was scored for twelve radios, each controlled by two performers. Changes in tuning frequency, amplitude and tone of each radio throughout the composition were determined by chance, drawing on the tradition of Dada artists, who had been inspired by Stéphane Mallarmé's 1897 poem *Un coup de des jamais n'abolira le hasard* (A throw of the dice will never abolish chance). To establish values for variable parameters, Cage consulted the I Ching, an ancient Chinese system of knowledge, wherein prophecy is accessed by casting coins or yarrow-stalks. The piece created an unpredictable pastoral of sounds, culled from the ethereal environment of

the airwaves and reproduced on the most common of consumer electronic devices. Drawing on Dada traditions of employing found objects as artistic media, Cage's use of radios conflates electronic devices designed to reproduce sound with acoustic devices designed to produce music. Similarly, the use of sound carried by a given radio frequency as sonic content conflates remotely transmitted sound, static (between stations), and the immediacy of live music performance.

Growing out of his enigmatic *4'33"* (1952), a piano composition that had no notes but invoked the ambient sounds of the environment as its sonic content, Cage's *Variations VII* (1966), engineered by Cecil Coker for E.A.T.'s '9 evenings', used as sound sources, 'only those sounds which are in the air at the moment of performance, picked up via the communication bands, telephone lines, microphones...' The performers revealed these ambient sounds by processing them with 'a variety of household appliances and frequency generators'.²⁶ Cage's publications and his lectures at the New



School, New York, influenced numerous visual artists, whose work impacted the history of electronic art by experimenting with audience participation and interactivity, thus challenging traditional boundaries between artist, artwork and audience. These include Allan Kaprow, who staged his first happening in 1956; George Brecht and Yoko Ono, members of Fluxus, whose event-scores of the late 1950s anticipated conceptual art; and Nam June Paik, a pioneer of video, robotics and other electronic media.

Paik's early electronic environments include his landmark 1963 exhibition, *Exposition of Music-Electronic Television* at the Galerie Parnass in Wuppertal, Germany. Inspired by Cage's technique of composing for 'prepared piano' (modified by inserting objects, such as nuts, bolts or pieces of rubber, lodged between and entwined around the strings in order to alter its sound), Paik's exhibition consisted of four prepared pianos, twelve prepared TV sets, mechanical sound objects and record and tape installations. Expanding Cage's vision,

Paik intended for his audience to interact with the prepared pianos and televisions, the latter of which altered TV broadcasts and revealed the internal electronic properties of cathode-ray tubes. In one of these, *Participation TV* (1963–6), an integrated microphone responded to sounds in the environment, altering the television's output. When portable video-recorders became available to consumers in 1965, Paik was one of the first artists to acquire one. In addition to his collaborations with engineer Shuya Abe, with whom he created one of the first video synthesizers, Paik also used closed-loop video systems, in which a video image is fed directly to a monitor without an intervening broadcast network, to create self-contained electronic environments. In *TV Buddha* (1974), an ironic aggregation of spirituality, cybernetics and pop culture, a statue of Buddha gazes at his own video image on a television, which returns its gaze in an endless, mantric regression.

Cybernetics, information theory and the circularity of feedback inherent in closed-loop video were at the theoretical and formal core of many important early interactive, electronic environments in the 1960s and 1970s. In *Expanded Cinema* (1970), Gene Youngblood documented the challenges posed by early interactive video installations to the uni-directionality of commercial media, providing a context for two-way creative exchanges. Art historian Inke Arnes has described such 're-use' of broadcast media in situationist terms, as a form of *détournement*, in which the (mis)appropriation and repurposing of conventions produce shifts in social consciousness.²⁷ Along these lines, in works like *Iris* (1968) and *Contact: A Cybernetic Sculpture* (1969; Works, 103) by Levine, and *Wipe Cycle* (1969; Works, 100) by Gillette and Schneider, video cameras captured various images of viewers, which were fed back, often with time-delays or other distortions, onto a bank of monitors. As Levine noted, *Iris* 'turns the viewer into information... *Contact* is a system that synthesizes man with his technology... the people are the software'.²⁸ Schneider amplified this view of interactive video installation, stating that, 'The most important function... was to integrate the audience into the information'.²⁹ Gillette described how *Wipe Cycle* was related to satellite communications: 'you're as much a piece of information as tomorrow morning's headlines – as a viewer you take a satellite relationship to the information. And the satellite which is you is incorporated into the thing which is being sent back to the satellite'.³⁰ The 1969 exhibition, 'TV as

Creative Medium', at the Howard Wise Gallery in New York, presented a variety of electronic environments, including *Wipe Cycle*, Paik's *Participation TV* and performances by Paik and Charlotte Moorman of *TV Bra for Living Sculpture* (see page 4). At the time, these installations offered the public an unprecedented opportunity to see itself as the content of television, to become integrated into the electronic environment of mass media; in other words, to establish a unity between subject and object, viewer and viewed.

Bruce Nauman, who was sceptical of participatory art, approached closed-loop video literally from a different angle, with a no less jarring effect. His *Live Taped Video Corridor* (1970; Works, 105) presciently suggested a more haunting and increasingly ubiquitous aspect of this technology: surveillance. In this installation, one walks down a claustrophobically narrow corridor towards two stacked video monitors, the bottom of which displays one's video image (captured in real-time from the rear) growing progressively smaller. As Dörte

Depending on where the observer stands in the piece the images can appear to look at each other, be separate or overlap, invoking feelings of uncertainty and playfulness. Dan Graham's *Present Continuous Past(s)* (1974; Works, 106) joins closed-loop video and mirrors with electronic delays in order to create an endless regression in space and time. Reflecting on Jeremy Bentham's eighteenth century theories of prison design, Steina's *All Vision* (1976) is an electronic panopticon. Two opposing video cameras, set at the ends of a crossbar, face a mirrored sphere in the middle. The whole assembly slowly rotates around the centre axis. Since each camera surveys half of the environment reflected in the sphere, the whole space becomes observable simultaneously from changing perspectives on two video monitors.

Building on the sort of aesthetic experiences, both interactive and self-contained, enabled by closed-circuit video and other media, artists have used emerging and evolving technologies to explore a wide range of electronic

environments.

Daniel Rozin's *Wooden Mirror* (1999) incorporates an interactive screen of 830 wooden slats. Each of physical pixels is set on a



Zbikowski has noted, 'the feeling of alienation induced by walking away from yourself is heightened by your being enclosed in a narrow corridor. Here, rational orientation and emotional insecurity clash with each other. A person thus monitored suddenly slips into the role of someone monitoring their ... own activities'.³¹ Similarly, Peter Weibel's *Observation of the Observation: Uncertainty* (1973; Works, 106), incorporates juxtapositions of three video cameras and monitors such that viewers cannot see themselves from the front – the angle from which one typically sees oneself. This perceptual prison restricts self-observation to the oblique angles from which one is typically seen only by others.

Peter Campus' *Interface* (1972; Works, 104) used closed loop video to turn things on their head, metaphorically. Set in a dark room, a video camera records from behind a piece of transparent glass while the image it records is projected on the front. Two images are produced: the viewer's reflection on the glass and the other unreversed, created by the projector.

motorized pivot that theoretically enables 255 grey-levels to be generated. A video camera hidden in the centre captures motion in front of the screen, which is then 'reflected' by the wooden pixels. Similarly, Kelly Heaton's *Reflection Loop (The Pool)* (2001) incorporates a 400 pixel screen of reprogrammed components culled from Furby dolls, which, when activated via a video camera, mirror the motion of viewers in their midst.

Electricity has been used by artists as a medium in and of itself to create highly charged experiences as well as more subtle meditations on the electrical foundations of life. In collaboration with Barry Schwartz, the Arterial Group created the site-specific multimedia performance, *Elektrostatic Interference* (2001; Works, 109), at the Brisbane Powerhouse Turbine Hall in Australia. The piece incorporated Schwartz's renowned electro-pyrotechnics, using high-voltage current as a medium to create lightning-like effects wherein bolts of electricity jumped nervously, snapping and cracking from one electrode to another. This spectacle framed Arterial Group's

sociological analysis of the electrical power industry and its workforce, with special attention to health and environmental issues. Privately commissioned and permanently installed in New Zealand, Eric Orr's *Electrum* (1998), created in collaboration with engineer Greg Leyh, consists of a 130,000 watt Tesla Coil, the largest of its kind in the world at the time. Born in Croatia, Nikola Tesla, the Serbian inventor and Edison rival, sought to develop a means for the wireless transmission of electricity. Applying Tesla's theories, *Electrum* produces phenomenal effects as arcing tongues of electricity leap between the coils, producing loud sonic zaps, and generating an energetic field powerful enough to illuminate fluorescent lights held by members of the audience. Quietly exploring the conceptual relationship between electricity, networking and communication, in Victor Grippo's *Analogia I* (1970–7) hundreds of potatoes are wired to a voltmeter that displays the amount of current generated by this unlikely battery of tubers, suggesting that all living things are interconnected and animated by immaterial energy.

Networks, Surveillance, Culture Jamming

The growing interest in creating interactive contexts for aesthetic encounters dovetailed with the increasing predominance of electronic telecommunications, particularly radio and television, as arbiters of contemporary cultural and values. This, of course, made such media an important locus of critical artistic exploration. The theoretical roots of artists' use of telecommunications for bi-directional exchanges may be traced to German dramaturge Bertolt Brecht's manifesto, 'The Radio as an Apparatus of Communication' (1932; Documents, 228), which has offered ongoing inspiration to artists working with a wide range of interactive media.³² As artist Peter D'Agostino has noted, Brecht sought to change radio 'from its sole function as a distribution medium to a vehicle of communication [with] two-way send/receive capability...'³³ Brecht's essay proposed that media should:

[L]et the listener speak as well as hear ... bring him into a relationship instead of isolating him. On this principle the radio should step out of the supply business and organize its listeners as suppliers... [I]t must follow the prime objective of turning the audience not only into pupils but into teachers. It is the radio's formal task to give these educational operations an interesting turn, i.e. to ensure that these interests interest people. Such an attempt by the radio to put its instruction into an artistic form

*would link up with the efforts of modern artists to give art an instructive character.*³⁴

Indeed, many artistic experiments with television, video and other mass media have been motivated by a Brechtian desire to wrest the power of representation from the control of corporate media and make it available to the public. In the mid-1970s, Douglas Davis noted that, 'Brecht... pointed out that the decision to manufacture radio sets as receivers only was a political decision, not an economic one. The same is true of television; it is a conscious (and subconscious) decision that renders it one-way...'³⁵ Taking advantage of thirty minutes of free network broadcast time on WTOP-TV in Washington, D.C., Davis's *Electronic Hakkadim* (1971; Works, 122) was billed by the artist as the 'world's first participative telecast.'³⁶ Viewers called the station via telephone and the wave patterns of their voices, routed to Paik-Abe and Eric Siegel video synthesizers, affected the movement of video images on screen. As David Ross wrote in 1974, this work, 'linked symbiotically with its viewers whose telephoned chants, songs and comments reversed through the set, changing and shaping images in the process.'³⁷ Davis later commented,

*My attempt was and is to inject two-way metaphors – via live telecasts – into our thinking process. All the early two-way telecasts were structural invasions... I hope [to] make a two-way telecast function on the deepest level of communication ... sending and receiving... over a network that is common property.*³⁸

Davis's work exemplifies the long and distinguished history of artistic attempts to democratize media by enabling users to participate as 'content-providers,' rather than as passive consumers of pre-fabricated entertainments and commercial messages.

Another early artistic attempt at multidirectional exchange took place on 30 July, 1971, when E.A.T. organized *Utopia Q&A*, an international telecommunications project that joined participants in New York, Tokyo, Ahmedabad and Stockholm. Telex enabled the exchange of texts between the remote sites via specialized local terminals that printed out incoming information. Participants from around the world posed questions and offered prospective answers regarding changes that they anticipated occurring over the next decade. As Billy Klüver observed in one of the early communications posted during the event:

Our hope is that this project will contribute to recognition of

and contact between different cultures. We have chosen a medium which was invented in 1846 which is essentially mechanical and which was not developed since the late nineteenth century. Like print, its very simplicity provides access. We believe that this is the first worldwide people-to-people project, imagining their future.³⁹

Utopia Q&A poignantly utilized telecommunications to enable an interactive exchange across geopolitical borders and time-zones, creating a global village of ideas about the future.

The prohibitive cost and inaccessibility of satellite links and computer-networking imposed severe limits on the creative potential of telecommunications media for artists in the late 1970s and early 1980s. Through tremendous resourcefulness, expansive personal networks and, at times, great personal expense, the pioneers of telecommunications art prevailed in their exploration of this medium. Given the proliferation of the Internet in the 1990s, it is now hard to imagine how difficult and expensive it was for artists to get online. Lobbying by grass-roots community organizations enabled limited public

Association. Collaboration was a key aspect of the work, which was spearheaded by several artists affiliated with the artists' collective, Collaborative Projects, also known as Colab. Conceived by Keith Sonnier, Liza Bear served as project manager and Willoughby Sharp and Duff Schweninger rigged a military infrared transmission system between the mobile satellite transceiver (affectionately known as the 'Bread Truck') at the Battery Park landfill and the Manhattan Cable system downlink at the Rector Street subway station. Artists Sharon Grace and Carl Loeffler coordinated the San Francisco end, gaining access to a fully equipped studio. For six hours over a period of two days, participants on both coasts engaged in a two-way interactive satellite transmission, which was edited and displayed in a split-screen format that was distributed live within the respective cities via cable television. An estimated audience of 25,000 watched bi-coastal dance improvisations and music performances along with discussions on the impact of new technologies on art.

As an outgrowth of their 'Aesthetic Research in Telecommunications' projects begun in 1975, Kit Galloway and Sherrie Rabinowitz organized the *Satellite Arts Project: A Space with No Boundaries* (1977). With the support of NASA, the artists produced an interactive dance concert between geographically disparate performers, two in Maryland and two in California.

Composite images enabled the dancers to coordinate their movements, mindful of latency (time-delay), with those of their local and remote partners. In 1980, Galloway and Rabinowitz organized *Hole in Space*, a satellite project that connected two storefronts in New York and Los Angeles. The artists purposely displaced the work from an art context and set it into the flux of everyday life, where it became activated when people happened upon it by chance. As Hank Bull noted of the video documenting the piece, 'The results were astounding and often very moving... People sang songs together, played games, even made contact with long lost relatives.'⁴⁰

Perhaps the first artistic application of computer networking took place in the Sat-Tel-Comp Collaboratory (1978). This event was organized by the Direct Media Association, an artists' group formed by Canadian artist Bill Bartlett in British Columbia. Bartlett gained access to the I. P. Sharp Associates (IPSA) international computer-timesharing



access to satellite communications in the late 1970s, just as artists started gaining access to computer-conferencing networks. In 1974, Vera Frenkel's *String Game: Improvisations for Inter-City Video*, used Bell Canada's fledgling teleconferencing technology to connect artists in Toronto and Montreal, bridging the distance between them through a virtual game of cat's cradle. In 1976, Davis undertook the first work of art using satellite, *Seven Thoughts*, a unidirectional transmission from the Houston Astrodome. For Documenta 6 in 1977, performances by Paik and Moorman, Joseph Beuys and Davis's *The Last Nine Minutes* were broadcast via satellite to over twenty-five countries, including the Soviet Union.

The first transcontinental, two-way satellite broadcast, *Send/Receive Satellite Network* (1977; Works, 123), sometimes referred to as *Two-Way Demo*, involved an alliance between the Center for New Art Activities and the Franklin Street Arts Center in New York, Art Com/La Mamelle Inc. in San Francisco and NASA, with assistance from the Public Interest Satellite

network through Toronto-based artist Norman White, who had befriended IPSA programmer Bob Bernecky and received a free account. The Collaboratory used this precursor to Internet-based email to exchange texts between four sites in the US and Canada. It also used telephone lines for the transmission of slo-scan video images at a rate of one frame every eight seconds between the Open Space Gallery in Victoria, British Columbia and nine sites in Canada and the US.

Within a few years artists all over the world were using computer-networking as a bona-fide artistic medium, dubbed 'telematic art' by Roy Ascott in 1983. Robert Adrian played an important role in enabling artists to explore the medium's unique creative and expressive potentials by helping develop a free system sponsored by IPSA, known first as ARTBOX and later as ARTEX (Artist's Electronic Exchange.) Adrian was also a pioneering practitioner, whose most ambitious early work, *The World in 24 Hours* (1981; Works, 124) won the Golden Nica prize at Ars Electronica. This project used ARTBOX to connect sixteen cities on three continents, creating a global network of artists and artist groups, each of which organized a contribution that made use of any combination of slo-scan, fax, telephone and computer-conferencing to exchange and create sounds, texts and images.

Identified by *Leonardo* editor Roger Malina as an unsurpassed landmark in the history of telematic art, Ascott's *La Plissure du Texte* ('The Pleating of the Text', 1983; Works, 125) used ARTEX to explore the potential of computer networking for the interactive, collective creation or 'distributed authorship' of an artwork by remote participants. Collaborators at eleven locations in the US, Canada, Europe and Australia each represented a character, such as Witch, Sorcerer or Princess and participated in producing and contributing texts and ASCII images to the emerging 'planetary fairytale'. Ascott had envisioned remote artistic collaboration via computer networking in 1966 and organized his first such project, *Terminal Art*, in 1980. He claimed that the collective, process-oriented and emergent characteristics of distributed authorship in telematic artworks challenges the conventional categories of artist, artwork and viewer and the opposition of subject and object. Aspects of traditional narrative structure may remain, while others are relinquished in order to allow a more open-ended development, fashioned by participants involved in a multi-directional creative exchange. Unlike satellite, which demands that interaction be synchronized in

real-time, computer networking is asynchronous, a quality Ascott embraced for its ability to enable exchanges that metaphorically punch holes through both space and time. Following Pierre Teilhard de Chardin's concept of the noosphere and Peter Russell's notion of the global brain, Ascott's theoretical essays such as 'Art and Telematics: Towards a Network Consciousness' (1984, see Documents, page 231) and '*Is There Love in the Telematic Embrace?*' (1990) posited that telematic art enables an expanded, planetary consciousness that is greater than the sum of its parts.

The potential of telecommunications to allow individual and cultural freedom was at the heart of the major satellite telecast that Nam June Paik organized on New Year's Day, 1984. *Good Morning Mr. Orwell* was intended as a liberating and multi-directional alternative to the threat posed by 'Big Brother' surveillance that George Orwell warned of in his novel 1984, first published in 1949. Paik explained that,

Orwell only emphasized the negative part, the one-way communication. I see video not as a dictatorial medium, but as a liberating one. That's what this show is about, to be a symbol of how satellite television can cross international borders and bridge enormous cultural gaps... the best way to safeguard against the world of Orwell is to make this medium interactive so it can represent the spirit of democracy, not dictatorship.⁴¹

Broadcast live from New York, Paris and San Francisco to the US, France, Canada, Germany and Korea, the event reached a broad international audience and included the collaboration of, among others, artists Laurie Anderson, John Cage, Salvador Dali and Charlotte Moorman.

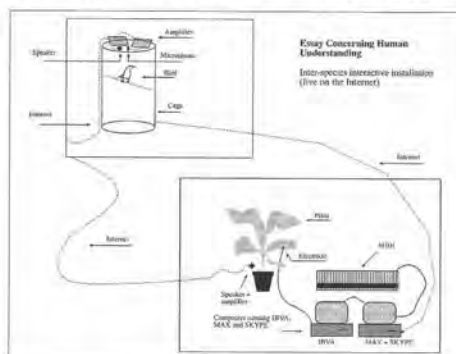
Paul Sermon's *Telematic Vision* (1993) builds on Ascott's theories of telematic art, joining them with the immediacy of bi-directional video transmission. It would be difficult to grasp either the playfulness or the emotional potency of this work without experiencing it directly. One participant reported feeling rejected by a counterpart at a remote location who sat next to him virtually on the sofa but spurned his overtures to interact. In another case, one person wanted to be more intimate than the other. Feeling violated by a phantom image, the less demonstrative participant felt compelled to leave. Sermon's *Telematic Dreaming* (1992), applied a similar strategy in an installation where participants virtually lay together on a bed, enhancing the feeling of intimacy.

Eduardo Kac has extended telematic interaction to plants and animals. *Essay Concerning Human Understanding* (1994),

created in collaboration with artist Ikuo Nakamura, facilitates remote communication between a canary in Kentucky and a philodendron plant in New York. As Kac explained,

*An electrode was placed on the plant's leaf to sense its response to the singing of the bird. The voltage fluctuation of the plant was monitored through a [computer] running software called Interactive Brain-Wave analyzer. This information was fed into another [computer]... which controlled a MIDI sequencer. The electronic sounds [sent from the plant to the bird] were pre-recorded, but the order and the duration were determined in real time by the plant's response to the singing of the bird.*⁴²

Although the piece focused on communication between the bird and plant, Kac noted that humans interacted with the bird and the plant as well, causing the bird to sing more or less, and the plant to activate a greater or lesser number of sounds. In this way, humans, plants and animals became part of a cybernetic system of inter-related feedback loops, each affecting the behaviour of the other and the system as a whole.



Perhaps the first artwork to join telematics and robotics, a research field known as telerobotics, was *Telephonic Arm Wrestling* (1986; Works, 126) by Norman White and Doug Back. The idea for the piece emerged from a bar-room conversation regarding the Arms Race. "Wouldn't it be great," Back asked, "if it could be resolved by arm-wrestling?" White explained that, 'the idea was to allow contestants in two different cities to arm-wrestle, using motorized force-transmitting systems interconnected by a telephone data link.'⁴³

Kac and Ed Bennett's *Ornitorrinco Project* (1992; see Documents, 234) joined telerobotics with 'telepresence'. Telepresence is a technologically mediated mode of awareness whereby one inhabits a point of view at a remote location and experiences what it is like to be physically present there. *Ornitorrinco* attempted to metaphorically generate empathy between real birds, a robotic bird and human members of the audience. A robotic bird incorporating video cameras for eyes was placed in a room-sized cage filled with live birds.

Through this telepresence system, viewers outside the cage were given a literal bird's eye view of what it is like to be a bird amongst birds from the perspective of the avian robot. Artist/engineer Ken Goldberg, working with a team of collaborators in the robotics lab at UC Berkeley, created *Tele-Garden* (1995). This work used a Web-based interface to enable remote participants from around the world to become part of a virtual community that collectively controlled a robotic device to seed and maintain a living garden. In 1996, Garnet Hertz, working in his garage in Saskatchewan, built *Interface*, a low-tech, Web-based telerobotic system that enabled remote participants on the Internet to view the interior of the garage, direct the movement of a mobile radio-controlled device in it and instruct the device to draw on the concrete surface, leaving a graphic trace of their telepresence.

In contrast to the idealism that characterizes these telematic and telerobotic works, electronic media have also been used to interrogate and actively fight censorship, corporate hegemony, pollution, gender discrimination and the proliferation of surveillance and control systems that threaten civil liberties. Concerned about the potential of technology both to support and resist censorship, *The File Room*, created by artist Antonio Muntadas with the collaboration of Paul Brenner and Maria Roussos in 1994 (Works, 129), is one the most provocative and enduring early works of Web-based art. It was conceived as an open-ended project comprised of a massive and expanding electronic database on the censorship of art. Utilizing the hyperlinking capacity of the Web, it provides a wealth of incisive information on the subject. In addition, users may contribute their own experiences of censorship, enabling the work to grow as a collaboration involving a global community of participators.

Also approaching the Web as an artistic means of resistance, the collaborative @TMark (pronounced 'artmark') serves as an activist consulting firm that uses subversive tactics to help artists fight hostile corporations, particularly with regard to issues of intellectual property. Two successful campaigns during 1999–2000 include defending the European artist-group eToy from a court injunction filed by Internet toy vendor eToys over rights to the domain eToy.com and defending the journal *Leonardo* from a law-suit filed by

Leonardo Finance, which was disgruntled because search engines returned the magazine higher in their rankings than the French financier. @TMark's culture jamming strategies against the eToys corporation resulted in a dramatic reduction of its stock-price and the case was dropped. The *Leonardo* strategy produced a plethora of protest websites, creating an even more competitive environment for search-engine results for Leonardo Finance, whose suit was dismissed by the court.

Heath Bunting's *Own, Be Owned, Or Remain Invisible* (1998; Works, 132) offers an ironic (mis)use of hyperlinking on the Web to question the utopian ideology of interactivity and connectivity by revealing the superfluous use of hypermedia, the unexpected presences and absences in cyberspace and the economic infrastructure of the Web. Taking a cue from Hans Haacke's artistic explorations of the systematic relationship between corporations, power and wealth, Josh On's Flash website, *They Rule* (2004), allows users to create maps that reveal the interconnected nature of board members at top US



companies. Users can post their own maps and see other's favorites. 'The Magnificent Seven', for example, visualizes the connections between seven individuals who, combined, sit on twenty boards and are but one-degree of separation from the boards of fifty-five other Fortune 500 companies. As the site ominously intones, 'They sit on the boards of Americas largest companies. Many sit on government committees. They make decisions that affect our lives. They rule.'

The relationship between industry and environmental pollution was made clear in Hans Haacke's *Rhine Water Purification Plant* (1972), which demonstrated how the river flowing through Krefeld, Germany, had been used as a repository for raw waste. Over three decades later, former US Vice-President Al Gore's influential film, *An Inconvenient Truth* (2006), helped raise popular awareness of the potentially catastrophic effects of carbon dioxide (CO₂), which has been linked to the destruction of the ozone layer and global warming. An increasing number of contemporary artists,

including Tiffany Holmes, Natalie Jeremijenko, Andrea Polli and Amy Youngs, are using electronic media to create artworks that explore questions of air, water and noise pollution and to employ art and design as a strategic tool for creating awareness and promoting conservation. For example, Beatriz DaCosta's *Pigeon Blog* (2006) used miniature air pollution sensors, GPS units, and transmitters attached to homing pigeons to evaluate and map local air quality, making that data available through the project website. Michael Mandiberg's *Real Costs* (2007) is a Firefox browser plug-in that inserts CO₂ emissions information into search results for flights from commercial travel websites, such as Orbitz.com. When researching airfares, the user retrieves not only the price in dollars but comparative data for carbon emissions for the journey by plane, car, bus and train, the number of tree-years required to offset the pollution and the annual per capita carbon emissions by country.

Electronic media also have been used extensively by artists to reveal attitudes and prejudices pertaining to gender. Cornelia Sollfrank's *Female Extension* (1997) is a legendary cyberfeminist art-hack. In response to the call for contributions for the net art exhibition 'Extensions', organized by the Gallery of Contemporary Art at the Hamburg Art Museum, she fabricated over 200 female alter-egos from seven countries and developed a software program that generated individual artworks for each of them. Delighted by the large number and diversity of contributions, the museum issued a press release noting that of the over 280 applications, two-thirds were from women. Despite the high proportion of ostensibly female submissions, the three top prizes were awarded to men and the jury failed to catch on to what the artist described as 'the apparently meaningless flood of data' produced by her 'automatically generated net art.'⁴⁴

Jodi.org, initially launched by artists Joan Heemskerk and Dirk Paesmans (Jo + Di) around 1995, is a Web-based artwork that uses the medium's vernacular as its content in a similarly critical manner. Although it has changed over the years, accessing the website in 1999 resulted in an ironic pseudo-error message, '403 Forbidden directory browsing is enabled on this server'. Instead of an error message suggesting that one may not browse the forbidden directory, here such browsing had been enabled. Other layers of the site could be accessed only by breaking in. This disruptive element paradoxically inhibited and enabled the exchange of

information, a seeming provocation to undermine the error message, to try to figure out a way around the authoritative, technologically-closed front door and gain entry by prying open a side window. Indeed, by manually changing the URL, one could receive another message, '404' (the typical error message received when a server cannot find the requested URL), which ironically had active hyperlinks to other interactive parts of the site. As artist Cary Peppermint has written,

*Jodi.org removes the shimmering facade of the World Wide Web. There is no longer a seductive guise of glamorous sound bytes and Photoshop splendor... We find the 'organism' exposed. Raw, writhing, pixelated code, unruly windows, and routines sometimes crashing the browser. This is our baptism in information technologies...*⁴⁵

The issue of surveillance that was raised in Nauman's *Live Taped Video Corridor* and reinforced in Steina's *All-Vision* was made more explicit in Robert Adrian's *Surveillance I* (1979), in which the artist produced a videotape of himself captured on



surveillance cameras as he walked through the Karlsplatz subway station in Vienna. Inspired by the situationist theory of détournement, since 1996, the New York Surveillance Camera Players have been enacting agit-prop theatre performances, based on sources including George Orwell's 1984 (1949) and Wilhelm Reich's *The Mass Psychology of Fascism* (1933), in front of publicly installed surveillance cameras.

Artists Julia Scher and Steve Mann have raised further challenges to issues of technology and surveillance. In her ongoing series since 1989, 'Security by Julia' (Works, 127), Scher has used performance, the Web and multimedia installation to increase people's awareness of various monitoring systems. Mann, on the other hand, has made himself into a cyborgian surveillance system by donning ever-more sophisticated wearable computing apparatus (Works, 126). These WearComp devices, as he calls them, contain recording equipment that allow him to monitor, in real-time, whatever locale he happens to occupy, and also to process that

information using an onboard computer. This enables expanded forms of perception and environmental adaptability, an instance of what Ascott has theorized as 'cyberception'.⁴⁶

In 2001 the ZKM held the exhibition, 'CTRL [SPACE] Rhetorics of Surveillance from Bentham to Big Brother', including the work of fifty-nine artists. Permanently installed at the ZKM since 2006, Marie Sester's public art installation, *ACCESS* (2001–3), uses a computer vision system controlling a robotic spotlight and acoustic beam that automatically track and follow individuals without their consent or ability to escape. After being mistakenly placed on the FBI's list of suspected terrorists in 2002 and repeatedly interrogated by US officials, Bangladesh-born, New York-raised artist and Rutgers University professor Hasan Elahi launched *Tracking Transience*, an exercise in self-surveillance that uses GPS (Global Positioning System) and the Internet to allow anyone, including federal agents, to know his whereabouts. In her public performances of *Life: A User's Manual* since 2003, artist

Michelle Teran has led guided walks through urban areas, hacking into surveillance cameras to map and make visible the proliferation of the invisible private wireless CCTV streams that monitor our movements. Also claiming the streets as the domain for their subversive art activities, Graffiti Research Lab has used electronic media, including magnetic LEDs and laser-guided projections,

rather than spray-paint or markers, to create luminous and spectacular interventions in public spaces (Works, 187). Their technologies are all open-source, encouraging other aspiring multimedia graffitiists to leave their own electronic tags.

Just as Paik used a satellite telecast to express the possibility of liberation and joy in contrast to Orwell's message of surveillance and control, so the advent of GPS technology and other forms of locative media have provided tools for artists to generate alternative forms of geography and mapping and to invent novel modes of awareness, interaction and exchange. In 2005, Latvian artists Esther Polak and Ieva Auzina, with Marcus The, Raitis Smits and the Riga Center for New Media Culture, won the Ars Electronica Golden Nica award for Interactive Art for *MILK* (2004; Works, 139). This multimedia installation uses GPS technology to map and visualize the continuous global flow of milk from the udder of a cow in Latvia to the consumer's plate in the Netherlands. Participants, including farmers, cheese

producers and consumers, offer reflections on their personal positions in relation to the transnational MilkLine, a flow that knows 'no borders, just land with people and things. People and things that move.'⁴⁷ For *Sun Run Sun* (2008), Yolande Harris created gumstick-sized, GPS-enabled musical instruments called 'satellite sounders', which generate live electronic music compositions based on the changing latitude and longitude coordinates of the player roving the earth and on the characteristics of a varying array of satellites orbiting the heavens. As such mobile locative devices become increasingly powerful, flexible, and ubiquitous, one can expect a proliferation of such work and the integration of its ideas into popular culture.

Bodies, Surrogates and Emergent Systems

I saw – with shut eyes, but acute mental vision, – I saw the pale student of unhallowed arts kneeling beside the thing he had put



together. I saw the hideous phantasm of a man stretched out, and then, on the working of some powerful engine, show signs of life, and stir with an uneasy, half vital motion. Frightful must it be; for supremely frightful would be the effect of any human endeavour to mock the stupendous mechanism of the Creator of the world.

–Mary Shelley, *Frankenstein: or, The Modern Prometheus*, 1818

Myth and legend abound with tales of artists, spiritualists, and scientists imbuing base matter with the qualities of living beings, including vitality, intelligence, development and reproduction. In Ovid's *Metamorphoses*, the artist-king Pygmalion, aided by Aphrodite, brought to life a marble sculpture of a woman, known as Galatea. In the sixteenth century legend of the golem, a lump of clay was brought to life by breathing a form of God's name into it. In Shelley's pre-Victorian techno-thriller, electricity is the animating force that brings matter to life. In the 1960s, Jack Burnham prophesied that, 'As the Cybernetic art of this generation grows more

intelligent and sensitive, the Greek obsession with "living" sculpture will take on an undreamed reality.'⁴⁸ Concerning the cultural and social implications of the growing field of robotic art in the 1990s, artist Eduardo Kac noted that,

*If artists working with or interested in robotics cannot ignore mythological, literary or industrial definitions of robots ... it is also true that these definitions do not directly apply to any given robotic artwork ... As artists continue to push the very limits of art ... they introduce robotics as a new medium at the same time that they challenge our understanding of robots – questioning therefore our premises in conceiving, building, and employing these electronic creatures.'*⁴⁹

Indeed, some contemporary artists have joined their own bodies (and/or those of their audiences) with electronic media and created robots and other forms of surrogate beings in order to examine the cyborgian aspects of human existence and to ponder what a post-human existence might comprise.

Others have used genetic algorithms or viral behaviour to

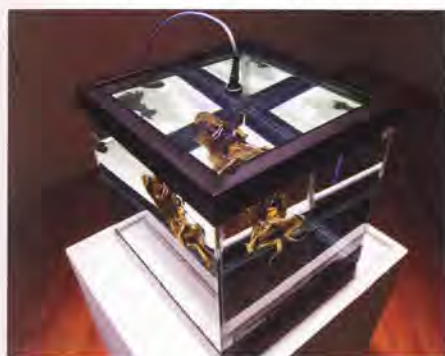
create and study self-organizing systems that possess many qualities of life itself, such as the replication and dissemination of information, or survival and reproduction in competitive environments. In many cases, artists have attempted to bridge the apparent divide between carbon-based organisms and silicon forms of intelligence and life, between the real and the

artificial, suggesting that these distinctions are becoming increasingly blurry and permeable.

Contributing to this ongoing dream of endowing base-matter with the qualities of life, Nam June Paik and Shuya Abe created one of the first art robots. *Robot K456 with 20-Channel Radio Control and 10-Channel Data Recorder*, 1965, was an anthropomorphic automaton whose aluminium skeleton was fancifully decorated with a pair of sponge-rubber falsies, suggesting a gendered humanity. In 1971, on the occasion of Paik's retrospective at the Whitney Museum of American Art, *Robot K456*, which by then had entered the museum's collection, enacted a memorable work of performance art. Strolling down Madison Avenue before an eager audience, the robot was broadsided by a taxi-cab, a staged event Paik referred to as *The First Accident of the 21st Century*. Paik also incorporated electronics and performance with collaborator Charlotte Moorman, in works such as the notorious *Opera Sextronique* (1967), which resulted in Moorman being arrested

for performing topless, and *TV Bra* (1968; page 4) in which Moorman's cello was wired to the electronic bra so that she was able to perform the video images emanating from her chest.

Also pushing the boundaries between organic and electronic bodies, Edward Ihnatowicz's *Senster*, (1969–70; Works, 141) was an interactive sculpture modelled on biological systems, in this case a lobster-claw. Like the artist's earlier *Sound Activated Mobile* (SAM, 1968), it responded smoothly and gracefully to the presence of the audience, simultaneously delighting and frightening those who encountered it and were encountered by it. Taking a different but equally organic approach to robotic art, Thomas Shannon's *Squat* (1966; Works, 142), was connected to an ivy plant. When the plant was touched, the changes in its electronic potential triggered motors that caused the sculpture to respond to the presence of viewers. Inspired by the notion that plants can respond to human emotions (a hypothesis



known as the Backster Effect), in the early 1970s architect John Lifton attached electrodes to a plant, the output voltages of which drove a sound synthesizer. Guided by different principles

though applying related techniques, Christa Sommerer and Laurent Mignonneau's *Interactive Plant Growing* (1993) incorporates real plants as an interface that, when touched by viewers, generates the growth of A-Life plants projected on a screen. Amy Youngs' *Rearming the Spineless Opuntia* (1999) combines sensors and a robotic, thorned shield that protects a genetically engineered, spineless cactus when would-be predators enter its vicinity. In *Experiments in Galvanism* (2003), Garnet Hertz implanted a Web-server in a preserved frog, the legs of which twitch when electrically stimulated via the Internet. Revelling in the jouissance of cause and effect, Hertz reflects light-heartedly on scientist Luigi Galvani's late eighteenth century experiments with electrophysiology that inspired Shelley's conception of Frankenstein, updating them with microelectronics and telerobotics. And in yet another take on joining organic and electronic media, in Adam Zaretsky's *MMMM* (*Micro Macro Music Massage*, 2001), sounds made by participants lounging in massage chairs altered the vibrational

energy in each other's seats as well as in plate speakers underneath flasks of phosphorescent *E. coli*, causing the transgenic organisms to 'bounce, splash, stretch, bear-down and/or jump to attention in response to the audio source.'⁵⁰

Lynn Hershman Leeson's *CybeRoberta* (1971–98; Works, 144) exemplifies the continuities between embodied performance and telematic art. This work furthers a cycle that spans the artist's early performances involving her human alter-ego Roberta Breitmore begun in 1971 through two decades of producing electronic art, leading to the creation of Breitmore's telerobotic alter-ego, CybeRoberta, and her Second Life re-incarnation in *Life Squared* (2007). These works share themes of voyeurism and surveillance that Hershman has explored since the 1970s. *Lorna* (1978), for example, is a story about a lonely woman who never leaves her apartment or has contact with the outside world, except through her television and telephone. The random-access capabilities of videodisk enable the users to interactively navigate a non-linear cinematic narrative: they may choose to observe Lorna's daily routine, see what she sees in her mirror or on TV, and so on. As with *Aspen Movie Map* (1978), by selecting a particular path the unfolding experience can branch in a variety of directions. This ultimately leads, as Hans-Peter Schwarz has noted, to one of three possible outcomes for Lorna: 'despair and death by suicide, departure and escape by leaving the apartment followed by air travel, and – maybe the most thrilling variant of all – shooting the television.'⁵¹

In Dick Raaijmakers' *Graphic Method Bicycle* (1979), a nude performer astride a bicycle was wired to sensors that transformed his breathing, pulse, perspiration and muscle contractions into sound during an excruciatingly slow and physically demanding ten metre performance. More than any other artist, Stelarc has challenged the physical limits of the human body with respect to technology. Perhaps best-known for his controversial suspension performances, begun in 1976, in which he suspends his body (which he invariably refers to as 'the body') by cables attached to meat-hooks inserted in his flesh, Stelarc has used electronic media in his artwork since the mid-1970s. Indeed, these two aspects of his practice are integrally related to his theories on the body's obsolescence. As in Hershman's work, the performative body and the cyborgian body are continuous in Stelarc's oeuvre. In some of his performances, such as *Evolution* (1983), which employs the *Third Hand* (1981), the artist retains full control of robotic

devices, activated by EMG signals of his abdominal and leg muscles. By contrast, in *Ping Body* (first performed in Sydney, 1996; Works, 154), Stelarc subjected his body to the control of the more or less random ebb and flow of amorphous data on the Internet, which triggered involuntary physiological responses, causing his arms and legs to jerk in a mysterious and disturbing dance.

The complex layers of control and authority with respect to the cyborgian body and electronic systems were explored in *Epizoo* (1995; Works, 153) by Spanish artist Marcel·lí Antúnez Roca. In the tradition of Yoko Ono's *Cut Piece* (1966) and Marina Abramovic's *Rhythm 0* (1974), the artist submitted his body to the whims of the audience. By activating motorized devices, viewers manipulated Roca's nose, mouth, ears, glutea and pectoral muscles, causing bizarre contortions. Like the unwitting subjects in psychologist Stanley Milgram's 1974 study 'Obedience to Authority: An Experimental View' (sixty-five percent of those tested agreed to mete out the maximum



punishment of 450 volts, several ticks beyond the indication, 'DANGER: SEVERE SHOCK'), so the audience of *Epizoo* was confronted with taking responsibility for its actions and the effects they caused on the performer, who was at their mercy.

Following the inquiries of Gustav Metzger and Jean Tinguely into the relationship between the body, technology and destruction in art, Survival Research Laboratory (SRL), founded in 1978, makes robotic artworks that reveal the devastating power of technology. SRL's *Increasing the Latent Period in a System of Remote Destructibility* (1997), models a prospective future when robots act autonomously, communicating with other robots and machines to unleash destructive force on human and non-human targets. Just as Stelarc and Roca reverse the master-slave relationship between human and machine, so SRL's work explicitly enacts the potential dangers of surrogate agents rather than celebrating the utopian ideal of technologically mediated agency.

Norman White, who created his first robot, *Menage*, in

1974, collaborated with Laura Kikauka to make *Them Fuckin' Robots* (1988), which, like *Increasing the Latent Period*, involves an interaction between anthropomorphic surrogates. Whereas Gordon Pask's earlier cyborgian mating ritual *Colloquy of Mobiles* (1968, see page 185) requires cooperative behaviour between male and female components, the explicitly sexual *Them Fuckin' Robots* suggests a robotic battle of the sexes. Magnetic fields generated by the female organ cause an increase in the male's breathing rate while charging a capacitor to strobing 'orgasm'. The female bot includes a boiling kettle, a squirting oil pump, a twitching sewing machine treadle and a huge solenoid, set on a fur-covered board.

On the more intellectual end of the spectrum of robot-to-robot interaction, in Ken Feingold's *If/Then* (2001), two talking robotic heads are nestled in packing peanuts in a cardboard shipping box. Complete with voice-synthesizers and motors that synchronize their mouth movements, they engage in a spoken philosophical discussion on the meaning of life.



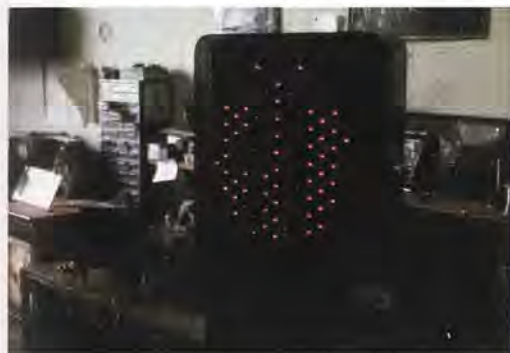
Drawing on natural language artificial intelligence research, such as ELIZA, Joseph Weizenbaum's famous 1966 computer program that emulated a psychotherapist, the conversation between the two bots is internally coherent but also very limited. Though human observers have found aspects of

these robotic exchanges to be profound and humorous, the existential conversation could go on infinitely without anything of lasting value being communicated between the robots. Even if it did, how would anyone know? Feingold's updated Galateas ironically propose a future in which angst-ridden machine intelligences will wax poetic about their silicon navel lint.

Expanding the bot-to-bot dialog, David Rokeby's *n-Cha(n)t* (2001) creates a community of artificially intelligent bots that communicate with each other. Developed at the Banff New Media Institute, the bots in this 2002 Prix Ars Electronica winner share the complex linguistic database generated by the artist's ongoing work, *The Giver of Names* (1991). They are programmed to engage in an internally coherent conversation, ultimately converging on a common 'chant' when they are part of a closed-system, unperturbed by external stimuli. But each of the bots is connected to a microphone that opens the system to interaction with human participants. A video image of a person's ear, displayed on each of several monitors,

visually represents the current state of each artificially intelligent bot: receptive to the spoken input from a viewer, concentrating on previous input, making associations or overstimulated. If it is receptive, when a visitor speaks a word or phrase into a microphone connected to a bot, the spoken input is translated by voice recognition software and displayed as text on the screen. This text then triggers the bot to make associations using the *Giver of Names* system. As this perturbation causes it to fall out of synch with the other bots in the community, it communicates these associations with its nearest neighbours, triggering a series of further associations that drive the whole community to diverge from the chant. Without further external stimulation, the new input will drive the community as the dominant stream of its thoughts until it again converges on a common chant.

Complementing art research on robotics and artificial intelligence, artists have embraced the relatively new field of artificial life. Such work draws on earlier experiments involving



algorithmically generated images, such as Norman White's cellular automata experiments in the late-1960s and Mandelbrot's visualization of fractals in the mid-1970s. Building on similar and related ideas, art research with theoretical foundations in cybernetics, autopoiesis, emergent behaviour and artificial life was vitalized in the 1990s, when it became possible to run simulations of evolutionary systems, such as Tom Ray's *Tierra* programme, on a personal computer.

Artists were quick to enter the fray. One of the first was Michael Joaquin Grey, who, with collaborator Randolph Huff, utilized genetic algorithms processed by a supercomputer to generate forms that were analogous to actual species. *Jelly Lovers* (1991), for example, bears an uncanny resemblance to jellyfish but is the emergent result of exhaustive iterations of relatively simple instruction sets. Karl Sims received the MacArthur Foundation 'genius award' for works such as *Genetic Images* (1993; Works, 150) and *Galapagos* (1997). Modelled on evolutionary theory and the principle of natural

selection, these works allow Sims to visualize artificial life forms and animates competitions between them for scarce resources. In *A-Volve*, 1994, an elaborate interactive installation by Christa Sommerer and Laurent Mignonneau (Works, 152), participants select various features to produce their own aquatic artificial life forms. These enter a virtual pool, which is projected onto an actual pool of water, and participants can interact with them by petting them. *A-Life* was hybridized with the Web in Jane Prophet's *TechnoSphere* (1995; Works, 130), which has been described by the artist as 'an evolution simulator that enabled people to create their own creatures and communicate with them as they grow, evolve and die in a virtual three-dimensional environment.'

Ken Rinaldo's *Autopoiesis* (2000; Works, 160) constitutes a community of robotic sound sculptures that interact with each other and the audience, resulting in emergent collective behaviour. Biologists Humberto Maturana and Francisco Varela use the term 'autopoiesis' to refer to the tendency of a system to establish its own organizational structure and maintain its internal state of organization, even as it is structurally coupled with other systems. They extend this metaphor from biology at the cellular level to culture at a social level. Similarly, Rinaldo's *Autopoiesis*, like Pask's *Colloquy of Mobiles* (Works, 185) and Rokeby's *n-Cha(n)t*, explores social interactions between robots and between humans and robots. Artistic inquiries involving cellular automata and autopoiesis also have been carried out by the UK collective boredomresearch, in works such as the Web-based project, *Wish* (2006).

In addition to these artistic examples of robotic surrogates, intelligent agents, and cyborgian hybrids that approximate the behaviour of living systems, artists have used a variety of other strategies to interrogate the relationship between the body and electronic technology. One strategy involves creating virtual electronic bodies and avatars. *Bodies INCorporated* (1996–9) by Victoria Vesna and collaborator Rob Nideffer, consists of a Web-based community of avatars created and owned by 'members' who select the traits of their digital surrogates. By participating in the community, members gain shares and symbolically climb the corporate ladder, becoming first 'adepts' then ultimately 'avatars', signifying their diminished attachment to flesh reality and increasing acculturation to cyberspatial reality. *Le Messenger* ('The Messenger', 1995;

Works, 155), developed by Catherine Ikam and Louis Fléri for IRCAM (Institut de Recherche et Coordination Acoustique/Musique) in Paris, uses a 3D digital scan of a model's head to create an interactive virtual environment. The massive, disembodied head, enlarged to two metres and projected on a screen, recalls the wizard's avatar in Victor Fleming's *The Wizard of Oz* (1939) and anticipates Dr. Know, the holographic fortune-teller in Steven Spielberg's film of Stanley Kubrick's screenplay *Artificial Intelligence: AI* (2000). Sensors in the installation track the motion of the audience and the Messenger uncannily responds as though it were looking at the viewer, following his or her movements with its eyes. To create *BodyScan (IN/OUT)*, (1997; Works, 178), Austrian artist Eva Wohlgermuth had her own body accurately scanned and rendered digitally in three dimensions. Using this as a foundation, the artist subjected her digital body to a wide variety of transformations and re-contextualizations, disembodying her 3D self-portrait from the materiality of



corporeal existence and setting it free, so to speak, in virtual reality and cyberspace.

Electronic media have begun to cross the threshold between silicon-based systems and biological systems, instigating public dialogue about the social implications of biotechnology.

In Kac's *Genesis* (1999; Works, 158), live bacteria were genetically modified to contain – coded within their DNA – a text from the biblical Book of Genesis, 'Let man have dominion over the fish in the sea, and over the fowl of the air, and over every living thing that moves upon the earth.' Participants, both locally and remotely over the Internet, could turn on an ultraviolet light at the installation, causing mutations in the bacteria's genetic code, which in turn caused alterations in the biblical verse after the DNA was decoded and reconstituted as text. Like Roca's *Epizoo*, *Genesis* raises questions about the shared responsibility of individuals to care for other living beings – in this case, to control environmental factors that are known to cause genetic mutations. Combining a concern with automata, biology and destruction, Joseph Nechvatal's work with genetic algorithms for artificial viruses has resulted in striking images of extraordinary complexity, executed in oil-paint applied by a robotic device (Works, 160). For *Fish and Chips* (2001; Works, 163), the Tissue Culture and

Art project collaborated with the SymbioticA Research Group at the University of Western Australia in Perth to grow fish neurons over silicon chips, connected to video and audio output devices, creating a cyborgian confluence of hardware, software and 'wetware', the latter referring to biotechnological media, as distinct from the silicon-based media of computers. This semi-living entity was endowed with the ability to make sound and images – in other words, to make art – begging questions about the future of human interaction with cyborgs whose behaviour may be unpredictable, if not creative.

Simulations And Simulacra

Pliny (23–79 AD) recounts the legend of grapes painted by Greek artist Zeuxis (5–4c. BC) that were so life-like that birds attempted to eat them. Not to be outdone, rival painter Parrhasius presented his work to Zeuxis, who attempted to pull back what appeared to be a curtain covering the painting, only to discover that the 'curtain' was the painting. Such accounts attest to the ongoing pursuit by artists to create simulations that are so convincingly true to life that they fool the eye into thinking they are real. Continuing this long tradition, panoramic paintings, photography, stereoscopy and cinema in the nineteenth century attempted to provide ever more compelling illusions that emulate the experience of being in the midst of an actual scene. In this context, it is worth recalling that in 1895, some viewers of the Lumière brothers' first publicly presented film were purportedly so afraid of a moving image of a train shown approaching the near-ground of the screen that they fled the theatre! Following this thread, the 1960s saw the initial development of navigable, interactive, computer-generated environments that later came to be known as virtual reality (VR), first used for artistic purposes in the 1970s. The 1970s also saw the emergence of commercial videogames such as PONG in which participants interactively played a simulated game of ping pong viewed on a television screen. In 1982, movie audiences were entranced by the stunning use of computer graphics to envision a digital virtual environment in the stylish sci-fi film *Tron*. Multimedia personal computing enabled the creation of increasingly complex and visually sophisticated computer-games, such as MYST in 1994. A year later, *Toy Story* took honors as the first motion-picture created solely by computer animation. Also in the mid-1990s, the growth of the Web made it possible for simulations and simulacra to exist in cyberspace and for

multiple users to share and interact with the same 'consensual hallucination' of a simulated environment.

By the mid-2000s, videogame sales exceeded box-office revenues for the motion picture industry in the US, propelled by increasingly compelling illusionism in games such as Halo and Half-Life 2. The convergence of computer-gaming and the Web enabled people from around the world to play with each other over the Internet, competitively or socially, as in The Sims. Artists, such as Mary Flanagan (Works, 181), began using game engines to create works of art and filmmakers did the same, giving rise to the genre known as 'machinima', exemplified by the popular online series, Red vs. Blue. In *Last Riot* (2005–7), Russian collective AES+F cast beautiful, scantily clad youth as protagonists in ultraviolent high-definition 3-D battle-scenes modeled after popular videogames, such as America's Army, which was designed to lure teens into the US military. In 2003, the 3-D virtual world known as Second Life (SL) was launched, creating a platform for 'residents' to view



and modify the SL community and participate in its virtual economy, including the production and sale of art. On 18 October, 2006, the population of SL hit one million residents and grew to over twelve million by February, 2008.

Simulations are copies that share many attributes with the concrete originals that they represent (i.e. a painting of grapes: real grapes). By contrast, the term 'simulacra' can refer to a form of similarity particular to media culture, wherein distinctions between original and copy become increasingly murky. The originals may no longer exist, may never have existed, or their significance has been dwarfed in comparison to the simulacra, which attains a level or primacy and authenticity that traditionally had been the exclusive province of the original. As Jean Baudrillard has written:

Abstraction today is no longer that of the map, the double, the mirror or the concept... It is the generation by models of a real without origin or reality: a hyperreal. The territory no longer precedes the map, nor survives it. Henceforth, it is the map that

*precedes... that engenders the territory.*⁵²

Simulacra may be understood as second-order simulations, or simulations of simulations, wherein that which is being simulated is presented and received not as a simulation but as an original.

Les Levine's *Systems Burn-Off x Residual Software* (1969) is an early and insightful meditation on the implications of simulacra and the conditions in which they flourish. Like Levine's earlier video-works, such as *Contact: A Cybernetic Sculpture* (1966; Works, 103), *Systems Burn-Off* was informed by cybernetics, systems theory and media studies but used 'unplugged' media. The work consisted of 1000 copies of each of 31 photographs documenting the March, 1969 opening of the highly publicized 'Earth Works' exhibition in Ithaca, New York. Except for a few that were for sale, the 31,000 images were randomly scattered on the floor and covered with gelatine or stuck to the wall with chewing gum. Levine suggested that the proliferation of mass media was changing knowledge into

a second-hand mental experience of simulated representations or simulacra:

*All activities which have no connection with object or material mass are the result of software. Images themselves are hardware. Information about these images is software... In many cases an object is of much less value than the software concerning the object.... [I]n a software controlled society ... anything seen through the media carries just as much energy as first hand experience... In the same way, most of the art that is produced today ends up as information about art.*⁵³

Electronic media offer artists extraordinary opportunities for producing simulations and simulacra. None of these tools have captured the imagination more than virtual reality (VR). Typically, VR manifests a direct correspondence between real and virtual space and a predictable cause-and-effect relationship between one's actions in the former and the way in which the latter responds to them, i.e., a user's physical movement forward in real space might correspondingly alter

his/her apparent position forward in the simulation. By 1970, Sketchpad inventor Ivan Sutherland also had developed the first head-mounted computer display (HMD), a common device for rendering the interactive visual environments of VR.

VR's many uses include pilot-training for the military and travel industry, virtual 'walk-throughs' of a proposed architectural structure, digital reconstructions by archaeologists of a lost building or city and environmental modelling for resource management and prospecting. Such applications demand a close correspondence between reality and virtual reality. Painting, photography and cinema have conditioned viewers to modes of simulated experience that require the suspension of disbelief. Similarly, many VR installations typically utilize immersive environments to help users bracket out their knowledge that the fictional world they are experiencing is the product of computers and projectors in order to imagine it as 'an autonomous reality populated by solid objects and embodied individuals.'⁵⁴ By the same token,



in an attempt to extend the embodied experience of multimedia, artists have created virtual models that translate between spatial and temporal dimensions.

Marcos Novak's *Liquid Architectures* (begun 1991; Works, 169), for example, consist of virtual, multidimensional, multimedia architectural constructs that evolve over time. Art+Com's *The Invisible Shape of Things Past* (1997; Works, 176) transforms a temporal sequence of two-dimensional video images into a static three-dimensional object. In these examples, VR extends Vera Molnar's ambition to create 'unimaginable' combinations 'never seen before'.

Because there are many different types of virtual reality and diverse technologies to support them, VR has taken various forms in art. One important distinction in VR revolves around the degree to which the user is encumbered by the technical apparatus. In unencumbered VR, the user need not wear special equipment; the installation space itself is capable of tracking movement and responsively generating corresponding changes in the virtual environment. In encumbered VR, equipment such as a motion-tracking device, HMD, data-glove that responds to hand and finger motions,

tracking and force-feedback mechanisms or other apparatus must be worn by the user. There are trade-offs in terms of the suspension of disbelief in both cases. Unencumbered VR benefits from the realism afforded by the absence of the invasive apparatus that constantly reminds users wearing encumbered technologies that they are in a highly mediated environment. Encumbered VR benefits from more precise interactivity and more responsive output, which enhances the realism of content and responsiveness. As David Rokeby notes in his essay, 'Transforming Mirrors' (see Documents, page 223), some artists do not attempt to suspend the user's disbelief, but rather strive to employ the unmistakably mediated qualities of VR as part of the vernacular of their work in order to draw attention to the material and technical constraints of human machine interfaces. Pushing VR in yet another direction, technologies known as augmented reality and mixed reality seek to join aspects of the direct perception of reality with aspects of the mediated experience of virtual reality, a combination that promises many potential medical, military, commercial and entertainment applications.

The first use of VR in art emerged from Myron Krueger's graduate research in human-machine interface design in the late 1960s and early 1970s. Krueger envisioned a playful 'responsive environment', in which one could interact with computers intuitively through body movement and gesture. Nothing of the sort existed. Following a long line of artist-inventors, Krueger's desire for a particular sort of aesthetic experience inspired him to create the technologies required to realize his dreams. Deceptively simple in appearance, Krueger's *Metaplay* (1970) and *Video Place* (1974–5; Works, 166) demanded significant accomplishments in both art and engineering in order to ensure that the system responded smoothly and predictably to the behaviour of the user. In these works, which anticipate the Wii videogame (2006) by over three decades, the participant's gestures trigger a graphic response that is projected on a screen next to the user's shadow. Krueger's pioneering VR art explicitly makes the viewer an active participator in shaping the unfolding action of the piece. At the same time, it results in a performative spectacle that is almost as engaging for a bystander observing the action as it is for the user. Krueger also has made valuable contributions to the theorization of VR in the context of art: in the mid-1970s he coined the term 'artificial reality' to refer to the technologies he and others were developing; and in 1983,

he wrote a classic text on the subject, *Artificial Reality*, updated and reprinted in 1991 as *Artificial Reality II*.

Due to the expense and technical expertise required to work with virtual reality, little artistic inquiry in this field occurred until the 1990s, when VR research by artists began benefiting from substantial corporate and institutional support. In the early 1980s, Jaron Lanier, who coined the term 'Virtual Reality', was head of VPL Research, a company that sold VR products, including data-gloves and head-mounted displays. With these resources, he developed *The Sound of One Hand* (1992), a virtual environment for music performance. This work includes a variety of musical instruments, some simulating conventional ones and others that are simulacra and have no actual referent in the physical world. As head of Visual Research for Canadian software firm Softimage from 1987–97, Char Davies participated in the development of cutting-edge VR software and interface design, producing the artworks *Osmose* (1995; Works, 175) and *Ephemere* (1998).



In 1991 the Banff Centre in Canada created VR facilities and began sponsoring residencies that enabled artists to research and experiment with this emerging medium, yielding some of the first VR artworks. These include Catherine Richards' *Spectral Bodies* (1991), Brenda Laurel's *Placeholder* (1992), Michael Naimark's *See Banff!* (1993), and Perry Hoberman's *Bar Code Hotel* (1994). Based on technology evolved from *Aspen Movie Map* (1978) at MIT, Naimark's work uses a retro device resembling a nineteenth century Edison Kinetoscope as the interface that allows viewers to experience an interactive, stereoscopic VR representation of Banff.

In Germany, the Institute for New Media (INM), founded in 1989 by Peter Weibel at the Städelschule in Frankfurt am Main, was the locus of important VR art research by artists including Weibel, Christian Möller and Ulrike Gabriel (Works, 170). Students, often working in collaborative teams produced outstanding work. For example, Christa Sommerer and Laurent Mignonneau's *Interactive Plant Growing* (1993) won a

Golden Nica at Ars Electronica in 1994 and alumni Constanze Ruhm and Peter Sandbichler exhibited *Kanal* at the Austrian Pavilion at the Venice Biennale in 1995. Spearheaded by Michael Saup, the Supreme Particles was founded at the INM in 1992 and has included various members, including Dutch programmer Gideon May. Indeed, technical genies like May, Bert Bongers, and Sukandar Kartadinata are the unsung heroes of electronic art, and their creative contributions to this growing field deserve wider recognition.

At the Zentrum für Kunst und Medientechnologie (Center for Art and Media Technology, ZKM) in Karlsruhe, where Jeffrey Shaw was founding director of the Institute for Visual Media from 1992–2003, artist residencies and superb resources and personnel (May was software developer and systems administrator there from 1990–3, followed by Christian Ziegler and Volker Kuchelmeister) enabled international artists to develop important work, including Luc Courchesne's *Portrait One* (1990; Works, 168), Tamas Waliczky's *The Forest* (1993),

Miroslaw Rogala's *Lovers Leap* (1994–5; Works, 172), Jill Scott's *Frontiers of Utopia* (1995; Works, 174), Masaki Fujihata's *Beyond Pages* (1995; Works, 173), Toshio Iwai's *Piano as an Image Media* (1995; Works, 113) and Bill Seaman's *The World Generator* (1996–8). Indeed, the mid-to-late 1990s at the ZKM was a heyday of artistic and technological innovation involving

electronic media.

In the US, universities have been a primary site for art research involving VR. At the Interactive Telecommunications Program at New York University, Camille Utterback and Romy Achituv created *Text Rain* (1999), a piece that carries forward the spirit of Krueger's playful approach to unencumbered VR. Participants stand or move in front of a large projection screen where they see a mirrored video projection of themselves in black and white, combined with a colour animation of falling text. Like rain or snow, the text appears to land on participants' heads and arms. The text responds to the participants' motions and can be caught, lifted and then let fall again, landing on anything sufficiently dark and falling whenever that obstacle is removed.

In a similar manner, artist Victoria Vesna and scientist James Gimzewski, both at UCLA, collaborated on *Zero@Wavefunction* (2003), which allows participants to interact with and experience the dynamic elasticity of virtual

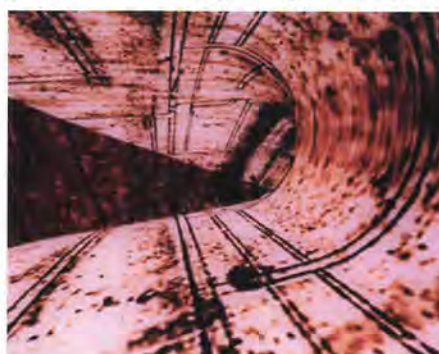
'Bucky Balls', spherical nano-scale molecules that resemble the geodesic domes designed by Buckminster Fuller. Taking cues from Charles and Ray Eames' film, *Powers of Ten* (1977), *Nanomandala* (2004) enables viewers to interact with a mandala, projected on an eight-foot diameter disk of sand, at diverse scales, fluidly telescoping back and forth from the molecular structure of a single grain of sand (imaged with a scanning electron microscope) to the whole mandala of Chakrasamvara.

Development of the versatile VR technology known as the CAVE (Cave Automatic Virtual Environment or Computer Automated Virtual Environment) began in 1991, led by computer scientist Tom DeFanti and artist Dan Sandin at the Electronic Visualization Laboratory (EVL) at the University of Illinois Chicago. CAVEs typically afford stereoscopic views that are projected on one or more walls of a cubic space. The projections are corrected so that they blend seamlessly among up to six walls (including floor and ceiling), making the



physical corners disappear and producing a continuous sense of space. More typically a CAVE will have two to four sides; a six-sided CAVE provides an illusion of continuous space that extends infinitely in all directions and completely surrounds the viewer, offering a vivid experience of 3-D immersion. The interactive and immersive qualities of VR vastly extend the ability to perceive and understand objects and datasets greater than three dimensions. CAVEs lend themselves to unencumbered modes of interaction, yet they may incorporate a variety of interface devices to enhance navigation.

Sandin has collaborated closely with engineers, mathematicians and scientists to produce stunning visualizations of complex systems such as Quaternion Julia Sets – four-dimensional objects generated from fractals. These visualizations also were made available online using VRML, a Web-based protocol that emulates VR, so that general audiences could interact with them. *Oort Continuum* (1994–6; Works, 174), a project supervised by Sandin and programmed



by Marcus Thiebaux (then a graduate student) comprises a meta-world that enables access to multiple virtual realities created by EVL students. At the National Center for Supercomputing Applications, artist Donna Cox has collaborated with scientists and engineers to develop visualizations such as the Academy Award nominated IMAX film, *Cosmic Voyage* (1996) and *Passport to the Universe* (2000; Works, 187), the inaugural film for the domed theatre at the Hayden Planetarium in New York City. Cox also worked with Thiebaud and Robert Patterson to develop the software framework Virtual Director, a networked, multi-user VR application that enables researchers to interact remotely with one another in local CAVEs, sharing and modifying data in a virtual reality environment.

Jeffrey Shaw's early expanded cinema events of the 1960s laid the foundations for interactive computer simulations and VR installations, including works designed for the CAVE beginning in the 1990s. In *Movie-Movie* (1967), a happening



created together with Theo Botschuijver, Sean Wellesley-Miller and Tjebbe van Tijen for the Fourth Experimental Film Festival at Knokke-le-Zoute, film, slides and liquid-light show effects were projected on and through a thirty foot inflatable plastic dome and the people interacting in and around it. The artist intended for the air-filled structure, which consisted of a transparent outer membrane and inner white surface, to transform the traditional flat cinematic screen into a 'three dimensional kinetic and architectonic space of visualization'. In 1993 at the MultiMediale 3 in Karlsruhe, Shaw presented a version of his VR art gallery, *The Virtual Museum* (1991) using a new projection technology known as EVE (Extended Virtual Environment) developed at the ZKM. Reminiscent of *Movie-Movie*, EVE's domed, interactive visualization space enables a viewer to direct the projection of video along its hemispherical surface. In *The Golden Calf* (1994), Shaw employed a small hand-held LCD monitor tethered to a pedestal that enabled users to walk around and interactively examine a virtual 3D

bovine simulacrum – a found object in the Silicon Graphics software library. In *conFIGURING the CAVE* (1996; Works, 177), he and collaborators Agnes Hegedüs and Bernd Lintermann created a four-sided CAVE that incorporates a novel interface – a mannequin – which enables the user to navigate seven distinct audiovisual domains. Much of the work's densely composed symbolic imagery is based on Jewish mysticism and the kabbalah, which, itself may be considered a simulacra: a structural mapping of an unknowable, virtual territory, comprised of various interconnected orders of matter, consciousness and spirit. *conFIGURING the CAVE* is, then, both a simulation and simulacrum that examines multiple levels of simulation by using a human surrogate as its interface, incorporating various tiers of symbolic mapping, in virtual reality.

Exhibitions, Institutions, Communities, Collaborations.

The aesthetic, technical and financial challenges of electronic



media have demanded that artists perform non-traditional tasks and form unconventional partnerships. These exigencies spurred the formation of communities of like-minded individuals and catalyzed collaborations with scientists and engineers. Artists theorized their own work, developed publishing venues and gained support from academic institutions, not-for-profit organizations and corporate and public sponsors. These alliances also characterize the production of major works of electronic art as well as many of the important historic and contemporary exhibitions that popularized the idea of joining art and technology. Increasingly, scientists and engineers are recognizing that artists make valuable collaborators who contribute to research and invention not just by making pretty visualizations of data but by asking provocative questions, offering alternative perspectives and stimulating creativity and innovation.

In the politically charged environment of the US in the 1960s, the Vietnam War, the Cold War, the 'Space Race,'

growing ecological awareness and rising concerns about what President Dwight Eisenhower described as the military-industrial complex, led many visionary artists, curators and engineers to believe that art could play an important role in humanizing technology. Indeed, the idea of joining art and technology seemed captivating, if not necessary, to prominent artists such as Cage, Rauschenberg and Paik. Similarly, the Artist Placement Group (APG), founded in London in 1966 by Barbara Steveni and John Latham with Jeffrey Shaw and Barry Flanagan, placed artists within corporate contexts, where their unique vision and problem-solving capabilities could contribute to the transformation of industry and ultimately, society in general.

Corporations have generously sponsored the creation and exhibition of work joining art and technology. Philips Corporation, for example, supported the work of artists including Le Corbusier, Schöffer and Ihnatowicz from the 1950s to the 1970s. The 'Software' exhibition at the Jewish



Museum (1970; Works, 185) was sponsored by American Motors Corporation and IBM. The Art and Technology programme (A&T) at the Los Angeles County Museum of Art (1967–71; Works, 184) and the 'Magic Theater' exhibition organized by the Nelson Gallery of

Art in Kansas City (1969) brought together artists with many industry partners, ranging from Lockheed Aircraft Corporation to Universal Studios, that helped fund and produce technically complex work. It must be noted that some artists were wary of that work produced under the aegis of such sponsors would serve to whitewash tarnished corporate images that should remain sullied. Jean Toche withdrew his proposed piece about air pollution from 'Software' when he learned that the lead sponsor was American Motors; indeed, art and industry often make strange bedfellows.⁵⁵

Memorable outcomes from A&T included Newton Harrison's *Glow Discharge Tubes*, Claes Oldenberg's *Giant Ice-Bag*, Robert Rauschenberg's *Mud Muse* and a spectacular optical mirror environment by Robert Whitman and John Forkner. These works were exhibited in the US Pavilion at the 1970 World Fair, EXPO 70, in Osaka, Japan. 'Magic Theater' resulted in a variety of works including James Seawright's *Electronic Peristyle* (Works, 66) and Terry Riley's *Time Lag*

Accumulator. Software joined technological objects with art objects, claiming to make no distinction between them and included a computerized gerbil environment by Negroponte, Haacke's teletype machines, Sheridan's 3M colour photocopier and a hypertextual catalogue by Ted Nelson.

Artists working with electronic media since the mid-twentieth century eagerly collaborated with scientists and engineers to explore the potential of interdisciplinary research as a means of producing innovative work. Perhaps the most prominent historic example of this tendency is E.A.T. The group's first event, '9 evenings: theatre and engineering' (1966; Works, 184) consisted of a collaboration among ten artists and thirty engineers that yielded nine evenings of technologically enhanced performances and several patents. Seen by an audience of 10,000, the project benefited from 8500 hours of donated engineering expertise, some 'midnight requisitions' from Bell Labs and significant personal donations from Klüver, Rauschenberg, and others. Klüver eventually left

staff researchers and contributed to the development of sound synthesis and computer graphics and animation. Residency programmes at Bell, 3M and other companies, along with partnerships generated by A&T and 'Magic Theater', inspired subsequent corporate programmes at XEROX PARC (1993–9), Interval Research (1992–2000), the Intel Corporation (1996 – present; Works, 188), the Advanced Telecommunication Research Labs (ATR) in Kyoto, Japan, and the Artists in Labs programme co-ordinated by the Hochschule für Gestaltung und Kunst, Zürich (2004– present). Researchers in diverse fields are increasingly recognizing that the intellectual challenge and excitement of working as part of a transdisciplinary team often generates insights and produces results that could not have been achieved by using the methods and techniques of any single discipline. Indeed, an idealized goal of such research is the synergistic creation of hybrid end-products that could only have been imagined and executed as a result of collaboration. As Florian Schneider has

noted, 'Collaborations are the black holes of knowledge regimes. They willingly produce nothingness, opulence and ill behaviour. And it is their very vacuity that is their strength... It does not entail the

transmission of something from those who have to those who do not, but rather the setting in motion of a chain of unforeseen accesses.'⁵⁸

Although the public fascination with art and technology in the 1960s was short-lived, the annals of the journal *Leonardo* (Works, 183) demonstrate that artists, scientists and engineers remained committed to the potential of collaborative research throughout the 1970s and 1980s. Artists whose research compelled them to work with technology – and especially with computers, which at the time were prohibitively expensive and far from user-friendly – gravitated to universities where they could have access to the specialized equipment, technical support and intellectual climate that enabled them to develop their work. Examples of this migration in the US include Dan Sandin at the University of Illinois at Chicago and Charles Csuri at The Ohio State University, both of whom became faculty members in the late 1960s and have participated in innovative collaborative research. In the belief that 'if we can



Bell Labs to lead E.A.T.'s effort to make 'materials, technology and engineering available to any contemporary artist.'⁵⁶ At its peak, the organization could boast of twenty-eight chapters in the US and some 6000 members. Among its many subsequent projects, E.A.T. was commissioned to design and programme the Pepsi Pavilion at Expo 70, an endeavour that stretched the group's creative, technical and organizational limits, resulting in a remarkable spectacle of artistic and engineering wizardry.⁵⁷ Following the Apollo 11 lunar landing in 1969, signifying America's technological supremacy in the 'Space Race', in 1970 art and technology appeared to become, at least momentarily, official US art, dominating both the US Pavilion and the Pepsi Pavilion at the 1970 World Fair, seen by an estimated 1,000,000 visitors.

In addition to encouraging its engineers to work on '9 evenings', beginning in the early 1960s Bell Labs hosted artists in residence including James Tenney, Stan VanDerBeek (Works, 82) and Lillian Schwartz (Works, 86), who worked alongside

control the "dots" we can do anything,' David Em sought and gained access to computers at Xerox PARC in 1975 and Jet Propulsion Lab (JPL), where he was artist in residence from 1976–84. Having cut their teeth working on *Aspen Movie Map* at MIT in the mid-1970s, artists Rebecca Allen, Scott Fisher and Michael Naimark have balanced academic and industrial research throughout their careers.

While electronic media went underground, so to speak, in the 1970s, important exhibitions and symposia took place throughout Europe in the 1980s: Ars Electronica in Linz, Austria (annual since 1979); Electra (1983) and Les Immatériaux (1985) in Paris; the Venice Biennale (1986); V2 Organization's Manifestation for the Unstable Media ('s Hertogenbosch, Netherlands, annually 1986–92); the International Symposium of Electronic Art (ISEA, launched in Utrecht, 1988; held internationally); and the WRO Media Art Biennale (Wrocław, Poland, since 1989). These events played a major role in developing an international community with a



common interest in the intersections between art, science and engineering and in forging the practical and theoretical and institutional foundations of what has

become known as new media.

Despite the vitality and dynamism of this emerging community, it was confined to the margins of the larger international art world in the 1980s. Mainstream galleries and museums embraced various types of neo-expressionism along with diverse forms of neo-conceptualism and photo-based practices under the rubric of post-modernism. While historians and critics interpreted these developments via the lenses of semiotics, critical theory and poststructuralism, many artists using electronic media were posing arguably more profound challenges to modernist conventions. For example, Ascott's *La Plissure du Texte* (1983) and *Organe et Fonction* (1985) questioned notions of authorship and originality, transformed the relationship between the artist, artwork and audience, and created behavioural, time-based, process-oriented, and interactive contexts for emergent, dialogical exchange, in both local and remote environments. Moreover, these works exemplified and expanded key

principles of post-modernity: the notions of readerly texts and textual pleating theorized by Roland Barthes in the 1970s, the intertextual invocation of 'différance' evidenced in Jacques Derrida's *Glas* (1974) and the principle of 'paralogy' propounded by Jean-François Lyotard in *The Postmodern Condition* (1979).

A second wave of enthusiasm towards art and technology emerged in the 1990s with advances in personal computing, the advent of the Web and a booming E-commerce economy. Combined with the fall of Berlin Wall, signalling the end of the Cold War and the televised spectacle of US military technology in the first Gulf War, public fear of technology waned – at least in the US and Europe. Moreover, new facilities were built, providing a robust institutional infrastructure and a growing number of major exhibitions took place internationally.

In Europe, investment in electronic art is recognized as a vital force for cultural regeneration, economic development, and the growth of creative industries. Funding from municipal, regional, national and EU sources has helped the field flourish, particularly in Austria, Germany, Netherlands, and the UK. Ars Electronica's annual prize and symposium have continued to support innovative work and lively dialogue. The construction of the Ars Electronica Center (AEC; Works, 187) in 1995 provides not only a formal home for the event but a museum to display its permanent collection, production resources and a VR CAVE. Also in 1995, V2 relocated to Rotterdam, where it offers a wide range of programmes, including artist residencies, production facilities and technical support, scholarly publishing and the biennial Dutch Electronic Art Festival (DEAF). The Netherlands Media Art Institute has an extensive video collection and offers diverse programmes, including residencies, exhibitions and events, including the Sonic Acts festival. ISEA festivals (Works, 189) have been held in Europe, Australia, US, Canada, Japan, across the Baltic Sea (Helsinki, Stockholm, Tallinn, via a connecting boat) and Singapore. Begun in 1988, the Berlin VideoFilmFest morphed into the annual Transmediale festival. In the UK, The Arts Catalyst, CRUMB and Tate have supported new media production and exhibition by commissioning work, curatorial scholarship and exhibitions. In 1999, the ZKM (Works, 188) came under Weibel's leadership and moved into expanded, permanent quarters that include a Media Museum to display its permanent collection and additional space to mount extensive exhibitions, such as *net_condition* (1999) and

Lichtkunst aus Kunstlicht (2005–6), documented with well-illustrated, scholarly catalogues. These established institutions were joined by the opening in 2007 of the LABoral Centro de Arte y Creación Industrial in Gijón, Spain.

Major exhibitions in North America were organized in the 1990s and early 2000s by the Whitney Museum, Walker Art Center, Wexner Art Center, Guggenheim Museum, Eyebeam and San Francisco Museum of Modern Art. Since 1981, SIGGRAPH (Special Interest Group Graphics of the Association for Computing Machinery) has sponsored annual exhibitions of computer art organized in conjunction with its industry-focused conference held in various cities and the Boston Cyberarts festival has been held biennially since 1999. The ISEA festivals in Montreal (1995) and Chicago (1996) included extensive exhibitions. The Banff New Media Institute in Alberta Canada has produced diverse programmes, including symposia, think-tanks, residencies, collaborations and exhibitions. In Montreal, the Images du Futur festival was active from 1986–96 and in 1997 the Daniel Langlois Foundation (Works, 187) began building extensive archives and started sponsoring fellowships for artists and researchers.

In Japan, the InterCommunication Center supports a wide range of exhibitions, prizes, programming and publishing and the Tokyo Metropolitan Museum of Photography has hosted numerous exhibitions of electronic art, including the 10th Japan Media Arts festival in 2006. New conferences and festivals have emerged around the world, including Transmediale in Berlin, Art + Communication in Riga, Microwave in Hong Kong, Biennial of Electronic Arts Perth, the Beijing International New Media Arts Exhibition and Symposium, and ZERO1, first held in 2006 in conjunction with ISEA in San Jose.

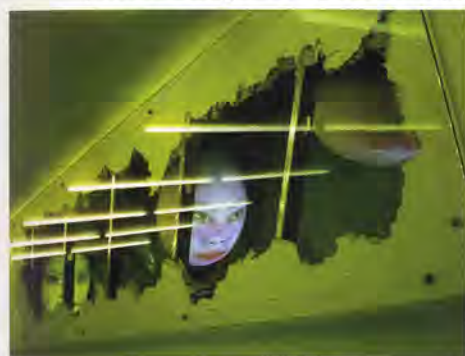
The broad cultural fascination with new media has generated a substantial literature. *Art Journal* (US), *Kunstforum* (Germany), *Artlink* (Australia) and *Parachute* (Canada) all have published special issues dedicated to art, science and technology, joining *Leonardo* as important forums for scholarship. New journals emerged internationally, including *Mediamatic* (Netherlands, 1985), *Neural* (Italy, 1993), *MUTE* (UK, 1994), *Convergence* (UK, 1995), *Digital Creativity* (1995), *Intelligent Agent* (US, 1996), *Artbyte* (US, 1998–2001) and *a mínima* (Spain, 2000), while listserves, hosts and E-journals including ctheory.net, Rhizome.org (Works, 188), *The Thing*, *Telepolis*, *Noema* and *Leonardo Electronic Almanac* have

spawned communities of affinity and additional contexts for discourse on electronic media. Other online resources, including *Media Art Net*, *Multimedia: From Wagner to Virtual Reality*, and the *Leonardo Pioneers and Pathbreakers* project provide multimedia content and critical insights pertaining to the intellectual and aesthetic genealogy of new media, an invaluable resource for teaching and learning. Despite the slowness of art historians to enter the fray of theorizing and historicizing the use of electronic media in art, a substantial number of anthologies and monographic studies from various disciplines published in the 1990s and 2000s have helped make sense of this growing and diverse field from myriad perspectives. The role of artists is important in this regard. Indeed, texts written by artists have played a central, although under-recognized, role in the critical and theoretical development of art and its discourses. This is especially the case in experimental art, where artists often anticipate art historical and critical appraisal by many years.

Electronic art poses numerous challenges to curators and museums, ranging from the presentation and maintenance of works that are vulnerable to break-downs, to the custodianship and preservation of such work, complicated by rapid cycles of technological obsolescence. Such challenges were not new in the 1990s and advocates for electronic art recognized that they had to be addressed in order for collectors and museums to acquire and exhibit work made with technological media. This seal of approval remains an important but elusive source of validation in the 2000s, though in 2001, Bill Viola's *The Quintet of Remembrance* (2000) became the first work of video art to enter the permanent collection of the Metropolitan Museum of Art, New York. The integration of major works by Gary Hill, George Legrady and Tony Oursler into the architectonic fabric of the Seattle Public Library (2004) makes perhaps an even bolder statement of the acceptance of electronic art by public institutions, albeit not necessarily museums.

In support of Web-based works of art, curator Steve Dietz organized the landmark exhibition 'Beyond Interface' in 1998, and many other exhibitions of 'net.art' can be accessed through the Whitney Museum's *Artport*, a comprehensive portal for such work. Although electronic art, especially Web-based work, has remained peripheral to mainstream contemporary art, commercial galleries dedicated to it are contributing to its acceptance, along with growing interest in

The difficulties of producing and exhibiting electronic art stem, in part, from the nature of the media themselves, which often demand institutional and community support structures at odds with traditional modes of art-making and generate works that resist conventional models of public display. For example, when Norman White first gained access to computer networking in the late 1970s, he was excited by the prospect of being able to use it to explore the medium's potential for art-making. The prohibitive cost of long-distance telephone calls prior to deregulation posed one problem. But White



collaborative, participatory process that enables the emergence of a distributed form of collective consciousness. As public interest grows in such artforms, galleries and museums will undoubtedly develop more effective ways of preserving, collecting, and sharing it.

Just as the production of electronic art often demands the formation of communities and institutions and frequently leads to the production of open-ended exchanges rather than concrete works, some art and science research agendas demand collaboration between experts in a variety of fields without a clearly defined or functional outcome. The performances in '9 evenings', for example, were possible only as a result of teamwork between artists and engineers. Working alone, neither the artists nor the engineers could have accomplished the end result. As in the late 1960s and 1970s when artists whose practices demanded access to technology gravitated towards universities, so in the 1990s and 2000s, leading artists have sought out collaborative contexts at universities in order to explore the potential of practice-based transdisciplinary research. Such research challenges the boundaries of traditional disciplinary inquiry and education, generating hybrid outcomes and practitioners. As the number of such hybrid practitioners increases, their impact on the centrality of technology and science in the production of art and design (and vice-versa) will force a reconsideration of the canons of art history and the histories of science and technology. Ideally, such work will create new forms and structures of meaning that expand the languages of art, design, engineering and science, and that open up new vistas of creativity and invention.

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- 4 Ibid, 50.
- 5 Some key international figures include Vladimir Bonačić (Yugoslavia, now Croatia), Lucio Fontana (Argentina/Italy), Gyula Kosice (Argentina), Abraham Palatnik (Brazil), Julio Le Parc (Chile/France), Zdenek Pesánek (Czechoslovakia), Otto Piene (Germany), George Rickey (US), Nicolas Schöffer (Hungary/France), Jesus Raphael Soto (Venezuela/France), Takis (Greece/UK), and Jean Tinguely (Switzerland). New Tendency collectives, including ZERO (Düsseldorf), the Groupe de Recherche de l'Art Visuelle (GRAV, Paris), Matko Mestrovic (Zagreb), Gruppo M and Gruppo T (Italy) and Equipo 57 (Spain) also explored this direction.
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